Activity Book

TA Orientation
School of Physics and Astronomy
University of Minnesota

Fall, 2005

TABLE OF CONTENTS
FOR CLASS ACTIVITIES

What is a TA?

What is your image of a teaching assistant (TA)? What would you see a TA doing? Who does a TA work with? etc.

Formulate **an answer individually.**

Share **your answer with a partner.**

Listen **carefully to your partner's answer.**

Create **a new answer through discussion.**

2

Notes: ____

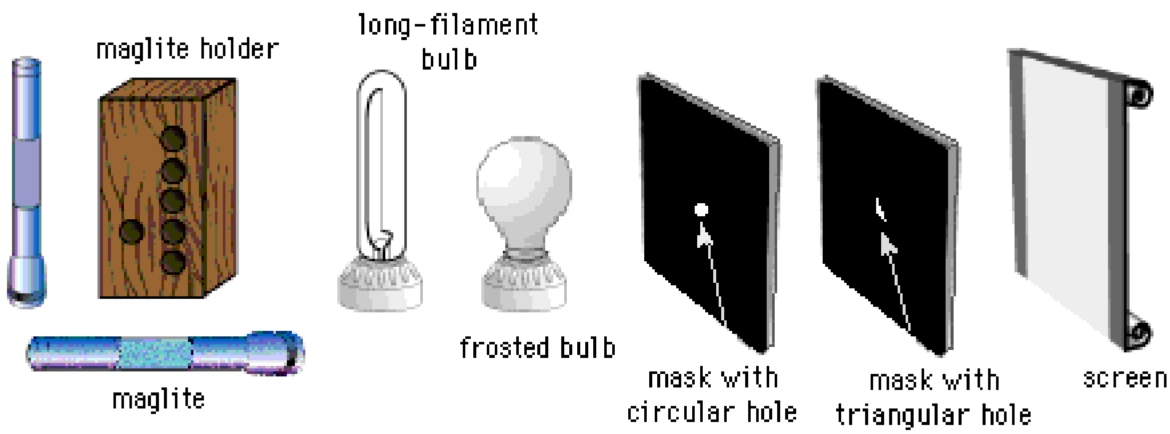
Notes:

EXPLORATORY PROBLEM #1:
Light Patterns

Because of your physics background, you have been asked to consult for the FBI on an industrial espionage investigation. A new invention has been stolen from a workroom, and the FBI is trying to determine the time of the crime. They have found several witnesses who were walking outside the building that evening, but their only recollections are of unusual light patterns on the side of the building opposite the workroom. These patterns were caused by light from the workroom coming through two holes in the window shade, a circular hole and a triangular hole. The room has several lights in it, including two long workbench bulbs. During the theft, the burglar hit one of the workbench lamps and broke the supporting wire, leaving it hanging straight down. Together with the other bulb, it forms a large "L" shape. Going outside, you see that the lamps do leave interesting patterns on the sidewalk. Your job is to determine, based on the light patterns the witnesses recall seeing, when the theft took place. You decide to model the crime scene in your lab using the equipment shown below.

? What patterns of light are produced with different shaped holes and light sources?

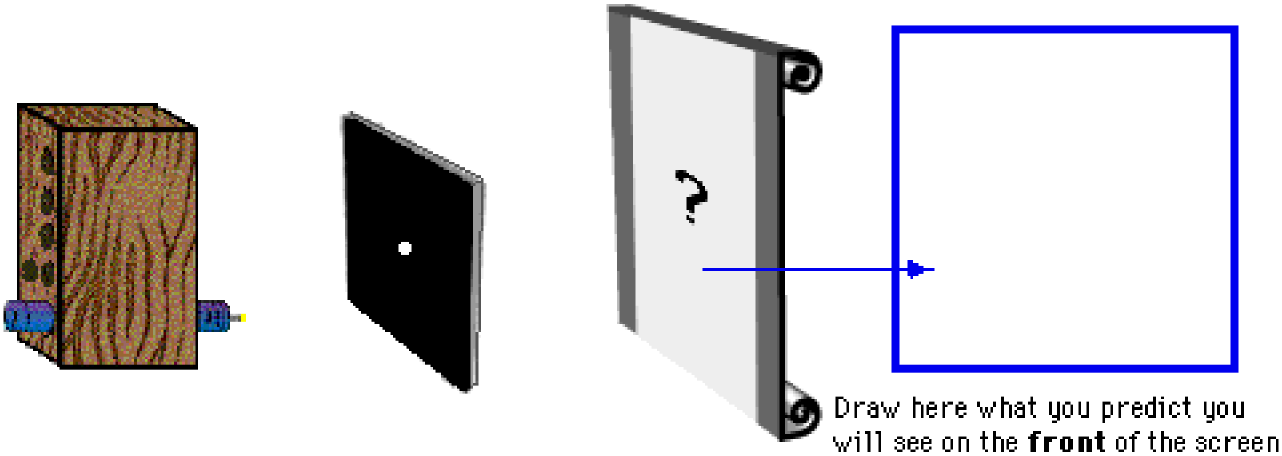
EQUIPMENT



You will have: a maglite holder; two mini maglites; a clear tubular bulb with a straight filament mounted in a socket (representing a long workbench bulb); two cardboard masks, one with a circular hole and one with a triangular hole (representing the holes in the window shade); and a large white cardboard screen (representing the side of the building).

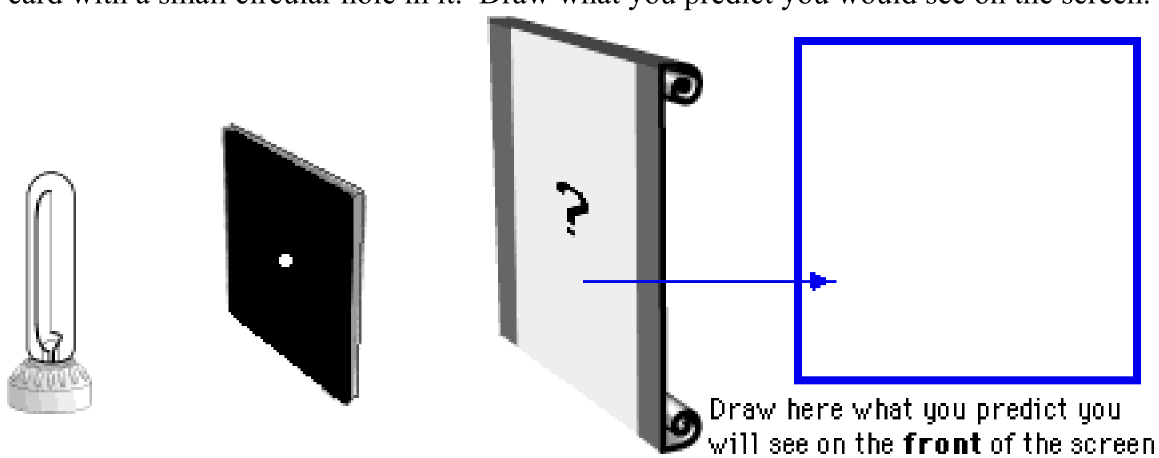
Predictions

1. Suppose you took a Maglite flashlight, took the cover off, and held it close to a card with a small circular hole in it. What would you see on the screen behind the card? Draw what you think you would see on the screen.



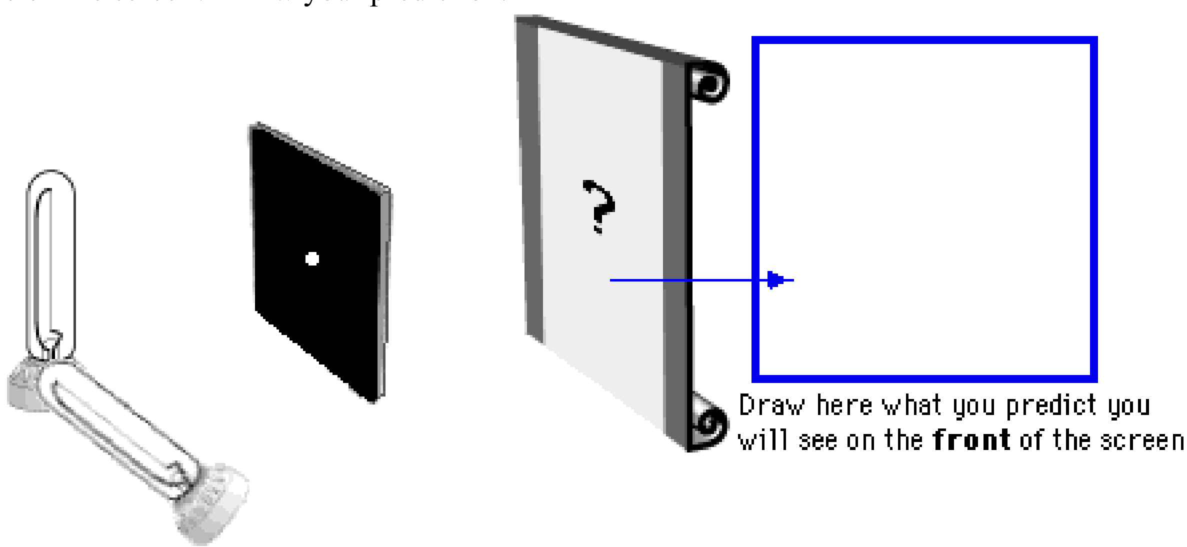
Explain your reasoning. Why do you think this is what you will see?

2. Now suppose you had a bulb with a long filament inside. Imagine you were to hold this near the card with a small circular hole in it. Draw what you predict you would see on the screen.



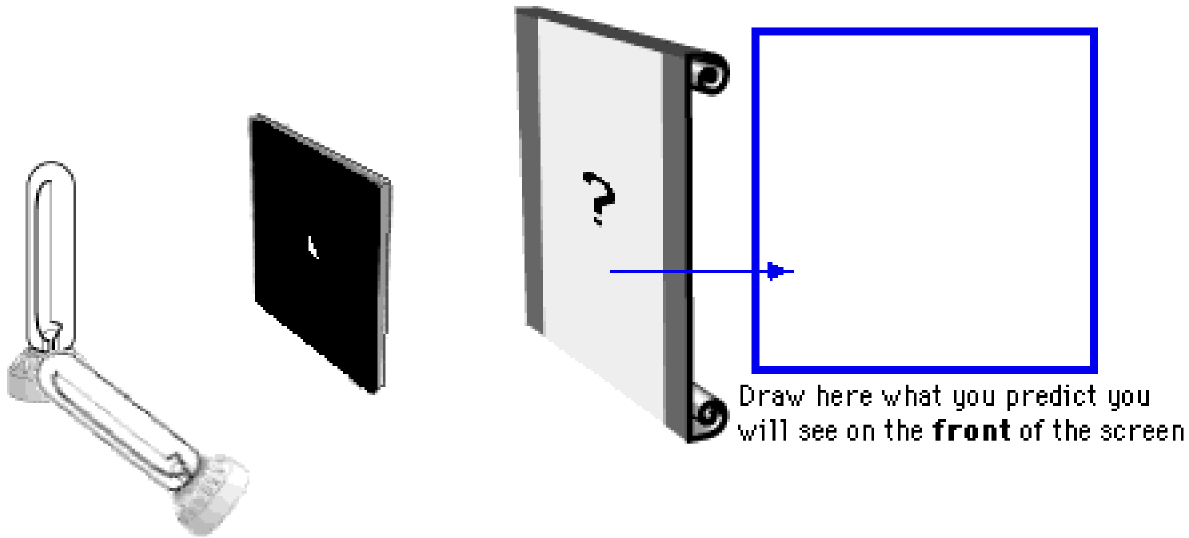
Why did you draw what you drew? Explain your reasoning.

3. Suppose you took two of the long filament bulbs and held them together to form an "L" shaped filament, and held this setup near a card with a small circular hole in it. What would you see on the screen? Draw your prediction.



What was your reasoning?

4. Now imagine you kept the bulbs in the shape of an “L”, but now replace the hole in the card with a triangle instead of a circle. Predict what you would see on the screen, and draw your prediction.

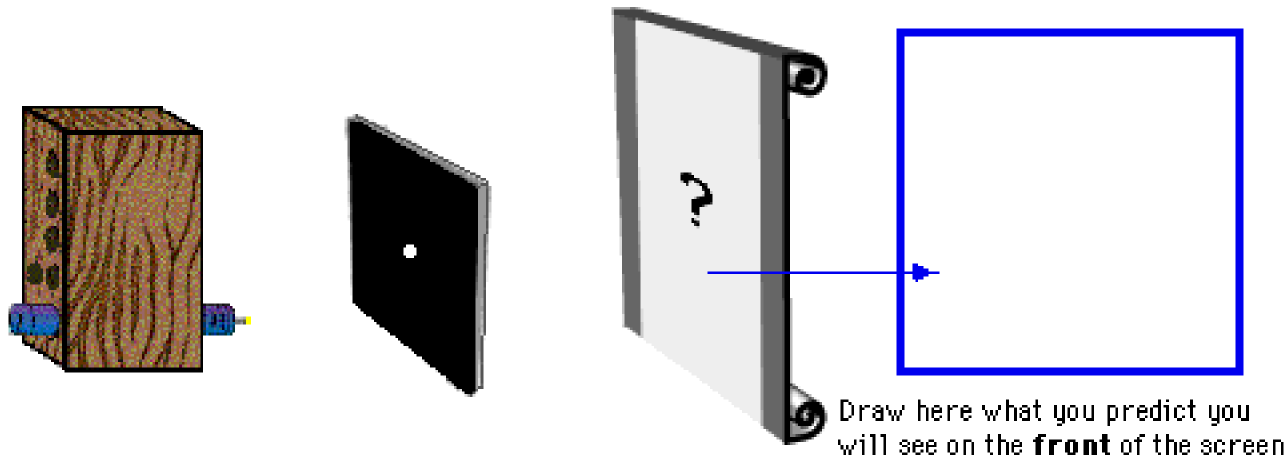


Explain your reasoning.

EXPLORATION

Before you tackle the complex problem, you decide to explore the different light patterns you can get on a screen when light from different kinds of sources shine through holes with different shapes.

1. Suppose you had a maglite, arranged as shown below, close to a card with a small circular hole. **Predict** what you would see on the screen with a lit maglite in a darkened room.



Explain your reasoning.

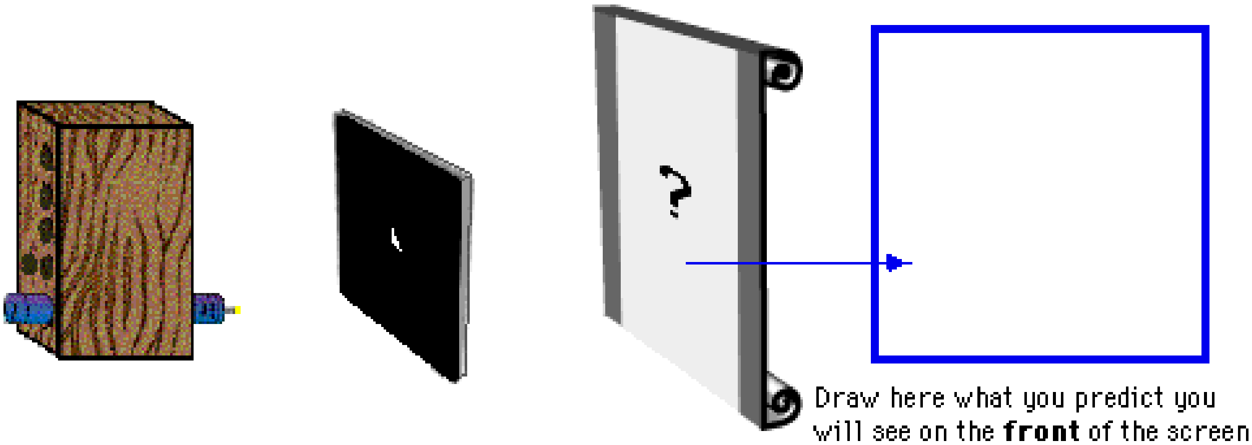
Predict how moving the maglite upward would effect what you see on the screen. Explain.

Test your predictions. Ask an instructor for a maglite. Unscrew the top of a maglite, and mount the maglite in the lowest hole of the maglite holder, as shown above. Place the card with the circular hole between the maglite and the screen.

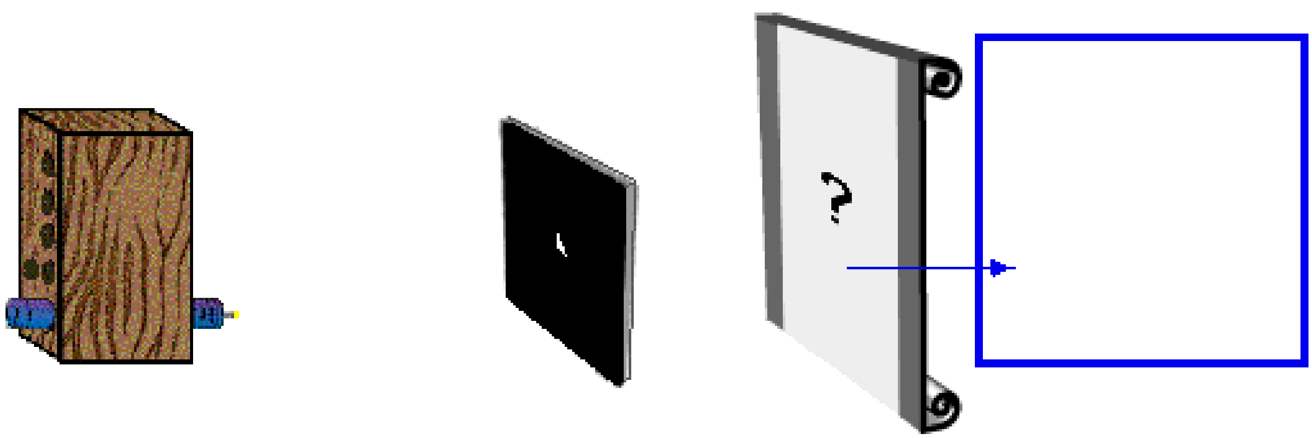
If any of your predictions were incorrect, resolve the inconsistency.

2. **Predict** how each of the following changes would affect what you see on the screen. Explain your reasoning and include sketches that support your reasoning.

A. The mask is replaced by a mask with a triangular hole.

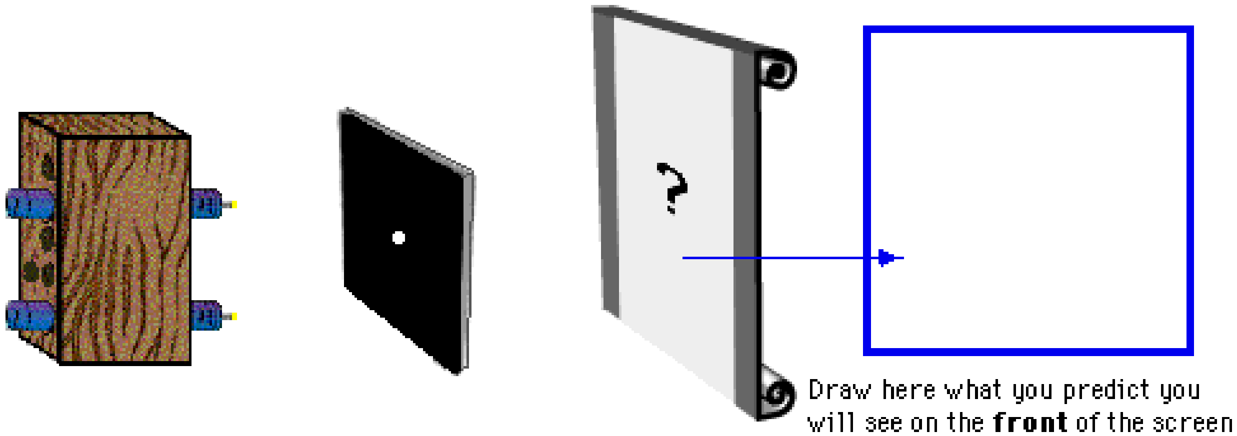


B. The bulb is moved further from the mask.



C. **Test your predictions.** Ask your instructor for a card with a triangular hole, and perform the experiments. If any of your predictions were incorrect, resolve the inconsistency.

3. Predict how placing a second maglite above the first would affect what you see on the screen.

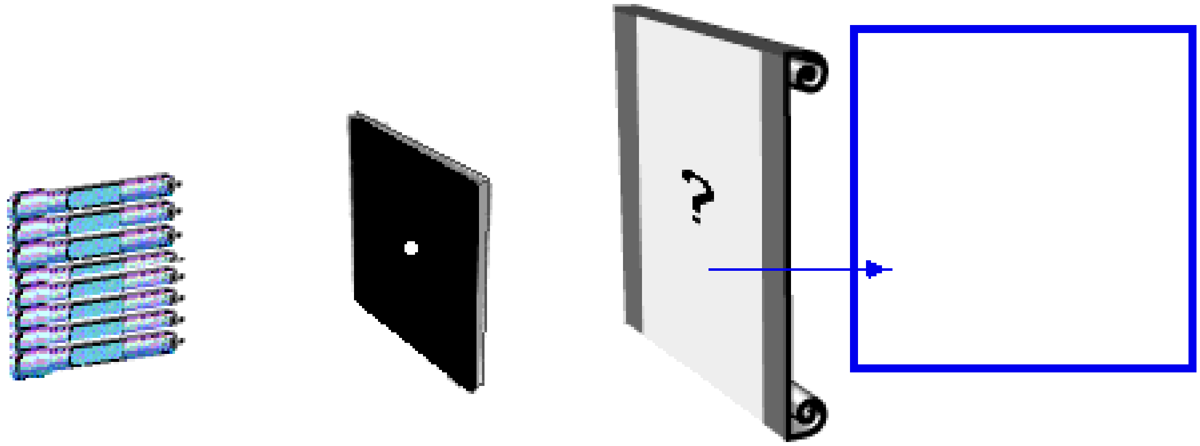


Explain your reasoning.

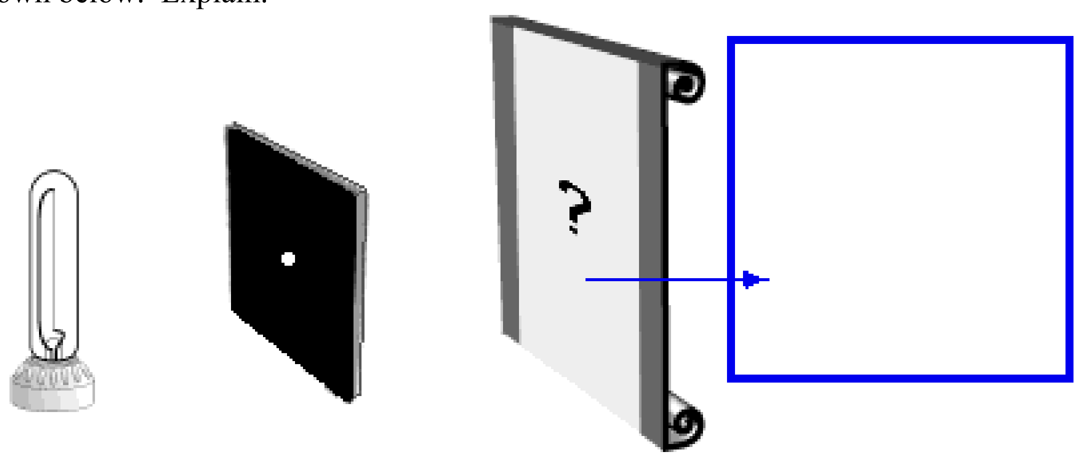
Test your predictions. Ask an instructor for a second maglite, and perform the experiments. If any of your predictions were incorrect, resolve the inconsistency.

4. What do your observations suggest about the **path** taken by the light from the maglite to the screen?

5. Imagine that you had several maglites held close together, as shown below. **Predict** what you would see son the screen. Explain.

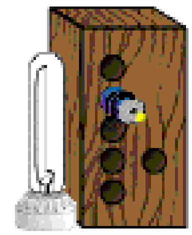


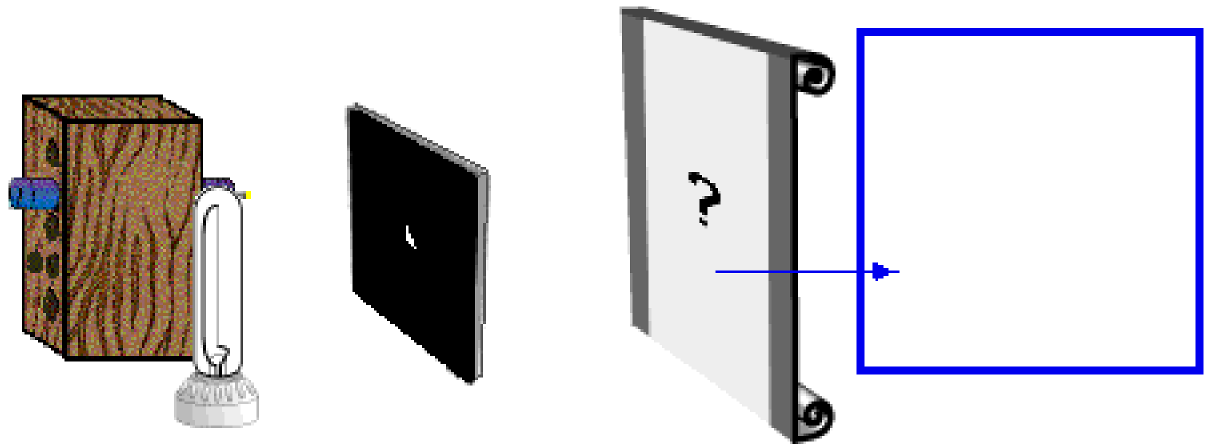
Predict what you would see on the screen if you used a bulb with a long filament instead, as shown below. Explain.



Test your predictions. Ask an instructor for a long filament bulb, and perform the experiments. If any of your predictions were incorrect, resolve the inconsistency.

6. **Individually predict** what you would see on the screen if you had both a maglite and a long filament bulb arranged side by side, as shown at right and below.





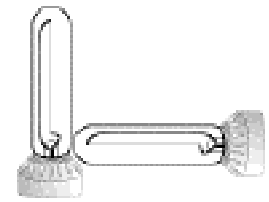
Explain your reasoning.

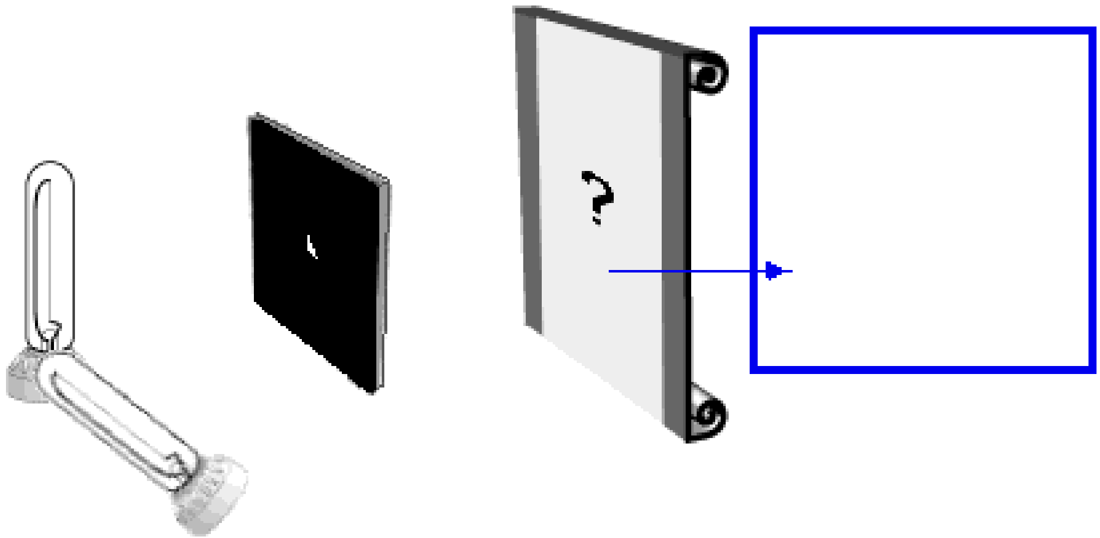
Compare your prediction with those of your partners. After you and your partners have come to an agreement, **test your prediction** by performing the experiment. Resolve any inconsistencies.

MEASUREMENT & ANALYSIS

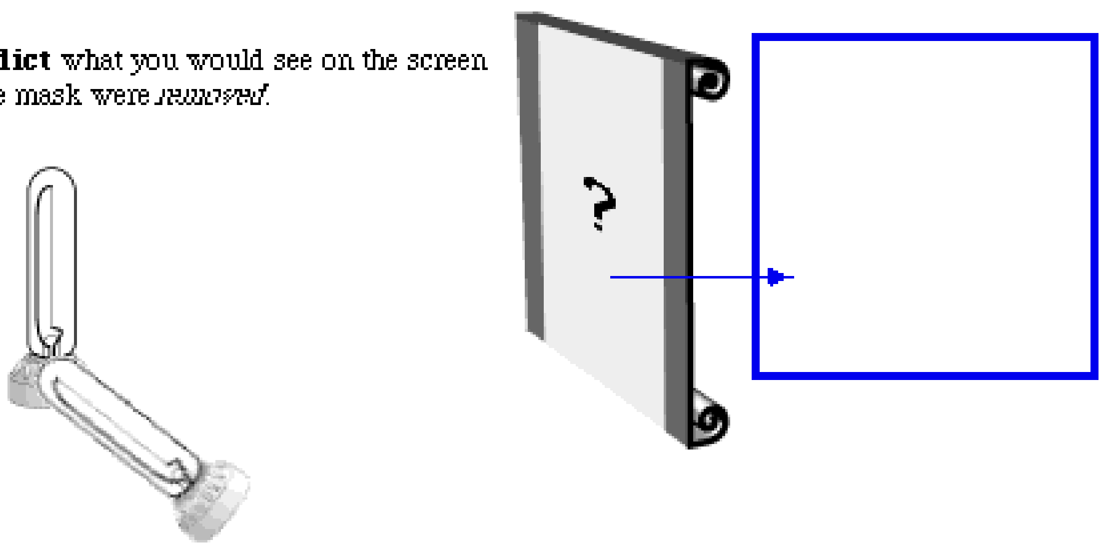
You are now ready to investigate the light patterns that would be seen by the witnesses who passed the crime scene.

1. **Predict** what you would see on the screen if you had two long filament bulbs arranged as shown at right and below.





Predict what you would see on the screen if the mask were *removed*.



Test your predictions. Ask your instructor for a second long-filament bulb, and perform the experiments. If any predictions were incorrect, resolve the inconsistency.

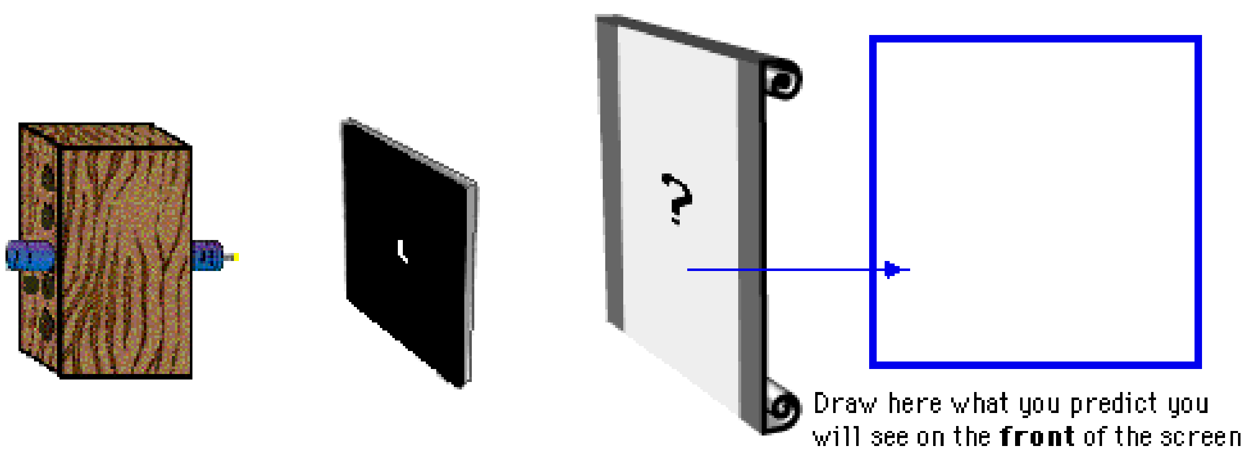
Conclusion

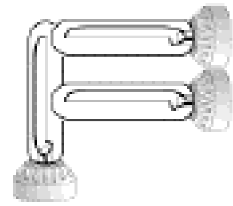
What pattern would a witness see on the building wall from two horizontal lit bulbs through a circular hole and a triangular hole in the window shade? What would a witness see when one bulb was horizontal but the other bulb was vertical? How would you determine the approximate time of the crime?

☑ CHECK YOUR UNDERSTANDING

A mask containing a hole in the shape of the letter **L** is placed between the screen and a very small bulb of a maglite as shown below.

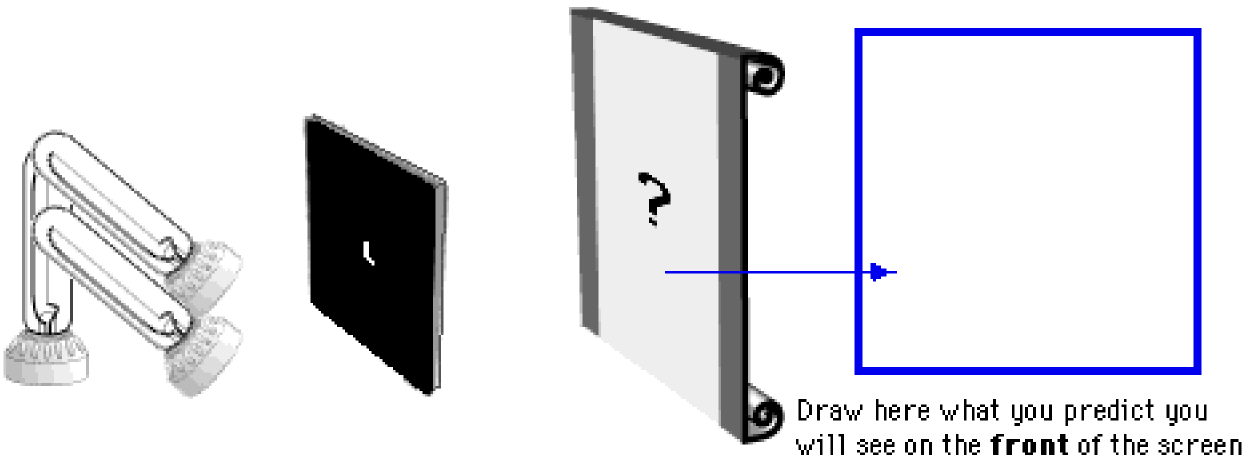
1. On the diagram below, sketch what you would see on the screen when the maglite is turned on.



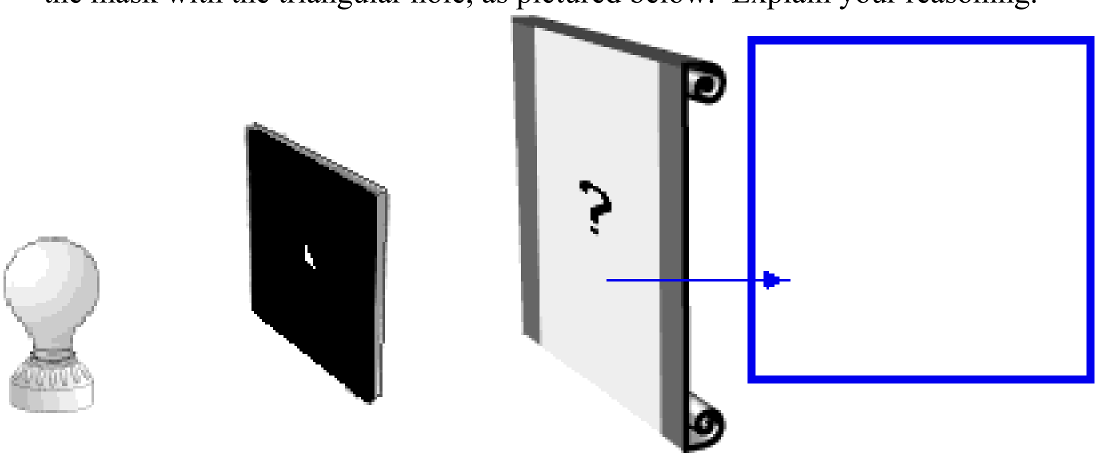


2. The maglite is replaced by three long filament light bulbs that are arranged in the shape of the letter **F**, as shown at right a below.

   On the diagram, sketch what you would see on the screen when the bulbs are turned on. ***Explain how you determined your answer.***



3 **Predict** what you would see on the screen when an ordinary frosted bulb is held in front of the mask with the triangular hole, as pictured below. Explain your reasoning.



Physics Teaching Assistant Orientation
Team and Technical Aspects of Engineering

Delta Design Project

Write a brief report (1) summarizing your group's design that includes the technical specifications for each aspect--Architect, Project Manager, Structural Engineer, and Thermal Engineer, and (2) summarizing your group's experience and learning in the Delta Design Exercise.

Delta Design

Present your design, including the photo of your final design. Summarize the technical aspects of your design and compare them with the specifications. Include assumptions and interpretations.

Delta Design Review

Review your design, including the process your group used to develop it. Include the photo of your design team. Describe the things your group did well and the things that could be improved. Discuss the implications of your experience in the Delta Design Exercise for teaching engineering students. Use the additional questions on the back of this handout to help complete this section.

Engineering Design

Karl A. Smith
Civil Engineering
University of Minnesota
ksmith@umn.edu
http://www.ce.umn.edu/~smith

Physics Teaching Assistants Orientation

August 2005

Engineering = Design

Design in a major sense is the essence of engineering; it begins with the identification of a need and ends with a product or system in the hands of a user. It is primarily concerned with synthesis rather than the analysis which is central to engineering science. Design, above all else, distinguishes engineering from science (Hancock, 1986, National Science Foundation Workshop).

Design defines engineering. It's an engineer's job to create new things to improve society. It's the University's obligation to give students fundamental education in design (William Durfee, ME, U of Minnesota, *Minnesota Technolog*, Nov/Dec 1994).

Engineering Design

Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints.

Engineering Design Thinking, Teaching, and Learning -- http://www.asee.org/about/publications/jee/upload/2005jee_sample.htm

Skills often associated with good designers – the ability to:

- tolerate ambiguity that shows up in viewing design as inquiry or as an iterative loop of divergent-convergent thinking;
- maintain sight of the big picture by including systems thinking and systems design;
- handle uncertainty;
- make decisions;
- think as part of a team in a social process; and
- think and communicate in the several languages of design.

Engineering Design Thinking, Teaching, and Learning -- http://www.asee.org/about/publications/jee/upload/2005jee_sample.htm

Languages of Design

- verbal or textual statements
- graphical representations
- shape grammars
- features
- mathematical or analytical models
- numbers

Engineering Design Thinking, Teaching, and Learning -- http://www.asee.org/about/publications/jee/upload/2005jee_sample.htm

Delta Design

- Design as a social process
- Negotiation

Bucciarelli, Louis, L. 1996. **Designing engineers.** Cambridge, MA: MIT Press.

1

Delta Design Task

Design of a residence for the inhabitants of an imaginary world – an assemblage of red and blue triangles into an envelope anchored in two-dimensional space.

Design Team Roles

- Project Manager
- Structural Engineer
- Thermal Engineer
- Architect

Project Manager

Responsible for (1) Cost and schedule, (2) Interpretation and reconciliation of performance specifications, (3) Negotiations with the contractor and client.

E.g.,
Total cost = K x (delta cost + cement cost + module cost)

K = overhead factor = 1.5

Structural Engineer

Responsible for (1) Structural integrity, (2) Selecting and evaluating anchor points, (3) Ensuring strength of joints

E.g.,

$$\sum_{j=1}^{N}(f \times D_{ij}) = N \times F \times D_{i,cg}$$

Thermal Engineer

Responsible for (1) Comfort zone, (2) Maintaining suitable average temperature, (3) Ensuring no hot or cold spots

$$N_R \times q_0 = T^* \times N^* \times L^* \times k_R$$

Architect

Responsible for (1) Form of design, (2) Maintaining acceptable living space, (3) Creating a distinctive design

Blue Dispersion = $(B \cap R)/((B \cap B)+(B \cap R))$

Delta Design Schedule

1. Design Team Meeting ~ 10'
   Assemble team, Check Roles (Architect, Project Manager, Structural Engineer, Thermal Engineer)
2. Skill Development – Meet with your "expert" group – Review role and plan ~40' (Architects start initial design after ~20')
3. Designing – Work together (all 4 roles) to create the "best" design ~60'
4. Design Review – Each group presents their design including technical specifications – 5'/team ~30'
5. Discussion

3

Delta Design THE DESIGN TASK

Project Manager's Primer appended.

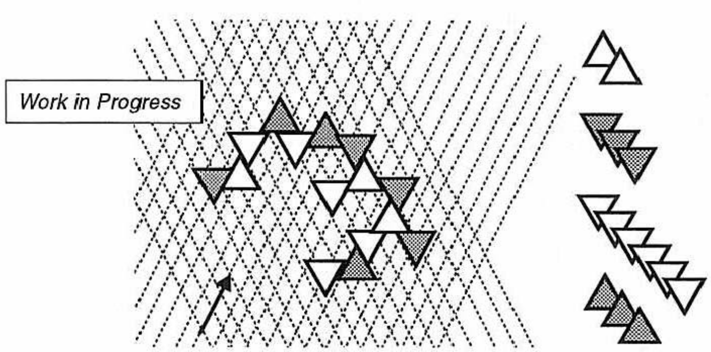
1.1 Introduction

Congratulations! You are now a member of an expert design team. Your collective task will be to design a new residence suitable for inhabitants of the imaginary Deltoid plane. These written materials, provided to help you prepare for this task, are organized in four sections.

The next section provides an overview of life on the Deltoid plane, DeltaP as it is known to the natives. The following section describes your team, and the final, your design task. A second handout, different for each team member, provides the specific information you will need to perform the role you have been assigned within your team. Each team member will contribute different expertise to the project, and each has different design responsibilities to fulfill. All must work together for your team to create a first-rate design.

1.2 Life on DeltaP

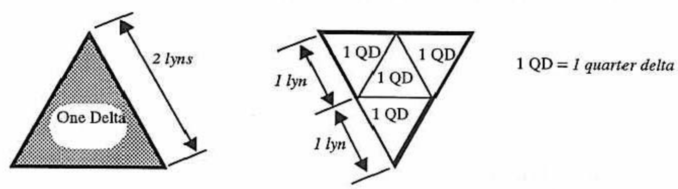
Life on DeltaP, residential and otherwise, is quite different from what you have grown accustomed to here on Earth. First off, DeltaP is a plane, not a planet, so your team will be designing in two-dimensional rather than three-dimensional space. If your design "meets spec" and is considered attractive and functional by your Deltan clients, one view on a single sheet of paper will convey to those responsible for constructing it all the information they need to do so.



Life on DeltaP

The view on this single sheet may not be quite what you expect, however, because in addition to lacking a z axis, Deltoid space has unfamiliar relations between the x and y axes as well. What we think of as "perpendicular" is hopelessly skewed to a Deltan, and vice-versa. In our units, a right angle on DeltaP measures 60° or $\pi/3$ radians. Thus all sides of an equilateral triangle form lines considered perpendicular to all others. If there were such a thing as a "circle" on DeltaP, it would be composed of only $4\pi/3$ radians.

But there is no such thing as a "circle" on DeltaP, nor even the concept of continuity embodied therein. In this flat though angular world, residents construct their artifacts strictly with discrete triangular forms. Of these, the equilateral triangle -- with its three perpendicular sides (!)-- is considered the most pleasing. Accordingly, your team will design the residence by assembling into a



cluster the most prized building materials on DeltaP, equilateral triangular components called "deltas." Deltas come in red and blue versions and always measure *2 lyns* per side. Four "quarter-deltas", *QDs*, triangular units of area measure with sides of *1 lyn*, fit within a delta.

Lyns? QDs? Not surprisingly, Deltan systems of measurement are as unfamiliar as that for spatial coordinates. Table 1 summarizes the measurement schemes on DeltaP that you will need to know to carry out your design task.

All of DeltaP's units of measure share the divisibility and extensibility conventions of the metric system; in the measure of time, for example, there are both microwex (μwx) and megawex (*Mwx*). In relation to the attention-and life-spans of Deltans, these units are roughly equivalent to seconds and years, respectively, here on Earth.

TABLE 1. Measurements on DeltaP

Measurement	Unit of Measurement	Symbol
Time	Wex	wx
Distance	Lyn	ln
Area	Quarter-Delta	qd
Heat	Deltan Thermal Unit	DTU
Temperature	Degrees Nin	°Nn
Force	Din	Dn
Moment	Lyn-Din	LD
Currency	Zwig	!

As building components, deltas have functional and aesthetic characteristics that are more complex than their simple form and even dimensions would suggest. Especially when assembled into a cluster, as you will be doing, they behave in interesting ways. Deltas conduct heat among themselves, radiate heat to outer space, melt if too hot, and grow if too cool. Red deltas produce heat. All deltas are subject to DeltaP's two-dimensional gravity (which is itself subject to axial shifts during DeltaP's not-infrequent gravity waves). Three different kinds of cement are needed to join them together, and joint alignment with respect to gravity affects ease of production as well as

structural integrity. Different colors and different quantities of deltas cost different amounts of money per delta, and can be assembled in clusters that are either exceedingly ugly or very attractive to the Deltans. Your task will be to create a design that meets prescribed goals for all of these characteristics.

1.3 Design Team Roles & Responsibilities

Your design team is organized such that each of you will be responsible for a subset of the design goals. One of you will be PROJECT MANAGER. Your main concerns will be with cost and schedule, the interpretation and reconciliation of performance specifications, and negotiations with the contractor and client. You want to keep costs and time-to-build at a minimum, but not at the expense of quality. When your team submits its final design, the project manager must report the estimated cost (in zwigs) and the time (in wex) that it will take to build.

Another of you will be the STRUCTURAL ENGINEER. Your main concern will be to see that the design "holds together" as a physical structure under prescribed loading conditions. You must see to it that the two points at which your structure is tied to ground are appropriately chosen and that continuity of the structure is maintained. When your team submits its final design, the structural engineer must attest to its integrity by identifying the strongest and weakest joints, and estimating the average load on all joints expressed as a percentage of the failure load.

Another of you will be the THERMAL ENGINEER. You will want to insure that the design meets the "comfort-zone" conditions specified in terms of an average temperature. You must also ensure that the temperature of all individual deltas stays within certain bounds. When your team submits its final design, the thermal engineer must estimate internal temperature and identify the hottest and coldest deltas.

Finally, one of you will be the ARCHITECT. Your concern is with both the form of the design in and of itself and how it stands in its setting. You must see to it that the interior of the residence takes an appropriate form and that egress is convenient. You should also develop a design with character. When your team submits its final design, the architect should be prepared to present a sketch and discuss generally how and why the Deltans will find the residence attractive and functional. The architect will also be asked to estimate a few more quantitative measures of architectural performance.

The following section describes the specifications that your design must meet to be accepted by your clients on DeltaP. Familiarize yourself with these specifications. Then, for schooling in your specialty, turn to the separate primer you have received that discusses the science and technology of your domain. The primer contains the knowledge and heuristics you will need to estimate the design parameters for which you are responsible. If you have questions that it does not answer, do not hesitate to ask. You should be expert in your role before your team begins the design phase.

1.4 The Design Task

Your Deltan clients have cleared the space shown on the site map and come to your team with their need for the design of a new residential cluster. The cluster itself must meet the following specifications.

The client wants the cluster to provide a minimum interior area of 100 QDs (Each diamond on your girded site map defines an area of two QDs). The shape of this space, which can of course exceed the minimum, is a matter of design. The client has expressed enthusiasm for the newer

The Design Task

mode of segmenting interior space, a mode that breaks with the two-equal-zone tradition and values the suggested privacy of nooks and crannies. Still the space must be connected, i.e. no interior walls can cut the space into completely separate spaces. There must be one and only one entrance/exit.

The client is known to be color sensitive blue; too much blue brings on the blues, so to speak. No more than 60% blue ought to be allowed; certainly blue deltas are not to exceed 70% of the cluster.

The residence, as all clusters, must be anchored at two points and two points only. There is a limit to the amount of force each anchor can support, as well as to the amount of internal moment each joint can withstand. Exceeding either limit would cause catastrophic failure and send the unwary residents tumbling into the void. The cluster should be designed for a life of thirty megawex. Gravity waves, rare but always possible, should be considered.

The average interior temperature must be kept within the Deltan comfort zone, which lies between 55 and 65 °Nin. The temperature of the elements themselves must be kept above the growth point of 20 °Nn and below the melt-down point of 85 °Nn. Delta temperatures outside of this range will result in catastrophic structural failure with little more warning than excessive load.

All of this -- design, fabrication and construction -- must be done under a fixed budget and within a given time period. At your team meeting you are to develop a conceptual design that meets or exceeds all design goals. When each team submits their design, individual members will be asked to report design performance on parameters for which they are responsible.

TABLE 2. **Summary of Design Specifications**

Functional Internal Area	100 qd
Maximum Cool Deltas (% Total)	60-70%
Average Internal Temperature Range	55-65 °Nn
Individual Delta Temperature Range	20-85 °Nn
Maximum Load at Anchor Points	20 Dn
Maximum Internal Moment	40 LD
Overhead Factor -K	(varies)
Total Budget	! 1400.00

Delta Design PROJECT MANAGER PRIMER

1.1 Introduction

As project manager, your main concerns are cost and schedule, the interpretation and reconciliation of performance specifications, and negotiations with contractor and client. You want to keep costs and time-to-build at a minimum, but not at the expense of quality. When your team submits its final design, you must report the cost and time that you estimate will be required to build it. These estimates will be in zwigs (!) and wex, respectively.

As an experienced project manager, you know that all specifications are prone to slip during the conceptual design phase, and that budget and schedule, your specific responsibilities, are the most vulnerable. You have already realized that both are likely to be binding constraints, and further, that the Deltans are tight with a zwig and anxious to move in. Like clients everywhere, they desire a better residence then they can comfortably afford.

1.2 Estimating Project Costs

Your job of estimating project cost has been greatly simplified by finding a supplier-contractor that quotes material costs inclusive of delivery and most assembly charges. The cost schedules presented below for buying deltas and the cement needed to glue them together thus reflect near-final costs, with two important exceptions. One source of additional cost comes from the modular construction techniques used on DeltaP: material prices cover the labor cost to assemble deltas into modules, which is done at the factory, but not the on-site cost of positioning and joining these modules into the final structure. The second additional cost is overhead, which covers, among many other things, the cost of paying your design team.

To estimate the cost of your team's design:

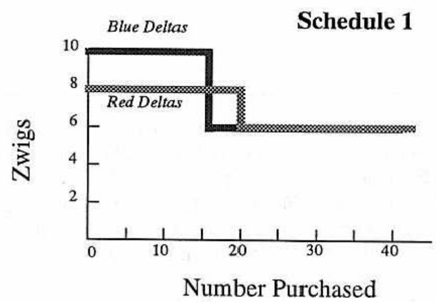
- figure the cost of the deltas used;
- figure the cost of the cement needed to joint them;
- figure the number of modules and the cost to join them; sum all these up and multiply by the overhead rate.

To estimate how long it will take to construct your design:

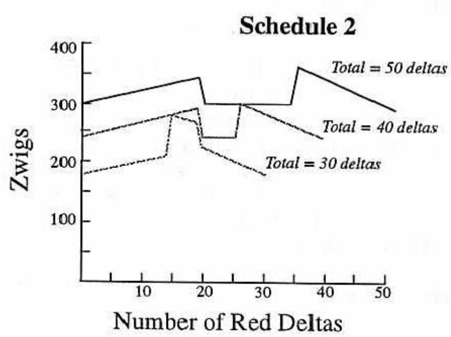
- identify the separate modules;
- determine how long it will take to construct each one;
- determine how long it will take to assemble them at the site;
- sum these up.

1.3 Delta Costs

The cost of deltas varies by color and quantity purchased. The price break for blue deltas is at 16 units: blues cost !10 apiece if fewer than 16 are purchased, !6 for 16 or more. The price break for red deltas is at 20 units: reds cost !8 each if fewer than 20 are purchased, !6 for 20 or more. These costs are shown in Schedule 1.



Schedule 2 illustrates how the total cost of deltas purchased varies with color composition. The y axis shows total ! cost and the x axis show the number of red deltas used. The three graphs show the color-mix variance in total delta costs for structures using a total of 30, 40, and 50 deltas, respectively. This schedule can help you calculate the most economical color mix for a given structure size.



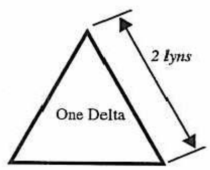
1.3.1 Cement Costs

You will need to purchase three different types of cement, at three different costs, to assemble deltas into your structure. Three types --*R^2*, *B^2*, and *RB* -- are required because different types of joints require different types of cement. R^2 (pronounced "r squared") is the red-red binder needed to bond one red delta to another red delta. *RB,* the most expensive, is the red-blue binder that bonds a red delta to a blue delta. Finally, B^2 is the least expensive and bonds two blue deltas. The following costs apply;

TABLE 1. Cement Costs

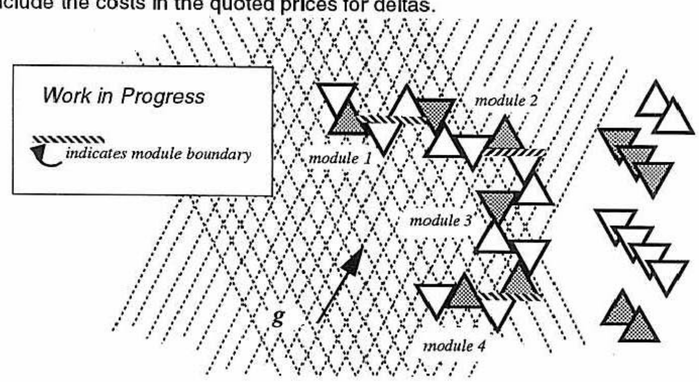
Cement Unit Costs	
R^2	!10 / lyn
RB	!20 / lyn
B^2	!5 / lyn

Note that the cost of fastening one delta to another will be determined by the length of contact between elements as well as by their respective colors: the longer the joint, the more glue is required. A fully overlapped 2 lyn joint between a red and a blue delta will cost !40; hardly pocket change.



1.3.2 Module Joining Costs

Should your team's design be selected, construction will proceed in two stages. In the first stage, individual deltas are joined into modules. This takes place at the factory, where the supplier firm has developed jigs and fixtures that simplify the task, allowing them to accurately predict and therefore include the costs in the quoted prices for deltas.



The individual modules into which a given structure will be decomposed and constructed at the factory are easy to identify, because the boundaries between them are defined by the orientation of the joints relative to gravity. To an earthly eye, any intersection of two deltas that runs left to right, across the page, is a module boundary. The figure shows how this works. The design has 3 such joints, and therefore 4 modules.

When all modules are complete, they are transported to the site, joined together, and anchored to the plane. This on-site work is more difficult to cost out in advance, so the client will essentially have to pay whatever costs are incurred. Your experienced contractor, however, has told you that her rule of thumb for predicting them is to figure the cost of glue needed for the module-to-module joints and double it. Thus the approximate on-site cost to joint Modules 1 and 2 in the figure could be estimated as 1 lyn of length times !5 per lyn of BB cement times 2, or !10. These module-joining costs are *in addition to* the cost of cement used in joining Module 1 to Module 2.

1.3.3 Total Cost

The total cost to execute your design may be estimated by summing up the cost of deltas, cement, and module joinery, and multiplying the result by an overhead factor K:

Total Cost = K x (delta cost + cement cost + module cost)

Because K takes into account the cost of living on DeltaP and must be updated frequently, it is not included in this primer. Refer to the earlier handout entitled "The Design Task" for its value, or ask the instructor.

1.4 Estimating Time-to-Build

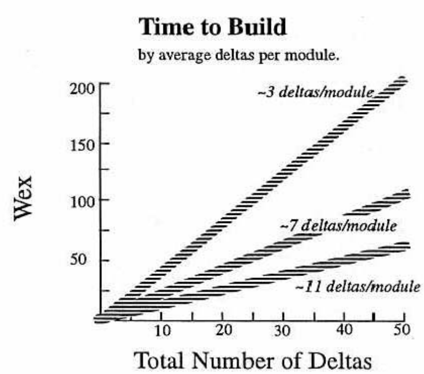
Estimating time-to-build is inexact, at best, but again your contractor has supplied some rules of thumb. Rough results are shown in the graph, but you will do better to figure them more precisely.

For each module consisting of three deltas or fewer, allow 2 wex;

For each module consisting of more than three deltas, allow 3 wex;

For each module-to-module joint, allow 4 wex;

Sum all of these up and double the result.



Delta Design THE DESIGN TASK

Architect's Primer appended.

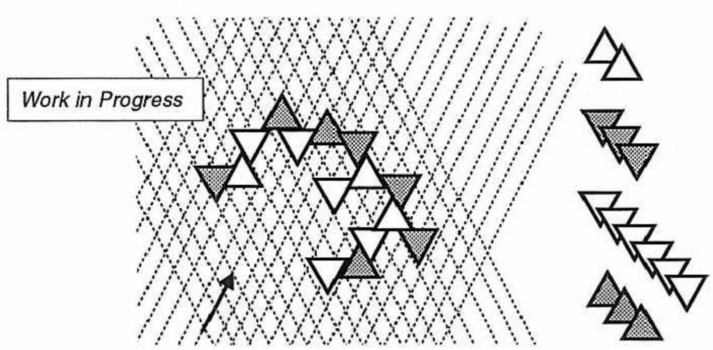
1.1 Introduction

Congratulations! You are now a member of an expert design team. Your collective task will be to design a new residence suitable for inhabitants of the imaginary Deltoid plane. These written materials, provided to help you prepare for this task, are organized in four sections.

The next section provides an overview of life on the Deltoid plane, DeltaP as it is known to the natives. The following section describes your team, and the final, your design task. A second handout, different for each team member, provides the specific information you will need to perform the role you have been assigned within your team. Each team member will contribute different expertise to the project, and each has different design responsibilities to fulfill. All must work together for your team to create a first-rate design.

1.2 Life on DeltaP

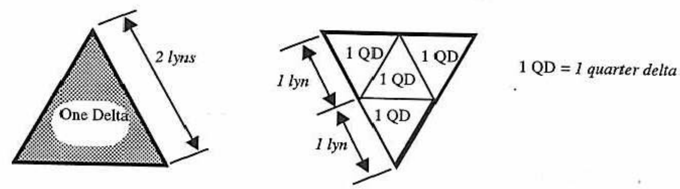
Life on DeltaP, residential and otherwise, is quite different from what you have grown accustomed to here on Earth. First off, DeltaP is a plane, not a planet, so your team will be designing in two-dimensional rather than three-dimensional space. If your design "meets spec" and is considered attractive and functional by your Deltan clients, one view on a single sheet of paper will convey to those responsible for constructing it all the information they need to do so.



Life on DeltaP

The view on this single sheet may not be quite what you expect, however, because in addition to lacking a z axis, Deltoid space has unfamiliar relations between the x and y axes as well. What we think of as "perpendicular" is hopelessly skewed to a Deltan, and vice-versa. In our units, a right angle on DeltaP measures 60° or $\pi/3$ radians. Thus all sides of an equilateral triangle form lines considered perpendicular to all others. If there were such a thing as a "circle" on DeltaP, it would be composed of only $4\pi/3$ radians.

But there is no such thing as a "circle" on DeltaP, nor even the concept of continuity embodied therein. In this flat though angular world, residents construct their artifacts strictly with discrete triangular forms. Of these, the equilateral triangle -- with its three perpendicular sides (!)-- is considered the most pleasing. Accordingly, your team will design the residence by assembling into a



cluster the most prized building materials on DeltaP, equilateral triangular components called "deltas." Deltas come in red and blue versions and always measure *2 lyns* per side. Four "quarter-deltas", *QDs*, triangular units of area measure with sides of *1 lyn*, fit within a delta.

Lyns? QDs? Not surprisingly, Deltan systems of measurement are as unfamiliar as that for spatial coordinates. Table 1 summarizes the measurement schemes on DeltaP that you will need to know to carry out your design task.

All of DeltaP's units of measure share the divisibility and extensibility conventions of the metric

TABLE 1. **Measurements on DeltaP**

Measurement	Unit of Measurement	Symbol
Time	Wex	wx
Distance	Lyn	ln
Area	Quarter-Delta	qd
Heat	Deltan Thermal Unit	DTU
Temperature	Degrees Nin	°Nn
Force	Din	Dn
Moment	Lyn-Din	LD
Currency	Zwig	!

system; in the measure of time, for example, there are both microwex (μwx) and megawex (*Mwx*). In relation to the attention-and life-spans of Deltans, these units are roughly equivalent to seconds and years, respectively, here on Earth.

As building components, deltas have functional and aesthetic characteristics that are more complex than their simple form and even dimensions would suggest. Especially when assembled into a cluster, as you will be doing, they behave in interesting ways. Deltas conduct heat among themselves, radiate heat to outer space, melt if too hot, and grow if too cool. Red deltas produce heat. All deltas are subject to DeltaP's two-dimensional gravity (which is itself subject to axial shifts during DeltaP's not-infrequent gravity waves). Three different kinds of cement are needed to join them together, and joint alignment with respect to gravity affects ease of production as well as

structural integrity. Different colors and different quantities of deltas cost different amounts of money per delta, and can be assembled in clusters that are either exceedingly ugly or very attractive to the Deltans. Your task will be to create a design that meets prescribed goals for all of these characteristics.

1.3 Design Team Roles & Responsibilities

Your design team is organized such that each of you will be responsible for a subset of the design goals. One of you will be PROJECT MANAGER. Your main concerns will be with cost and schedule, the interpretation and reconciliation of performance specifications, and negotiations with the contractor and client. You want to keep costs and time-to-build at a minimum, but not at the expense of quality. When your team submits its final design, the project manager must report the estimated cost (in zwigs) and the time (in wex) that it will take to build.

Another of you will be the STRUCTURAL ENGINEER. Your main concern will be to see that the design "holds together" as a physical structure under prescribed loading conditions. You must see to it that the two points at which your structure is tied to ground are appropriately chosen and that continuity of the structure is maintained. When your team submits its final design, the structural engineer must attest to its integrity by identifying the strongest and weakest joints, and estimating the average load on all joints expressed as a percentage of the failure load.

Another of you will be the THERMAL ENGINEER. You will want to insure that the design meets the "comfort-zone" conditions specified in terms of an average temperature. You must also ensure that the temperature of all individual deltas stays within certain bounds. When your team submits its final design, the thermal engineer must estimate internal temperature and identify the hottest and coldest deltas.

Finally, one of you will be the ARCHITECT. Your concern is with both the form of the design in and of itself and how it stands in its setting. You must see to it that the interior of the residence takes an appropriate form and that egress is convenient. You should also develop a design with character. When your team submits its final design, the architect should be prepared to present a sketch and discuss generally how and why the Deltans will find the residence attractive and functional. The architect will also be asked to estimate a few more quantitative measures of architectural performance.

The following section describes the specifications that your design must meet to be accepted by your clients on DeltaP. Familiarize yourself with these specifications. Then, for schooling in your specialty, turn to the separate primer you have received that discusses the science and technology of your domain. The primer contains the knowledge and heuristics you will need to estimate the design parameters for which you are responsible. If you have questions that it does not answer, do not hesitate to ask. You should be expert in your role before your team begins the design phase.

1.4 The Design Task

Your Deltan clients have cleared the space shown on the site map and come to your team with their need for the design of a new residential cluster. The cluster itself must meet the following specifications.

The client wants the cluster to provide a minimum interior area of 100 QDs (Each diamond on your girded site map defines an area of two QDs). The shape of this space, which can of course exceed the minimum, is a matter of design. The client has expressed enthusiasm for the newer

mode of segmenting interior space, a mode that breaks with the two-equal-zone tradition and values the suggested privacy of nooks and crannies. Still the space must be connected, i.e. no interior walls can cut the space into completely separate spaces. There must be one and only one entrance/exit.

The client is known to be color sensitive blue; too much blue brings on the blues, so to speak. No more than 60% blue ought to be allowed; certainly blue deltas are not to exceed 70% of the cluster.

The residence, as all clusters, must be anchored at two points and two points only. There is a limit to the amount of force each anchor can support, as well as to the amount of internal moment each joint can withstand. Exceeding either limit would cause catastrophic failure and send the unwary residents tumbling into the void. The cluster should be designed for a life of thirty megawex. Gravity waves, rare but always possible, should be considered.

The average interior temperature must be kept within the Deltan comfort zone, which lies between 55 and 65 °Nin. The temperature of the elements themselves must be kept above the growth point of 20 °Nn and below the melt-down point of 85 °Nn. Delta temperatures outside of this range will result in catastrophic structural failure with little more warning than excessive load.

All of this -- design, fabrication and construction -- must be done under a fixed budget and within a given time period. At your team meeting you are to develop a conceptual design that meets or exceeds all design goals. When each team submits their design, individual members will be asked to report design performance on parameters for which they are responsible.

TABLE 2. **Summary of Design Specifications**

Functional Internal Area	100 qd
Maximum Cool Deltas (% Total)	60-70%
Average Internal Temperature Range	55-65 °Nn
Individual Delta Temperature Range	20-85 °Nn
Maximum Load at Anchor Points	20 Dn
Maximum Internal Moment	40 LD
Overhead Factor -K	(varies)
Total Budget	! 1400.00

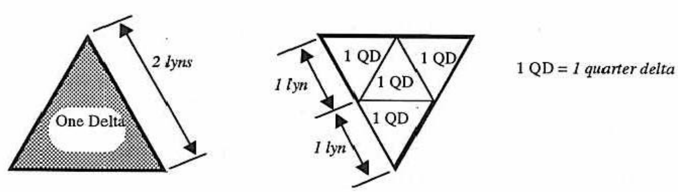
Delta Design ARCHITECT PRIMER

1.1 Introduction

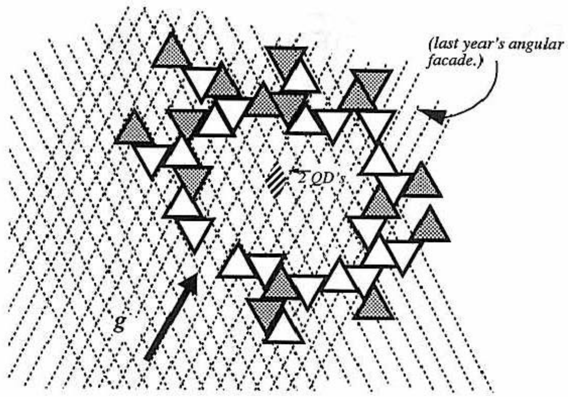
As architect, your concern is with the intrinsic form and function of your team's design, as well as how it relates to the site. When your team submits its final design, you should be prepared to discuss how and why the Deltans will find the residence attractive and functional. You will also be asked to report some more quantitative architectural measures discussed below.

1.2 Function Follows Form

As simple as the fundamental building elements appear, quite complex, intricate and angular form can be composed out of deltas. As architect, it is your responsibility to create design that not only meets the clients' physical needs but in some way stands as an expression of their vision of themselves and their community.



You read this vision as a vision of progress and innovation. You imagine a form that, while rooted in tradition, suggests a reaching out toward the unknown. Tradition has valued the angular exterior facade. You want to experiment with the smooth. Perhaps a rhythmic alternation of a smooth facade over a finite number of lyns with the traditional angular exterior will prove interesting



Coming more into vogue is the angular interior. There is some kind of reversal going on here. The interior traditionally has been made smooth, to maximize interaction ad communication. Nowadays privacy has become a common word in architectural discourse. While an argument can be made that the use of deltas to shape interior nooks and crannies is an inefficient use of this one resource, you think that this is a short-sighted view even though it is a view "rationally" argued by your engineering colleagues.

Your clients want to go even further. They seem to want some kind of "fractal" interior -- not just one space with nooks and crannies but sub-spaces which themselves suggest nooks and crannies. This is all very fuzzy in your mind but you are keen to experiment and have started sketching.

At the same time, you are keen to economize on space designated for circulation within the interior. You want, in other words, to maximize functional space. Note that a quarter-delta is an area within which three inhabitants could stand and talk comfortably, one to another. Several lyns are then required for circulation cross-section, not only within the interior but also at the entrance.

The single entrance/exit is conventionally aligned with the force field and "upstream" as viewed from outside; that is, one enters the cluster moving forward, in the direction of gravitational pull. This is so because Deltans are themselves subject to gravity. They have evolved over the many *gigawex* of their existence to the point where they now are able to maneuver in any direction without conscious attention to the force field. However, the entrance to most clusters is located so that the residents would fall into rather than out of the cluster if they were to lose this sense. This orientation is essential during passage of a gravity wave.

As noted in the description of the design task, your client is blue sensitive. While the allowable dosage of blue deltas in the environs is no set number, you conjecture that the blues ought not to constitute more than 60% of the elements. Dispersion of the blues is preferred as well, so that residents are not confronted with seemingly endless blue vistas when viewing the interior.

1.3 Some Quantitative Measures

Although the Deltans will ultimately judge the quality of your work by stepping back and casting a critical eye at the overall design, they have also requested that you provide some simple measures of design quality. These measures, and the methods to use to figure them, are as follows:

Some Quantitative Measures

- *Internal Area:* Estimate the internal area (in QDs) by using the grid on the site map. Each diamond has an area of 2 QDs.

- *Blueness:* Calculate the blueness of your design by figuring out how many of the deltas used are blue, expressed as a percentage of the total.

- *Blue Dispersion:* Count the total number of joints between deltas where either or both are blue. Now count how many of these do not join two blues, and express the result as a percentage of the total. 100% would mean you had achieved perfect dispersion.

- *I/E Perimeter Ratio:* Measure the interior and exterior wall lengths in lyns and divide the interior length by the exterior. Because a craggy wall will be longer than a smooth one, the higher this ratio is, the better you have met the clients desires discussed above. Certainly this ratio should be greater than 1.

A final note: unless told by the instructor that you will be remodeling the clients' existing residence rather than designing an entirely new one, you as architect are responsible for putting forward an initial configuration for consideration by your design team.

Delta Design THE DESIGN TASK

Structural Engineer's Primer appended.

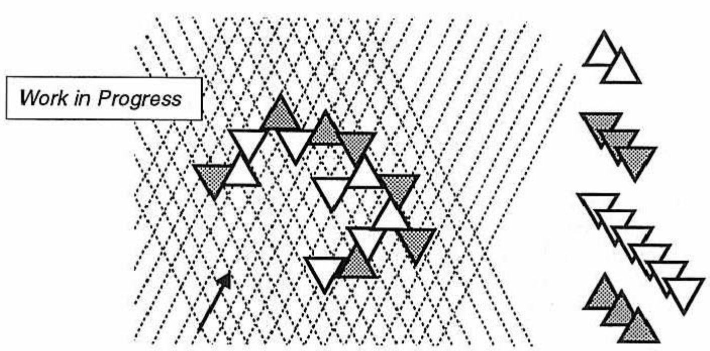
1.1 Introduction

Congratulations! You are now a member of an expert design team. Your collective task will be to design a new residence suitable for inhabitants of the imaginary Deltoid plane. These written materials, provided to help you prepare for this task, are organized in four sections.

The next section provides an overview of life on the Deltoid plane, DeltaP as it is known to the natives. The following section describes your team, and the final, your design task. A second handout, different for each team member, provides the specific information you will need to perform the role you have been assigned within your team. Each team member will contribute different expertise to the project, and each has different design responsibilities to fulfill. All must work together for your team to create a first-rate design.

1.2 Life on DeltaP

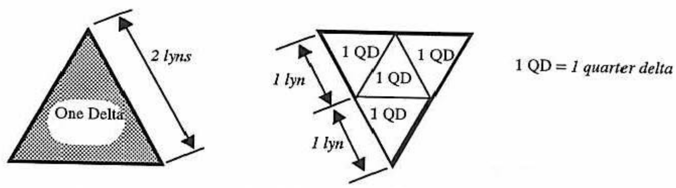
Life on DeltaP, residential and otherwise, is quite different from what you have grown accustomed to here on Earth. First off, DeltaP is a plane, not a planet, so your team will be designing in two-dimensional rather than three-dimensional space. If your design "meets spec" and is considered attractive and functional by your Deltan clients, one view on a single sheet of paper will convey to those responsible for constructing it all the information they need to do so.



Life on DeltaP

The view on this single sheet may not be quite what you expect, however, because in addition to lacking a z axis, Deltoid space has unfamiliar relations between the x and y axes as well. What we think of as "perpendicular" is hopelessly skewed to a Deltan, and vice-versa. In our units, a right angle on DeltaP measures 60° or $\pi/3$ radians. Thus all sides of an equilateral triangle form lines considered perpendicular to all others. If there were such a thing as a "circle" on DeltaP, it would be composed of only $4\pi/3$ radians.

But there is no such thing as a "circle" on DeltaP, nor even the concept of continuity embodied therein. In this flat though angular world, residents construct their artifacts strictly with discrete triangular forms. Of these, the equilateral triangle -- with its three perpendicular sides (!)-- is considered the most pleasing. Accordingly, your team will design the residence by assembling into a



cluster the most prized building materials on DeltaP, equilateral triangular components called "deltas." Deltas come in red and blue versions and always measure *2 lyns* per side. Four "quarter-deltas", *QDs*, triangular units of area measure with sides of *1 lyn*, fit within a delta.

Lyns? QDs? Not surprisingly, Deltan systems of measurement are as unfamiliar as that for spatial coordinates. Table 1 summarizes the measurement schemes on DeltaP that you will need to know to carry out your design task.

All of DeltaP's units of measure share the divisibility and extensibility conventions of the metric

TABLE 1. **Measurements on DeltaP**

Measurement	Unit of Measurement	Symbol
Time	Wex	wx
Distance	Lyn	ln
Area	Quarter-Delta	qd
Heat	Deltan Thermal Unit	DTU
Temperature	Degrees Nin	°Nn
Force	Din	Dn
Moment	Lyn-Din	LD
Currency	Zwig	!

system; in the measure of time, for example, there are both microwex (μwx) and megawex (*Mwx*). In relation to the attention-and life-spans of Deltans, these units are roughly equivalent to seconds and years, respectively, here on Earth.

As building components, deltas have functional and aesthetic characteristics that are more complex than their simple form and even dimensions would suggest. Especially when assembled into a cluster, as you will be doing, they behave in interesting ways. Deltas conduct heat among themselves, radiate heat to outer space, melt if too hot, and grow if too cool. Red deltas produce heat. All deltas are subject to DeltaP's two-dimensional gravity (which is itself subject to axial shifts during DeltaP's not-infrequent gravity waves). Three different kinds of cement are needed to join them together, and joint alignment with respect to gravity affects ease of production as well as

structural integrity. Different colors and different quantities of deltas cost different amounts of money per delta, and can be assembled in clusters that are either exceedingly ugly or very attractive to the Deltans. Your task will be to create a design that meets prescribed goals for all of these characteristics.

1.3 Design Team Roles & Responsibilities

Your design team is organized such that each of you will be responsible for a subset of the design goals. One of you will be PROJECT MANAGER. Your main concerns will be with cost and schedule, the interpretation and reconciliation of performance specifications, and negotiations with the contractor and client. You want to keep costs and time-to-build at a minimum, but not at the expense of quality. When your team submits its final design, the project manager must report the estimated cost (in zwigs) and the time (in wex) that it will take to build.

Another of you will be the STRUCTURAL ENGINEER. Your main concern will be to see that the design "holds together" as a physical structure under prescribed loading conditions. You must see to it that the two points at which your structure is tied to ground are appropriately chosen and that continuity of the structure is maintained. When your team submits its final design, the structural engineer must attest to its integrity by identifying the strongest and weakest joints, and estimating the average load on all joints expressed as a percentage of the failure load.

Another of you will be the THERMAL ENGINEER. You will want to insure that the design meets the "comfort-zone" conditions specified in terms of an average temperature. You must also ensure that the temperature of all individual deltas stays within certain bounds. When your team submits its final design, the thermal engineer must estimate internal temperature and identify the hottest and coldest deltas.

Finally, one of you will be the ARCHITECT. Your concern is with both the form of the design in and of itself and how it stands in its setting. You must see to it that the interior of the residence takes an appropriate form and that egress is convenient. You should also develop a design with character. When your team submits its final design, the architect should be prepared to present a sketch and discuss generally how and why the Deltans will find the residence attractive and functional. The architect will also be asked to estimate a few more quantitative measures of architectural performance.

The following section describes the specifications that your design must meet to be accepted by your clients on DeltaP. Familiarize yourself with these specifications. Then, for schooling in your specialty, turn to the separate primer you have received that discusses the science and technology of your domain. The primer contains the knowledge and heuristics you will need to estimate the design parameters for which you are responsible. If you have questions that it does not answer, do not hesitate to ask. You should be expert in your role before your team begins the design phase.

1.4 The Design Task

Your Deltan clients have cleared the space shown on the site map and come to your team with their need for the design of a new residential cluster. The cluster itself must meet the following specifications.

The client wants the cluster to provide a minimum interior area of 100 QDs (Each diamond on your girded site map defines an area of two QDs). The shape of this space, which can of course exceed the minimum, is a matter of design. The client has expressed enthusiasm for the newer

mode of segmenting interior space, a mode that breaks with the two-equal-zone tradition and values the suggested privacy of nooks and crannies. Still the space must be connected, i.e. no interior walls can cut the space into completely separate spaces. There must be one and only one entrance/exit.

The client is known to be color sensitive blue; too much blue brings on the blues, so to speak. No more than 60% blue ought to be allowed; certainly blue deltas are not to exceed 70% of the cluster.

The residence, as all clusters, must be anchored at two points and two points only. There is a limit to the amount of force each anchor can support, as well as to the amount of internal moment each joint can withstand. Exceeding either limit would cause catastrophic failure and send the unwary residents tumbling into the void. The cluster should be designed for a life of thirty megawex. Gravity waves, rare but always possible, should be considered.

The average interior temperature must be kept within the Deltan comfort zone, which lies between 55 and 65 °Nin. The temperature of the elements themselves must be kept above the growth point of 20 °Nn and below the melt-down point of 85 °Nn. Delta temperatures outside of this range will result in catastrophic structural failure with little more warning than excessive load.

All of this -- design, fabrication and construction -- must be done under a fixed budget and within a given time period. At your team meeting you are to develop a conceptual design that meets or exceeds all design goals. When each team submits their design, individual members will be asked to report design performance on parameters for which they are responsible.

TABLE 2. **Summary of Design Specifications**

Functional Internal Area	100 qd
Maximum Cool Deltas (% Total)	60-70%
Average Internal Temperature Range	55-65 °Nn
Individual Delta Temperature Range	20-85 °Nn
Maximum Load at Anchor Points	20 Dn
Maximum Internal Moment	40 LD
Overhead Factor -K	(varies)
Total Budget	! 1400.00

Delta Design STRUCTURAL ENGINEER PRIMER

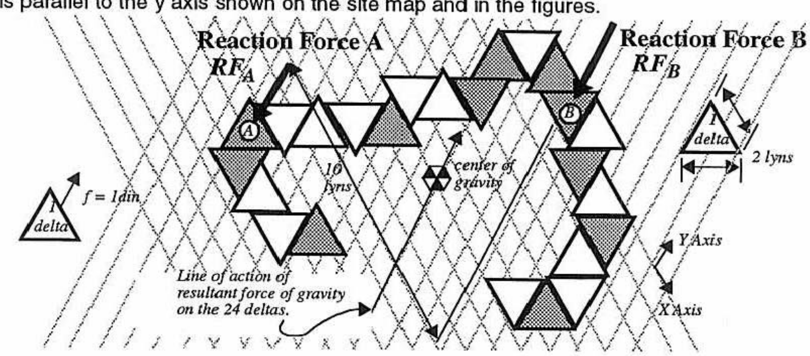
1.1 Introduction

As structural engineer, you are responsible for the physical integrity and robustness of your team's design. You must insure that the residence you propose will hold together under prescribed loading conditions. You should see to it that the two points at which your structure is anchored to the plane are appropriately chosen, that all joints are sufficiently strong, and that the overall shape of the cluster does not violate sound structural engineering practice. You should also strive for an elegant and efficient design, one that provides the requisite strength and durability with minimum costs and materials.

When your team submits its final design, you will be asked to attest to its quality by explaining the location of the anchors, identifying the strongest and weakest joints, and estimating, as a measure of robustness, the average load on all joints expressed as a percentage of failure loads. You may be asked to predict what will happen to your design during the next gravity wave.This primer will give you the tools, essentially the methods of static equilibrium analysis, with which to do your work. It assumes you have read the introduction to the Delta design exercise.

1.2 The Gravitational Field — The Center of Gravity

A uni-directional, gravitational force field acts on each delta in the plane. The direction of this force is parallel to the y axis shown on the site map and in the figures.



The Gravitational Field — The Center of Gravity

Each delta experiences a force of one *din.* Thus for the cluster of 24 elements shown in the figure, we can say

- that it has a total weight of *24 dins*, and
- that the resulting force due to Deltan gravity acts in the plane along a line parallel to the *y* axis and running through the cluster's center of gravity, as shown.

The structure is kept stationary despite this force by offsetting reaction forces at the anchors, marked in the figure as points *A* and *B*.

The first step in structural analysis is to locate the cluster's center of gravity (*CG*). For our initial purposes, we actually only need the CG's *x* coordinate, which gives us the line of action of the gravity force shown on the previous page. We do not need to know the *y* coordinate until we consider DeltaP's recurrent gravity waves, which flip gravity between axes, and when the time comes, you can determine it by similarly flipping the following moment equilibrium calculation. You may also use the moment equilibrium technique to locate the *CG* of any subsection of a cluster.

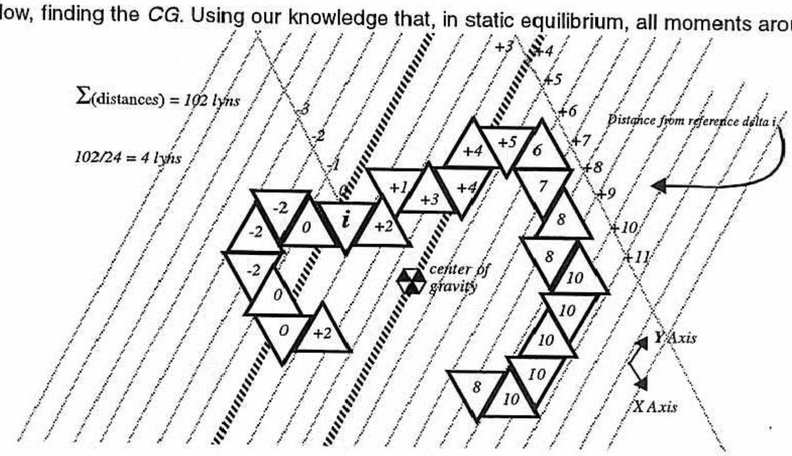
There are two things to keep in mind throughout your calculations. First, keep them as simple as possible. Work only in integers, always rounding up or down and estimating distances, forces and moments to the nearest *lyn, din*, or *lyn-din* respectively.

Second, keep in mind the peculiarities of Deltan space, where "perpendicular" describes an arc measuring only 60 degrees or $\pi/3$ radians in our units, and where distance measurements are made only along lines parallel to the axes. On DeltaP, the distance between anchors *A* and *B*, for example, measures *10 lyns*, as shown in the previous figure.

This distinction is critical in the calculation of *moment, the turning effect of a force about a point.* As on Earth, moment is still the product of the force and its distance from the point, but the distance must be measured in Deltan space. The moment that force RF_A exerts about point *B*, for example, is the product of the distance in *lyns*, measured parallel to the *x* axis, from the line of action of RF_A to anchor *B* (*10 lyns*), and force RF_A measured in *dins*. Not surprisingly, moment, M, is measured in *lyn-dins*, abbreviated *LD*:

M (RF_A about *B*), in *lyn-dins* = *10 lyns* XRF_A dins

Now, finding the *CG*. Using our knowledge that, in static equilibrium, all moments around any



given point will sum to zero, we can find a cluster's *CG* in reference to any delta, call it the i^{th}, by equating the sum of moments around it generated by gravity acting on each individual delta to the moment of the entire cluster around it:

$$\sum_{j=1}^{N} (f \times D_{ij}) = N \times f \times D_{i,cg}$$

where:

- N is the number of deltas in the cluster;
- f is the gravity force experience by each delta, equal to 1;
- D_{ij}, is the distance between the i^{th} and each other delta;
- $D_{i,cg}$ is the distance between the i^{th} delta and the *CG's* line of action du to gravity.

Simplifying and solving for $D_{i,cg}$ gives us:

$$D_{i,cg} = \frac{\sum_{j=1}^{N} D_{ij}}{N}$$

So finding the *CG's x* coordinate is as simple as summing up the distances between any delta and all others, dividing by the total number of deltas, and adding the result to the x coordinate of the delta used as a reference. Just be sure to adhere to Deltan measurement technique, and express distances to the left and right of the reference as negative and positive numbers respectively.

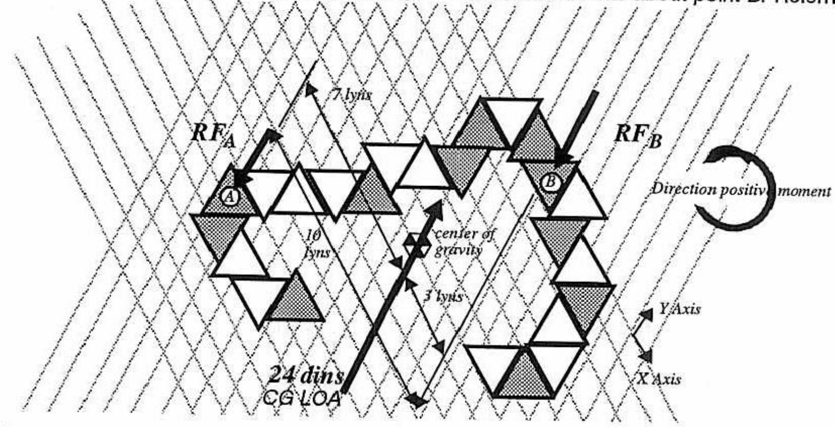
In the example shown in the figure, the distances from the i^{th} delta sum to *102 lyns*. Dividing by *N=24* gives us *4 lyns*, which we then count over, and *viola*, we have the location of the *CG's line of action* of the force due to gravity. Call this the *CG LOA*.

1.3 Estimating Support Loads

Each of the two anchors has sufficient strength to support a load of *20 dins*. They can resist no twisting effect, no moment, about their axes, i.e. they act as frictionless pins holding the cluster in place. To estimate the support loads that they will be subject to, first sum up the total force due to gravity acting on all deltas in the cluster. We know that this force, measured in *dins* as discussed above, is equal to the total number of elements N since each element experiences a force of *1 din*. We also know that, for equilibrium, the two reaction forces at the anchors, marked on the figure as RF_A and RF_B must also sum to this total force:

$RF_A + RF_B = N \, X f = 24 \text{ dins}$

We need a second equation to solve for the reaction forces, which we can get by calculating the moment equilibrium of the entire cluster with reference to either anchor. We will use anchor *B* as a reference. In Deltan equilibrium analysis lingo — *we take moments about point B.* Referring



to the figure, assume that a positive moment acts to rotate the cluster counter-clockwise. Measure the distance from the *CG LOA* to anchor *B*: these *3 lyns* are the distance over which the *24 din* gravity force acting on the entire cluster creates a moment about *B*.

Since we know that, in equilibrium, the (positive) moment of RF_A about anchor *B* must balance the (negative) moment of the entire cluster about B, we have that:

$10 \text{ lyns} \times RF_A - (24 \text{ dins} \times 3 \text{ lyns}) = 0$

We solve for RF_A

$$RF_A = 72 \text{ lyn-dins} / 10 \text{ lyns} = 7 \text{ dins}$$

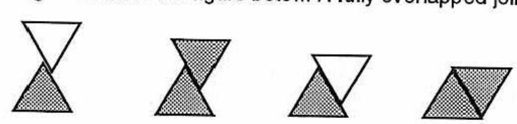
And, with the first equation, for RF_B

$$RF_B = 24 - RF_A = 17 \text{ dins}$$

Since anchors can withstand *20 dins*, anchor *A* is in fine shape. Anchor *B*, however, only has a safety margin of *20/17*, or roughly *1.2*. This is ok, but you won't win awards for robustness. Can you see how to relocate the anchors for a better balance of reaction forces?

1.4 Internal Moments and Fastener Requirements

Adjacent elements are held together by cement. The cement is necessary because otherwise the structure could not support the internal forces and moments, again due to gravitational loading. T internal moment is the most critical of these. Although the ***strength of the cement*** varies by supplier, your source has certified hers at ***20 LD per lyn of contact***, resulting in the linear relationship between length and strength shown in the figure below. A fully overlapped joint fastened with

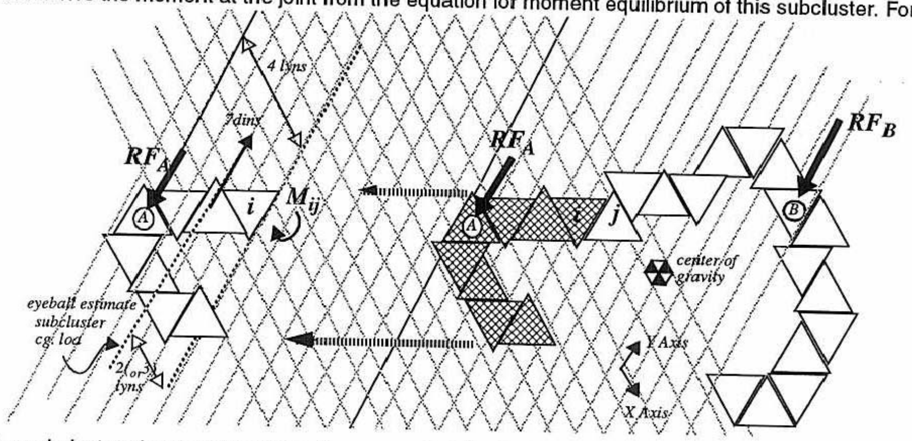


Joint Length = 0.5 lyn ***1.0 lyn*** ***1.5 lyn*** ***2.0 lyn***
Maximum Moment = 10 LD ***20 LD*** ***30 LD*** ***40 LD***

this cement will have a maximum allowable internal moment of *40 lyn-dins*.

Internal Moments and Fastener Requirements

Given this length-strength relationship, how do we estimate the actual internal moments that joints will experience and must withstand? Simply treat each joint as the boundary of a subcluster, and derive the moment at the joint from the equation for moment equilibrium of this subcluster. For



the subcluster shown in the figure the moment at the intersection of deltas i and j, denoted M_{ij} is found in the following steps:

- find the sub-cluster's *CG LOA* and its distance from the joint: here, about *2 or 3 lyns*;
- find the force exerted due to gravity by the subcluster, a quantity equal to the number of deltas in t: here *8 dins*;
- find the product, which gives us the moment of the subcluster about the joint;
- if the subcluster contains any anchor points, figure the moments of resulting reaction forces around the joint; in this case, we know that RF_A=*7 dins,* and measure the distance as *4 lyns*;
- taking moments about the joint as positive if they tend to rotate the section clockwise, express the fact that for equilibrium the sum of all the moments must be zero:

M_{ij} + *(moment of subcluster about joint) - (moment of* RF_A *about joint)* =0

- solve for M_{ij}

M_{ij} = *(moment of* RF_A *about joint) - (moment of subcluster about joint)*

So in our case, we get

M_{ij} =*(7din x 4 lyn)-(8 dn x 2 or 3 lyn) = 12 or 4 LD.*

This sounds pretty tame, since the joint is fully overlapped and can withstand *40 LD.* In fact, it sounds like a waste of cement, because a joint 25% shorter would still provide a hefty safety margin.

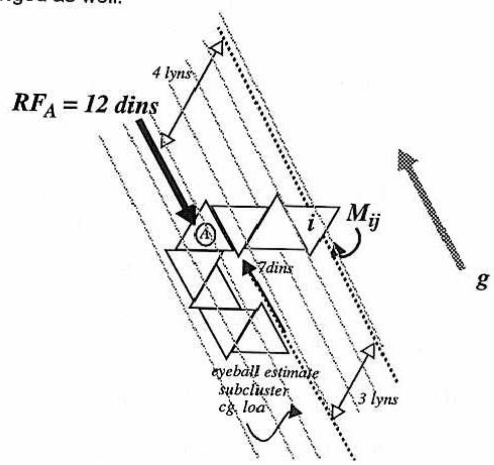
With these same six steps, we can estimate the internal moment at any joint we choose to examine, and compare it to the strength of the joint.

1.5 Gravity Waves

Finally, although the gravitational force across the Deltoid plane is forever constant in magnitude, the rare but inevitable gravity wave will, when it comes, instantaneously shift its direction orthogonally; from that of the y axis shown on the site map to that of the x axis. Gravity will then retain that direction until the next wave arrives and causes it to shift back. The figure shows the change in internal moment that the joint just discussed would undergo in the event of such a wave. We now obtain

$$M_{ij} = (12 \text{ dins} \times 4 \text{ lyns}) - (7 \text{ dins} \times 3 \text{ lyns}) = 27 \text{ LD}$$

which is significantly greater than the value previously obtained. Note that the reaction force at the anchor point has changed as well.



The last gravity wave passed through about 40 megawex (*Mwx*) ago, causing widespread destruction. The time period between waves is a random variable — a Poisson process with a mean arrival time of 80 *Mwx*. The statistics are generally considered "good" only for the past gigawex or so, and myths of old suggest that but ten Mwx separated two waves at the time of the flood. Should you worry about it?

Delta Design THE DESIGN TASK

Thermal Engineer's Primer appended.

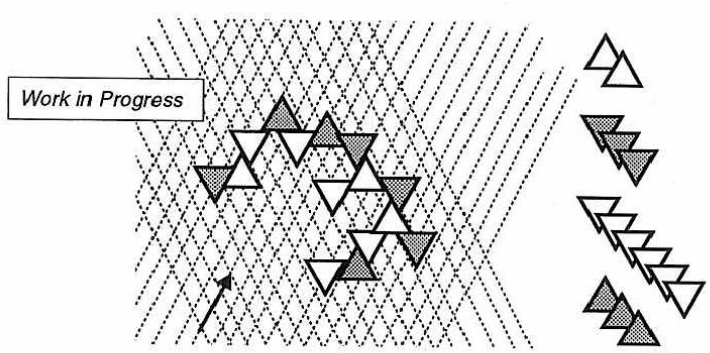
1.1 Introduction

Congratulations! You are now a member of an expert design team. Your collective task will be to design a new residence suitable for inhabitants of the imaginary Deltoid plane. These written materials, provided to help you prepare for this task, are organized in four sections.

The next section provides an overview of life on the Deltoid plane, DeltaP as it is known to the natives. The following section describes your team, and the final, your design task. A second handout, different for each team member, provides the specific information you will need to perform the role you have been assigned within your team. Each team member will contribute different expertise to the project, and each has different design responsibilities to fulfill. All must work together for your team to create a first-rate design.

1.2 Life on DeltaP

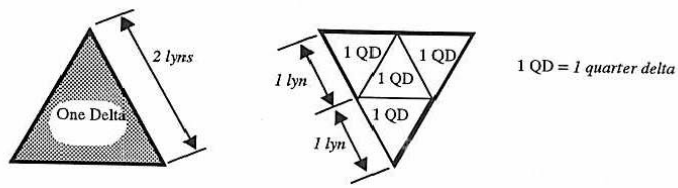
Life on DeltaP, residential and otherwise, is quite different from what you have grown accustomed to here on Earth. First off, DeltaP is a plane, not a planet, so your team will be designing in two-dimensional rather than three-dimensional space. If your design "meets spec" and is considered attractive and functional by your Deltan clients, one view on a single sheet of paper will convey to those responsible for constructing it all the information they need to do so.



Life on DeltaP

The view on this single sheet may not be quite what you expect, however, because in addition to lacking a z axis, Deltoid space has unfamiliar relations between the x and y axes as well. What we think of as "perpendicular" is hopelessly skewed to a Deltan, and vice-versa. In our units, a right angle on DeltaP measures 60° or $\pi/3$ radians. Thus all sides of an equilateral triangle form lines considered perpendicular to all others. If there were such a thing as a "circle" on DeltaP, it would be composed of only $4\pi/3$ radians.

But there is no such thing as a "circle" on DeltaP, nor even the concept of continuity embodied therein. In this flat though angular world, residents construct their artifacts strictly with discrete triangular forms. Of these, the equilateral triangle -- with its three perpendicular sides (!)-- is considered the most pleasing. Accordingly, your team will design the residence by assembling into a



cluster the most prized building materials on DeltaP, equilateral triangular components called "deltas." Deltas come in red and blue versions and always measure *2 lyns* per side. Four "quarter-deltas", *QDs*, triangular units of area measure with sides of *1 lyn*, fit within a delta.

Lyns? QDs? Not surprisingly, Deltan systems of measurement are as unfamiliar as that for spatial coordinates. Table 1 summarizes the measurement schemes on DeltaP that you will need to know to carry out your design task.

All of DeltaP's units of measure share the divisibility and extensibility conventions of the metric

TABLE 1. **Measurements on DeltaP**

Measurement	Unit of Measurement	Symbol
Time	Wex	wx
Distance	Lyn	ln
Area	Quarter-Delta	qd
Heat	Deltan Thermal Unit	DTU
Temperature	Degrees Nin	°Nn
Force	Din	Dn
Moment	Lyn-Din	LD
Currency	Zwig	!

system; in the measure of time, for example, there are both microwex (μwx) and megawex (*Mwx*). In relation to the attention-and life-spans of Deltans, these units are roughly equivalent to seconds and years, respectively, here on Earth.

As building components, deltas have functional and aesthetic characteristics that are more complex than their simple form and even dimensions would suggest. Especially when assembled into a cluster, as you will be doing, they behave in interesting ways. Deltas conduct heat among themselves, radiate heat to outer space, melt if too hot, and grow if too cool. Red deltas produce heat. All deltas are subject to DeltaP's two-dimensional gravity (which is itself subject to axial shifts during DeltaP's not-infrequent gravity waves). Three different kinds of cement are needed to join them together, and joint alignment with respect to gravity affects ease of production as well as

structural integrity. Different colors and different quantities of deltas cost different amounts of money per delta, and can be assembled in clusters that are either exceedingly ugly or very attractive to the Deltans. Your task will be to create a design that meets prescribed goals for all of these characteristics.

1.3 Design Team Roles & Responsibilities

Your design team is organized such that each of you will be responsible for a subset of the design goals. One of you will be PROJECT MANAGER. Your main concerns will be with cost and schedule, the interpretation and reconciliation of performance specifications, and negotiations with the contractor and client. You want to keep costs and time-to-build at a minimum, but not at the expense of quality. When your team submits its final design, the project manager must report the estimated cost (in zwigs) and the time (in wex) that it will take to build.

Another of you will be the STRUCTURAL ENGINEER. Your main concern will be to see that the design "holds together" as a physical structure under prescribed loading conditions. You must see to it that the two points at which your structure is tied to ground are appropriately chosen and that continuity of the structure is maintained. When your team submits its final design, the structural engineer must attest to its integrity by identifying the strongest and weakest joints, and estimating the average load on all joints expressed as a percentage of the failure load.

Another of you will be the THERMAL ENGINEER. You will want to insure that the design meets the "comfort-zone" conditions specified in terms of an average temperature. You must also ensure that the temperature of all individual deltas stays within certain bounds. When your team submits its final design, the thermal engineer must estimate internal temperature and identify the hottest and coldest deltas.

Finally, one of you will be the ARCHITECT. Your concern is with both the form of the design in and of itself and how it stands in its setting. You must see to it that the interior of the residence takes an appropriate form and that egress is convenient. You should also develop a design with character. When your team submits its final design, the architect should be prepared to present a sketch and discuss generally how and why the Deltans will find the residence attractive and functional. The architect will also be asked to estimate a few more quantitative measures of architectural performance.

The following section describes the specifications that your design must meet to be accepted by your clients on DeltaP. Familiarize yourself with these specifications. Then, for schooling in your specialty, turn to the separate primer you have received that discusses the science and technology of your domain. The primer contains the knowledge and heuristics you will need to estimate the design parameters for which you are responsible. If you have questions that it does not answer, do not hesitate to ask. You should be expert in your role before your team begins the design phase.

1.4 The Design Task

Your Deltan clients have cleared the space shown on the site map and come to your team with their need for the design of a new residential cluster. The cluster itself must meet the following specifications.

The client wants the cluster to provide a minimum interior area of 100 QDs (Each diamond on your girded site map defines an area of two QDs). The shape of this space, which can of course exceed the minimum, is a matter of design. The client has expressed enthusiasm for the newer

mode of segmenting interior space, a mode that breaks with the two-equal-zone tradition and values the suggested privacy of nooks and crannies. Still the space must be connected, i.e. no interior walls can cut the space into completely separate spaces. There must be one and only one entrance/exit.

The client is known to be color sensitive blue; too much blue brings on the blues, so to speak. No more than 60% blue ought to be allowed; certainly blue deltas are not to exceed 70% of the cluster.

The residence, as all clusters, must be anchored at two points and two points only. There is a limit to the amount of force each anchor can support, as well as to the amount of internal moment each joint can withstand. Exceeding either limit would cause catastrophic failure and send the unwary residents tumbling into the void. The cluster should be designed for a life of thirty megawex. Gravity waves, rare but always possible, should be considered.

The average interior temperature must be kept within the Deltan comfort zone, which lies between 55 and 65 °Nin. The temperature of the elements themselves must be kept above the growth point of 20 °Nn and below the melt-down point of 85 °Nn. Delta temperatures outside of this range will result in catastrophic structural failure with little more warning than excessive load.

All of this -- design, fabrication and construction -- must be done under a fixed budget and within a given time period. At your team meeting you are to develop a conceptual design that meets or exceeds all design goals. When each team submits their design, individual members will be asked to report design performance on parameters for which they are responsible.

TABLE 2. **Summary of Design Specifications**

Functional Internal Area	100 qd
Maximum Cool Deltas (% Total)	60-70%
Average Internal Temperature Range	55-65 °Nn
Individual Delta Temperature Range	20-85 °Nn
Maximum Load at Anchor Points	20 Dn
Maximum Internal Moment	40 LD
Overhead Factor -K	(varies)
Total Budget	! 1400.00

Delta Design THERMAL ENGINEER PRIMER

1.1 Introduction

As thermal engineer, you are responsible for the comfort and thermal stability of your team's design. This primer will review some basics of heat transfer on DeltaP, then cover methods you may use to estimate the average temperature and extreme values for individual deltas. It assumes you have read the introduction to the exercise.

To insure the comfort of prospective residents, you want the average temperature of all deltas in the cluster, a good proxy for interior temperature, to fall between 55 and 65 degrees *Nn*. For stability, you want the temperature of each delta to stay above *20 °Nn* and below 85 °*Nn* , as they melt at 85 °*Nn* and begin to grow at 20 °*Nn* . Either event would have catastrophic consequences, with your clients tumbling down the plane amidst the wreckage of their dwelling. When your team submits its final design, therefore, you will be asked to estimate internal temperature and the location and temperature of the hottest and coldest deltas.

1.2 Deltan Basics of Heat Transfer

Deltas, the building elements your team will use to design the residence, come in two flavors: red and blue. Red deltas are heat sources, while blue deltas are passive, neither a source nor a sink.

The red sources produce heat continually over time, at a rate, q_0 measure in Deltan Thermal Units per microwex (*dtu/µwx*). While q_0 varies from supplier to supplier and even from batch to batch due to manufacturing irregularities, your project manager has found a supplier willing to guarantee minimal variance around the value:

q_0 = units of heat produced by each red delta per unit time = *160 dtu/µwx*

All deltas, red and blue, conduct heat to and from adjacent elements in the cluster. The amount of heat conducted per unit time is determined by three things:

- the temperature difference between the adjacent deltas;
- the length of the joint between the adjacent elements;

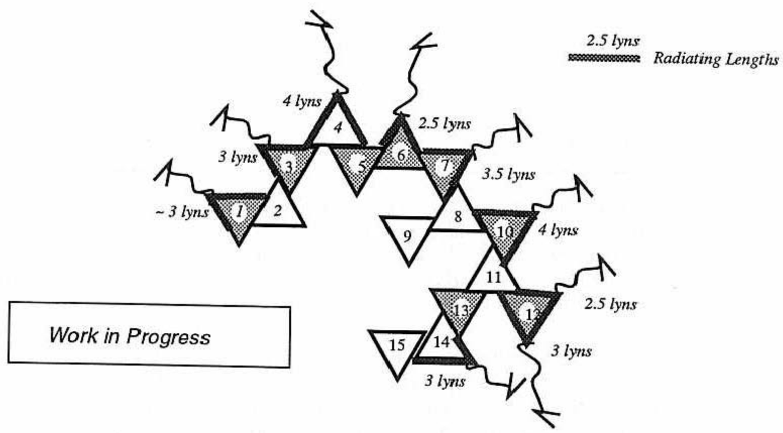
• a coefficient of conductivity, k_c

The coefficient k_c also varies by supplier, though because of differences in the cement used to join the deltas rather than in the deltas themselves. Your supplier has agreed to provide cement with conductivity that varies minimally around the value:

k_c =heat conducted per unit length, per unit time, per unit temperature difference

= *2 dtu/lyn/µwx/°Nn*

Deltas of either color also radiate heat into the Deltoid outer plane, but only when they have *outward-pointing, free nodes* on the exterior wall, as indicated in the figure below.



Like the rate of conductivity, the rate of heat transfer by radiation is proportional to:

• the temperature difference between the radiating element and the outer plane; since the plane's temperature is 0 degrees *Nn*, this term simply becomes the element's temperature

• the length of exposed edges on both sides of the free node, known as radiant length;

• a coefficient of radiative transfer, k_R

The coefficient k_R is fixed. Deltas with free nodes will radiate heat at the rate:

k_R = heat radiated per unit radiant length per unit time per unit temperature difference

k_R = *1 dtu/lyn/µwx/°Nn*

The figure shows a simple cluster to illustrate. Deltas #1, 3, 5, 6, 7, 10,12 and 13 are red: each produces *160 dtu/µwx*, together adding *1280 dtu/µwx* to the structure. This heat will be conducted through the cluster at rates dependent upon the length of the joints, which, starting with the joint between #1 and #2 and working up, look to be about 1, 1, 1/2, 1 1/2,.... lyn respectively. Remember that the side of the delta is 2 lyns long.

Regardless of conduction flows, looking at all of the deltas together as a single ensemble, all of the heat generated by the 8 red deltas must be radiated away at the same rate at which it is produced through the 9 free nodes indicated in the figure. Deltas #1, 3, 4, 6, 7, 10, 12, and 14 have free, outward pointing nodes, and thus will radiate heat into the plane at rates dependent upon their radiant lengths. (Note that #12 has two free, outward pointing nodes).The radiant length for #1 looks to be about *3 lyns*, allowing for the addition of an adjacent delta with further construction; #3 shows a radiant length of again *3 lyns*; #4, a full *4 lyns*; #6, *2.5 lyns* and so on. (We anticipate that with further construction, #15 will be left with no free node and show no radiating length). Along with the basics just discussed, this is all the information we will need to estimate the cluster's thermal properties.

1.3 Estimating Average Temperature

To determine whether your team's design will provide the Deltans with a comfortable living space, you should estimate the average temperature of all deltas in the cluster as a best guess of interior temperature. The easiest way to calculate this average is to first estimate the average temperature of the subset of radiating deltas from a steady-state heat balance. The following equation describes this equilibrium, where the heat generated by the red deltas is balanced by the heat radiated by all deltas with free nodes:

$$N_R \bullet q_o = T^* \bullet N^* \bullet L^* \bullet k_R$$

where:

N_R is the number of red deltas

N^* is the number of radiating deltas;

L^* is the average radiant length of deltas with free nodes;

T^* is the estimate of average temperature of the radiating deltas.

Solving for T^* gives us:

$$T^* = (N_R \bullet q_o) / (N^* \bullet L^* \bullet k_R)$$

and plugging in the values from the sample cluster on the previous page gives us:

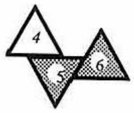
$$T^* = (8 \bullet 160) / (8 \bullet 3.5 \bullet 1) = 45.7\,^{o}Nn$$

In this I have taken the average radiating length as 3.5 *lyns*.

One could at this point take T^*, the average temperature of the *subset* of radiating deltas, as the estimate of the average temperature of the *entire cluster*. That would be an adequate estimate as long as the deltas that are *not* in the subset of radiating deltas, — i.e., #2, #5, #9, #11, #13 — are blue, not red. We see this is not the case; #5 and #13 are red, heat generating elements.

In this case we proceed to estimate the temperature of, let us call them the *interior reds*, as follows:

- Set up the heat balance for the interior red with its adjacent deltas. (We use #5 as an example). The heat *in* must balance the heat *out*.



Heat *in* through generation

$$q_o = (T_5 - T_4) \bullet l_{5,4} \bullet k_c + (T_5 - T_6) \bullet l_{5,6} \bullet k_c$$

Heat Conducted from #5 *out* to #6

Heat Conducted from #5 *out* to #4

- Assume the temperatures of the adjacent, radiating deltas are all equal to the average temperature of the subset, T^*, i.e., *45.7 °Nn.*

- Estimate the overlap lengths i.e., $l_{5,4} \sim 1.5$ *lyns*; $l_{5,6} \sim 1$ *lyn.*

- Given q_o = 160 dtu/mwx and k_c = 2 dtu/mwx/lyn, solve for the temperature of the interior red, i.e.,

$$160 = (T_5 - 45.7) \bullet 1.5 \bullet 2 + (T_5 - 45.7) \bullet 1 \bullet 2$$

giving:

$$T_5 = 77.7\ ^{o}\text{Nn}.$$

In a similar way, the temperature of the other, interior red delta is estimated to be the same, $T_{13} = 77.7\ ^{o}Nn$.

The other, interior but blue deltas are all taken as T^*, the average of the radiating deltas. Our estimate of the average temperature of the entire cluster of 15 deltas, with 2 interior reds at 77.7 and the remaining 13 at $T^* = 45.7$ is just

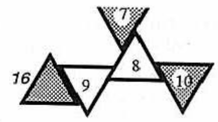
$$T \sim [2 \bullet 77.7 + 13 \bullet 45.7]/(15) = 50\ ^{o}\text{Nn}.$$

This estimate is within 5% of the value (*52.36 °Nn*) predicted by a sophisticated computer model of the cluster, and is certainly good enough for our purposes. We see that interior temperature is below the comfort zone, and hence that the design needs either another red or less radiant length.

Keep your calculations as simple as possible. Work only in integers and don't be reluctant to "eyeball" your estimates of average radiant length. It may be easier just to add up total radiant length, rather than figuring $N^* \bullet L^*$.

1.4 Estimating Maximum Temperature

The most likely "hot spot" occurs where there is an interior red, or where three or more red deltas are placed in sequence, as with elements #5-7 in the figure. As a general rule to prevent catastrophic overheating, you should avoid joining more than two red deltas in an unbroken string and be very careful with interior reds. For example, if an interior red were added to the structure adjacent to #9,



too high a temperature is liable to result. An estimate of the temperature of the additional, interior red is again obtained from a heat balance, namely

$$q_o \sim (T_{16} - T_9) \bullet l_{16,9} \bullet k_c$$

with $k_c = 2$, estimating $l_{16,9} \sim 1.5$ and taking $T_9 = 45.7 = T^*$ we obtain:

$$T_{16} = 99\ ^oNn$$

which is above the limit — meltdown is inevitable. Alocal fix would require ensuring a broad conductive path (good overlap) through #9 and #8 out to the radiating deltas. If the latter were blue as well as radiating, it is possible to keep the temperature of an interior red with spec

In a like manner, If your team's design does call for three reds in sequence, then you again must be careful: you ought to insist that at least two have free, outward pointing, nodes, as do #6 and #7. Even so you are walking on thin ice. Recall our estimate of T_5 was but $3\ ^oNn$ below the meltdown limit.

We might wonder about the temperature of #6. It no doubt is greater than T*, the average of the subset of radiating blue as well as red deltas. An estimate of its temperature follows from assuming that all heat generated by this middle element is radiated away and none is conducted to (or flows in from) adjacent deltas. Thus we obtain:

$$T_6 = q_o / (L^* \bullet k_R)$$

where L- is the radiant length of the delta in question. Plugging in the radiant length shown in the example gives us:

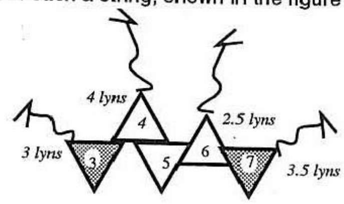
$$T_6 \sim 160/(2.5 \bullet 1) = 64\ ^oNn$$

which is high, but tolerable.

The computer model, however, gives the temperature of #6 as greater than 85 degrees, no doubt because #5 can't radiate and hence adds heat to #6. All of this merely reinforces the general rule: don't place more than 2 red deltas in sequence if you can help it, and arrange for ample radiant heat loss if you can't avoid doing so.

1.5 Estimating Minimum Temperature

A long string of radiating blue elements can result in very low temperatures. Consider, for example, the case where #5 and #6 of our original work in progress are blue instead of red. We can estimate the temperature of such a string, shown in the figure below, as follows:



The temperature of the blue string will stabilize when the amount of heat radiated by the string balances the amount of heat conducted into it. The red elements that bound the string will conduct this heat into the string at some rate $q_l + q_r$ where q_l and q_r are the rates of heat conducted into the string by the left and right red deltas respectively. This heat will radiate out of the string at the rate $T_4 \bullet 4\ lyns \bullet k_r + T_6 \bullet 2.5\ lyns \bullet k_r$.

If we take the sum $q_l + q_r$ to be on the order of q_o, that is, half of the heat generated by each of the two bounding reds is available to heat this sequence of three blues and if we further take T_4 equal to T_6, we obtain *24.6 °Nn* as an estimate for the temperature of #4 and #6. This is borderline. In fact, the computer program gives the temperature of all three blues to be just below *20 °Nn*: Note that once below 20 degrees Nn, the string would start to grow, the dwelling would deteriorate rapidly, and the clients and the insurance company would not be happy. You'd probably hear from their lawyer.

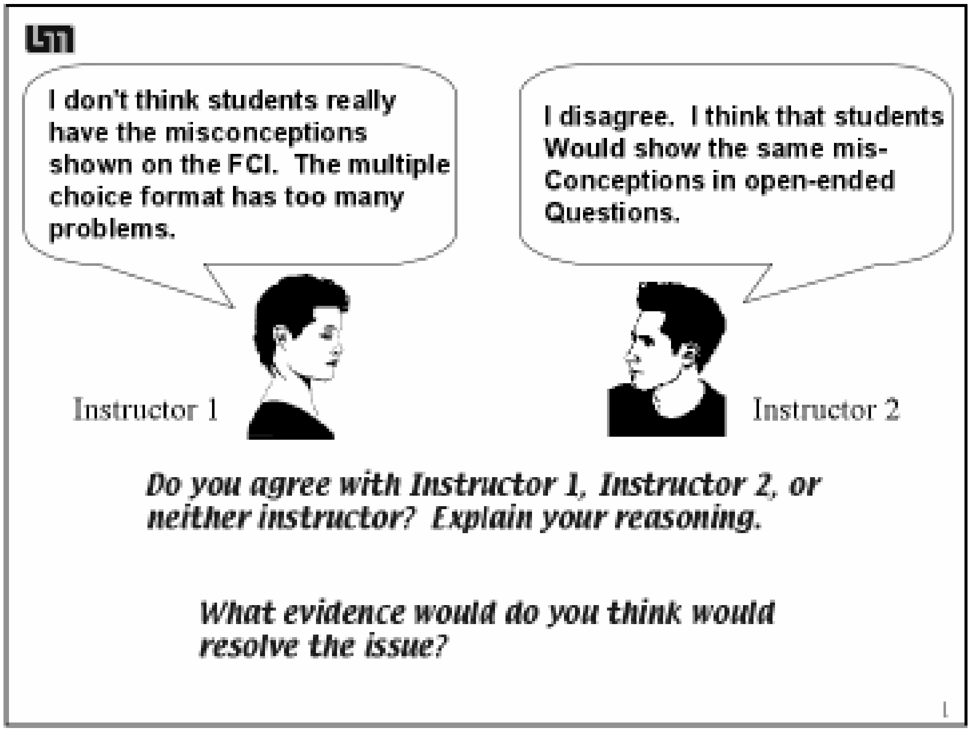
This completes the thermal engineering primer. These rules are not hard and fast, nor are they complete. But they should be sufficient to guide you in your task of assuring the comfort and thermal stability of your team's design.

Rationale for the UMn Model

Notes:

Notes:

The FCI and Alternative Conceptions



Notes: ____

____

____

____

____

____

____

____

____

Notes:

Below is a problem from an exam in Physics 1101 (algebra-based introductory course). Solve this problem as quickly as you can.

Cowboy Bob Problem: Because parents are concerned that children are taught incorrect science in cartoon shows, you have been hired as a technical advisor for the Cowboy Bob show. In this episode, Cowboy Bob, hero of the Old West, happens to be camped on the top of Table Rock in the Badlands. Table Rock has a flat horizontal top, vertical sides, and is 500 meters high. Cowboy Bob sees a band of outlaws at the base of Table Rock 100 meters from the side wall. The nasty outlaws are waiting to rob the Dodge City stagecoach. Cowboy Bob decides to roll a large boulder over the edge and onto the outlaws. Your boss asks you if it is possible to hit the outlaws with the boulder. Determine how fast Bob will have to roll the boulder to reach the outlaws.

Notes:

Differences in Expert-Novice Problem Solving

GROUP TASKS:

1. Make a list or flow chart of all the steps (major decision points and/or actions) that you took to solve a "real problem" (the Graduate Written Exam Problem).
2. Make a list or flow chart of all the steps (major decision points and/or actions) that you took to solve an "exercise" (the Cowboy Bob Problem).
3. Make a list of all the ways an expert problem solver (e.g., you, a professor) solves a "real problem" *differently* than an "exercise."
4. What does Larkin recommend be done to help students become better problem solvers? How should this be done? What do you think of this idea?

COOPERATIVE GROUP ROLES:

Skeptic: Ask what other possibilities there are, keep the group from superficial analysis by not allowing the group to agree too quickly; ask questions that lead to a deeper analysis; agree when satisfied that the group has explored all possibilities.

Manager: Suggest a plan for answering the questions; make sure everyone participates and stays on task; watch the time.

Checker/Recorder: Ask others to explain their reasoning process so it is clear to all that their suggestions can be discussed; paraphrase, write down, and edit your group's answers to the questions.

TIME: 25 minutes.

One member from your group will be randomly selected to present your group's answers to Questions #1 and #2.

PRODUCT:

Activity #7 Answer Sheet.

Answer Sheet for Activity 7

1. Examine your group solution to the Graduate Written Exam Problem. Make a flow chart of the major steps (decisions and/or actions) you took to solve the problem.

2. Now compare and contrast your group solution to the Graduate Written Exam (GWE) Problem and your individual solutions to the Cowboy Bob Problem. For you, as expert problem solvers, the GWE problem was a "real problem" -- one you did not know how to solve immediately -- and the Cowboy Bob Problem was probably more like an "exercise" -- a type of problem you have solved so many times before that you immediately knew how to approach the problem.

   (a) Make a flow chart of the steps (major decisions and/or actions) you took to solve the Cowboy Bob Problem.

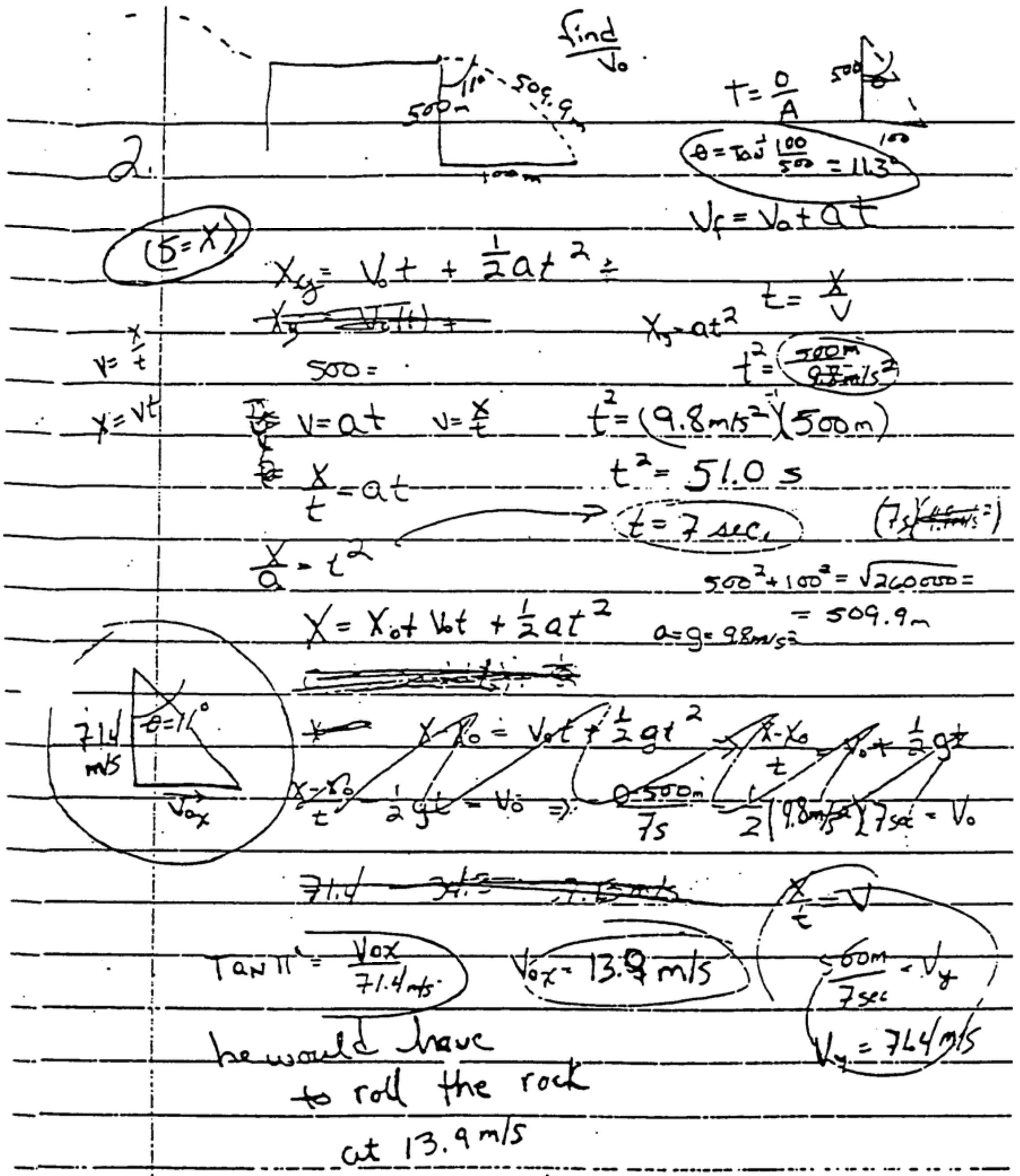
   (b) How were your solution steps different for the real problem and the exercise?

3. For students in an introductory physics class (novice problem solvers), the Cowboy Bob Problem **IS A REAL PROBLEM**. Compare and contrast the attached novice solution to the Cowboy Bob Problem with your group solution to the GWE Problem.

   Based on (a) your comparison of the solutions, and (b) the reading of Larkin (1979), make a list of all the ways that experts solve real problems (e.g., the GWE problem) ***differently*** than novices solve what is, for them, a real problem (e.g., the Cowboy Bob Problem).

Expert Solving Real Problem	Novice Solving a Real Problem

"Novice" Solution to Cowboy Bob Problem



4. Optional: Shown below is a standard textbook solution to the Cowboy Bob problem. Discuss why this solution promotes continued use of a novice strategy (i.e., discourages the use of a more expert-like strategy).

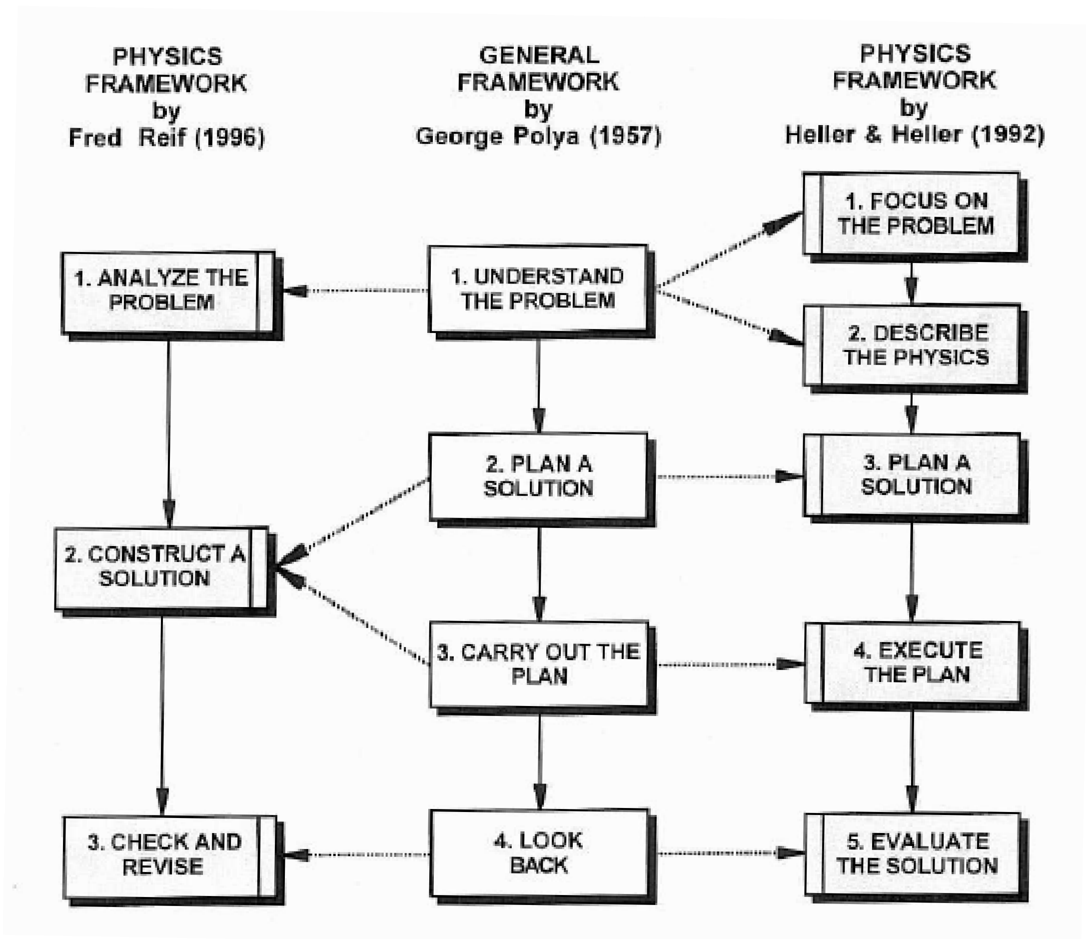
   "Choose a coordinate system with its origin at the point where the boulder goes off the cliff, with the x axis pointing horizontally to the right and the y axis vertically downward. The horizontal component of the initial velocity is:

$$v_{0x} = \frac{D}{t} = \frac{D}{\sqrt{2h/g}} = \frac{100\ \text{m}}{\sqrt{2(500\ \text{m})/9.8\ \text{m/s}^2}} = 10\ \text{m/s}$$

   Since the fastest athletes run at about this speed, it is unlikely that Cowboy Bob would be able to push a big boulder this fast."

Design a Problem-solving Flow Chart for Your Students

You learned in your reading that several research-based problem-solving frameworks for introductory physics have been developed and successfully used. These frameworks divide the important actions into a different number of steps and sub-steps, describe the same actions in different ways, and emphasize different heuristics depending on the backgrounds and needs of population of students for whom they were developed.



GROUP TASK:

The purpose of this task is for you to design a simple, one page problem-solving flow chart that you can have your students use. The flow chart will have **only three steps**, and **not include the last step** (Check and Revise, Look Back, or Evaluate the Solution).

1. Review the flow chart (expert) you made in activity 7. Also, look at the description of the problem-solving steps in the Competent Problem Solver: Calculus Version (pages 1-4 to 1-5, and 1-8 to 1-9). Also look at the problem solving steps by Fred Reif and from two textbooks (next two pages).

2. Decide which actions you think students should make in each step. Describe these actions on the Activity #8 Answer Sheet.

COOPERATIVE GROUP ROLES:

Skeptic: Ask what other possibilities there are, keep the group from superficial analysis by not allowing the group to agree too quickly; ask questions that lead to a deeper analysis; agree when satisfied that the group has explored all possibilities.

Manager: Suggest a plan for answering the questions; make sure everyone participates and stays on task; watch the time.

Checker/Recorder: Ask others to explain their reasoning process so it is clear to all that their suggestions can be discussed; paraphrase, write down, and edit your group's answers to the questions.

TIME: 40 minutes.

One member from your group will be randomly selected to present your group's flow chart to the class

PRODUCT:

Activity 8 Flow Chart and Description for Students

The problem-solving framework by Frederick Reif for a calculus-based course.

1. **Analyze the Problem:** Bring the problem into a form facilitating its subsequent solution.
   - Basic Description -- clearly specify the problem by
     - describing the *situation*, summarizing by drawing diagram(s) accompanied by some words, and by introducing useful symbols; and
     - specifying compactly the *goal(s)* of the problem (wanted unknowns, symbolically or numerically)
   - Refined Description -- analyze the problem further by
     - specifying the *time-sequence* of events (e.g., by visualizing the motion of objects as they might be observed in successive movie frames, and identifying the *time intervals* where the description of the situation is distinctly different (e.g., where acceleration of object is different); and
     - describing the situation in terms of important *physics concepts* (e.g., by specifying information about velocity, acceleration, forces, etc.).

2. **Construct a Solution:** Solve simpler sub-problems repeatedly until the original problem has been solved.
   - Choose sub-problems by
     - examining the *status* of the problem at any stage by identifying the available known and unknown information, and the obstacles hindering a solution;
     - identifying available *options* for sub-problems that can help overcome the obstacles; and
     - selecting a useful sub-problem among these options.
   - If the obstacle is lack of useful information, then apply a *basic relation* (from general physics knowledge, such as $ma = \mathbf{F}_{TOT}$, $f_k = mN$, $x = (1/2)a_x t^2$) to some *object or system* at some *time* (or between some times) along some *direction*. the unwanted quantity by combining two (or more) relations containing this quantity.

   Note: Keep track of wanted unknowns (underlined twice) and unwanted unknowns (underlined once).

3. **Check and Revise:** A solution is rarely free of errors and should be regarded as provisional until checked and appropriately revised.
   - Goals Attained? Has all wanted information been found?
   - Well-specified? Are answers expressed in terms of known quantities? Are units specified? Are both magnitudes and directions of vectors specified?
   - Self-consistent? Are units in equations consistent? Are signs (or directions) on both sides of an equation consistent?
   - Consistent with other known information? Are values sensible (e.g., consistent with known magnitudes)? Are answers consistent with special cases (e.g., with extreme or specially simple cases)? Are answers consistent with known dependence (e.g., with knowledge of how quantities increase or decrease)?
   - Optimal? Are answers and solution as clear and simple as possible? Is answer a general algebraic expression rather than a mere number?

1. Begin by drawing a neat diagram that includes the important features of the problem.
2. Choose a convenient coordinate system and indicate it on your diagram. Show the origin and positive directions. When possible, choose the origin to be on the particle at $t = 0$ so that $x_o = 0$.
3. Show known quantities on your diagram.
4. When possible, write an equation for the quantity to be found in terms of other quantities that are known or can be found. Then proceed to find the other quantities in your equation.
5. When possible, solve the problem two different ways to check your solution.
6. Examine your answer to see if it is reasonable.

Problem Solving Steps from Another Textbook

Gather Information

The first thing to do when approaching a problem is to understand the situation. Carefully read the problem statement, looking for key phrases like "at rest" or "freely falling." What information is given? Exactly what is the question asking? Don't forget to gather information from your own experience and common sense. What should a reasonable answer look like? You wouldn't expect to calculate the speed of an automobile to be 5×10^6 m/s. Do you know what units to expect? Are there any limiting cases you should consider? What happens when an angle approaches 0^o or 90^o or when the mass becomes huge or goes to zero? Also make sure you carefully study any drawings that accompany the problem.

Organize Your Approach

Once you have a really good idea of what the problem is about, you need to think about what to do next. Have you seen this type of question before? Being able to classify a problem can make it easier to lay out a plan to solve it. You should almost always make a quick drawing of the situation. Label important events with circled letters. Indicate any known values, perhaps in a table or directly on the sketch.

Analyze the Problem

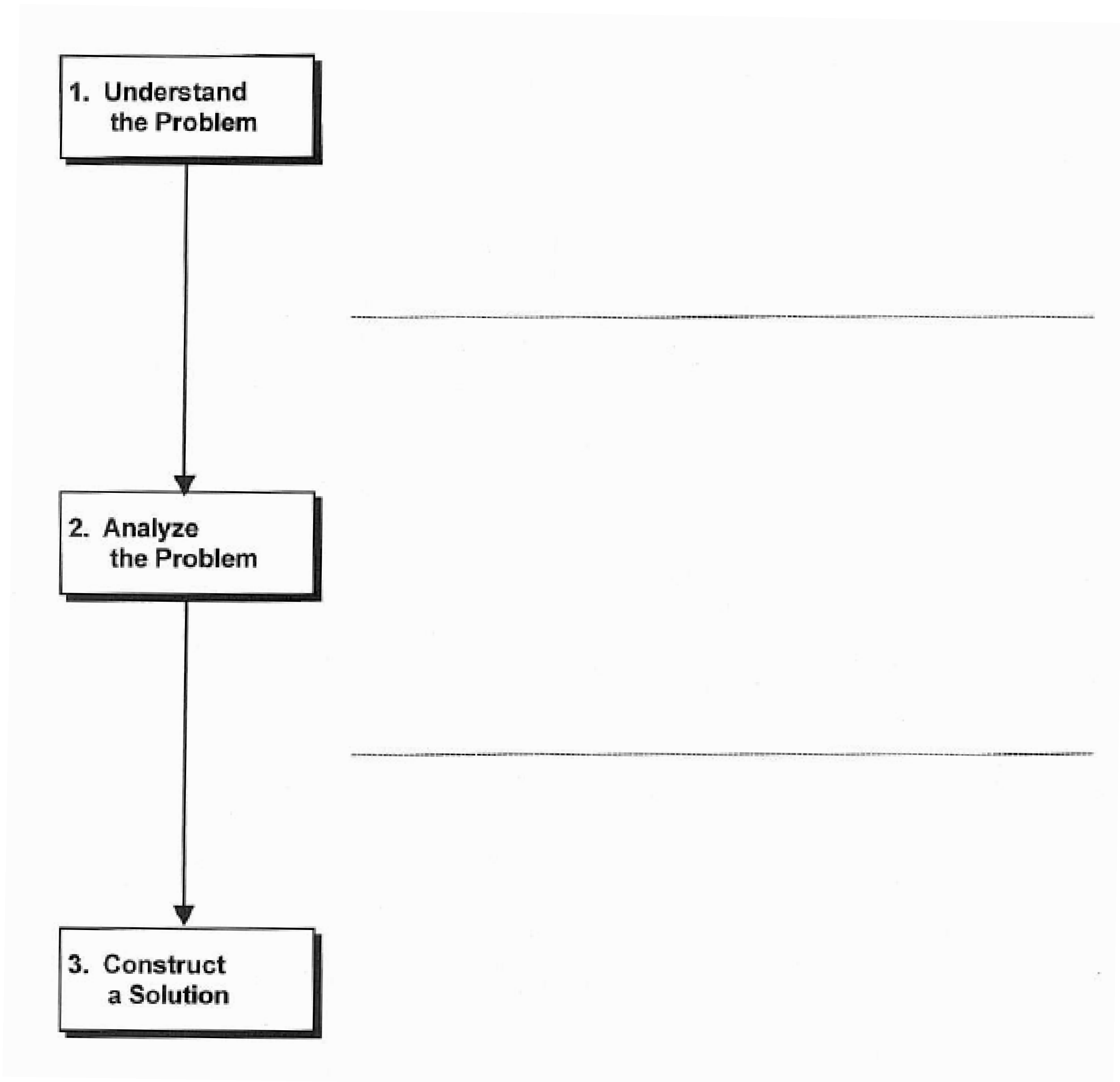
Because you have already categorized the problem, it should not be too difficult to select relevant equations that apply to this type of situation. Use algebra (and calculus, if necessary) to solve for the unknown variable in terms of what is given. Substitute in the appropriate numbers, calculate the result, and round to the proper number of significant figures.

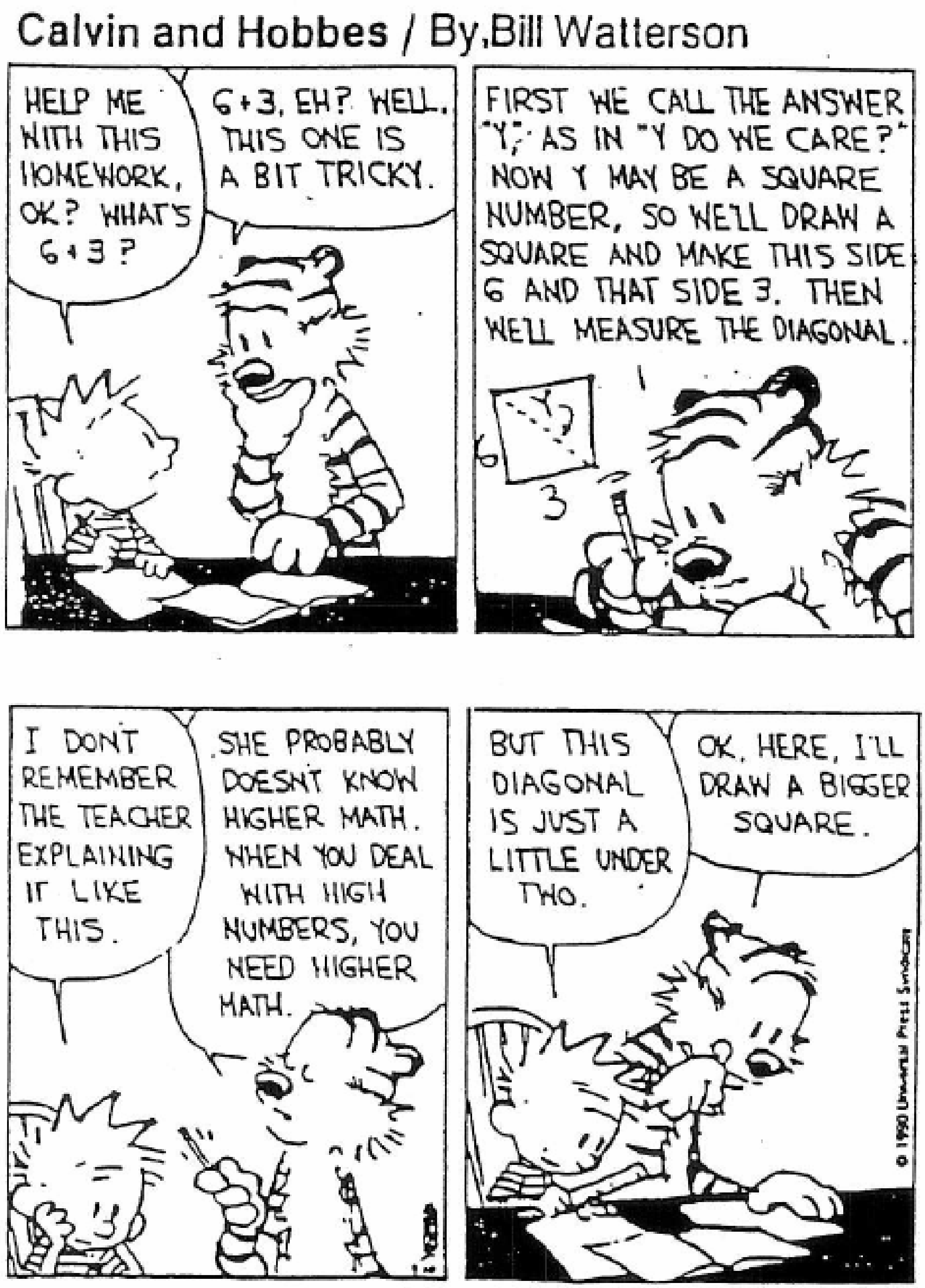
Learn from Your Efforts

This is the most important part. Examine your numerical answer. Does it meet your expectations from the first step? What about the algebraic form of the result – before you plugged in numbers? Does it make sense? (Try looking at the variables within it to see whether the answer would change the answer in a physically meaningful way if they were drastically increased or decreased or even became zero.) Think about how this problem compares with others you have done. How was it similar? In what critical ways did it differ? Why was this problem assigned? You should have learned something by doing it. Can you figure out what?

Manager:______________________________
Recorder:______________________________
Skeptic:______________________________
Summarizer:____________________________

Description for Students




Calvin and Hobbes / By Bill Watterson
HELP ME WITH THIS HOMEWORK, OK? WHAT'S 6+3?
6+3, EH? WELL, THIS ONE IS A BIT TRICKY.
FIRST WE CALL THE ANSWER "Y," AS IN "Y DO WE CARE?" NOW Y MAY BE A SQUARE NUMBER, SO WE'LL DRAW A SQUARE AND MAKE THIS SIDE 6 AND THAT SIDE 3. THEN WE'LL MEASURE THE DIAGONAL.
Y?
6
3
I DON'T REMEMBER THE TEACHER EXPLAINING IT LIKE THIS.
SHE PROBABLY DOESN'T KNOW HIGHER MATH. WHEN YOU DEAL WITH HIGH NUMBERS, YOU NEED HIGHER MATH.
BUT THIS DIAGONAL IS JUST A LITTLE UNDER TWO.
OK, HERE, I'LL DRAW A BIGGER SQUARE.

Design an Answer Sheet for your Students

You learned in the reading that it is helpful to provide students with answer sheets during the first 3-6 weeks of the course. Answer sheets provide students with cues for the major steps of your problem-solving framework.

GROUP TASK:

1. Review the answer sheets in the Competent Problem Solver.
2. Decide what cues you want to provide on the answer sheets for your students. Write these cues on the Activity #9 Answer Sheet.

COOPERATIVE GROUP ROLES:

Skeptic: Ask what other possibilities there are, keep the group from superficial analysis by not allowing the group to agree too quickly; ask questions that lead to a deeper analysis; agree when satisfied that the group has explored all possibilities.

Manager: Suggest a plan for answering the questions; make sure everyone participates and stays on task; watch the time.

Checker/Recorder: Ask others to explain their reasoning process so it is clear to all that their suggestions can be discussed; paraphrase, write down, and edit your group's answers to the questions.

TIME: 20 minutes.

One member from your group will be randomly selected to present your group's answer sheet to the class

PRODUCT:

Activity 9 Answer Sheet

Answer Sheet

Understand the Problem
Analyze the Problem
Construct a Solution

Teaching Lab Sessions at UMn

Today, a mentor TA will demonstrate how to teach a problem-solving laboratory session at the University of Minnesota. The goals of this activity are for you to learn:

- the structure of the problem-solving labs you will be teaching;
- the rationale for each teaching action in the lab sessions.

During the demonstration, another mentor TA will observe the teacher. At the end of the demonstration, the teacher will be mentored by the observer. Compare your impressions with those of the mentor.

INDIVIDUAL AND GROUP TASKS:

1. Participate in the laboratory demonstration as undergraduates might.
2. Periodically, we will stop the demonstration. Discuss the reasons for *each part* of the lesson plan with your group. Then *individually* write the reasons under "Rationale" on the attached lesson plan. These reasons will then be shared and expanded upon by the class and instructors.
3. Work on the assigned laboratory problem and be prepared to discuss your results.

COOPERATIVE GROUP ROLES:

Skeptic: Ask what other possibilities there are, keep the group from superficial analysis by not allowing the group to agree too quickly; ask questions that lead to a deeper analysis; agree when satisfied that the group has explored all possibilities.

Manager: Suggest a plan for discussing the reasons for each part of the lesson plan; make sure everyone participates and stays on task; watch the time.

Checker/Recorder: Ask others to explain their reasoning process so it is clear to all that their suggestions can be discussed; paraphrase, your group's rationale.

TIME: 2 hours.

PRODUCT:

We will randomly collect the answer sheet of one group member to grade. Every group member will receive this grade.

Activity 10 Answer Sheet Name: ______________________________

Time	**Opening Moves**	Rationale
	0 Get there early and lock door. - Collect one piece of equipment needed for lab problems - Write new groups/roles on board (when appropriate) - Write which methods questions groups should write on board - Open Door	
10 min.	**1.** Prepare students for group work by showing group/role assignments.	
	2. Prepare students for lab.	
~1 min.	**a)** Focus on what students should learn. Tell students which Methods Question(s) they should discuss and put on the board.	
5 min	**b)** Diagnose student difficulties. While groups discuss *Methods Questions*, circulate around the class, ***observe/listen to*** each group, and diagnose difficulties.	
2 min	**c)** Post Group Answers. Select (randomly) one person from each group to write/draw on board answers to the *Methods Questions*.	
5-10 min	**d)** Lead a class discussion. Give students a few minutes to read all the answers on the board. Ask the representatives of each group to give their reasons for each of their answers.	
1 min	**e)** How much time. Tell class time they need to stop (usually about 30 – 40 minutes) and remind Managers to keep track of the time.	

NOTES:

Time	Middle Game	Rationale
5 min	**3.** Coach groups in problem solving (making decisions) by: **a)** Diagnose initial difficulties with the problem or group functioning. - Return equipment to groups - Watch class from front of room: Don't answer questions. Is class able to proceed? Stop class and discuss difficulty if everyone is off task.	
~5 min.	**b)** Monitor groups and intervene to coach when necessary. Monitor and diagnose : 9-□ Establish a circulation pattern around room. Listen to each group (without them knowing) at least one before answering questions. Diagnose difficulties with physics; Diagnose difficulties with group functioning. Prioritize who needs the most help. Is entire class confused on the same thing? If so, stop the class and discuss the difficulty.	
variable	Coach Groups with the Most Need. - coach first with the group that needs the **most** help, and so on - Always join a group at eye level. - If you spend a long time with group, circulate around class again, listening briefly to each group and diagnose difficulties, before intervening again. - Be sure groups are completing all parts of the problem - If a group finishes early, have them start the next problem.	

Time	**Middle Game (continued)**	Rationale
	9-□ <u>Start grading lab procedures (journals)</u>.	
10 min	**5.** Prepare Students for class discussion by **a)** <u>Ten-Minute Warning</u>. Ten minutes before you want the groups to stop, tell them to find a good stopping place and clean up their area. (Make sure you are done grading journals). (If groups are new, you may want to pass out the group functioning forms.)	
5 min	9-□ <u>Posting Corrected Methods Questions and/or Results</u>. Tell one person in each group, who is *not* the Recorder/Checker, to write their corrected answers (if necessary) to the methods questions on the board (and/or their results).	

NOTES:

Time	End Game	Rationale
~10 min	9-□ Lead a class discussion. Usually, focus the discussion on the qualitative analysis of problem.	
5 -10 minutes	**7.** Optional: Discuss group functioning. Call on one group for "good" response, another group for a "problem," and a third group for a "specific action." Repeat until every group has spoken twice.	
5 min	**8.** Start next problem. If there is time, have students start the next assigned lab problem. Repeat Steps 1 through 7.	
	9. End of Lab Session. **a)** Tell students what lab problem(s) to do Methods Questions for next week. **b)** Assign students problems to write up (if last session of lab). In each group, randomly assign each student in the group a different problem for a lab report. **c)** Leaving the Lab. Leave a neat lab room for the next class.	

NOTES:

Preparation for Peer Teaching of Labs and Discussion Session

INDIVIDUAL AND TEAM TASKS:

1. **Individually** read through the next four pages. These pages describe how the four afternoon peer-teaching sessions are structured and graded. Be prepared to ask questions in a class discussion.

2. **Lab Preparation:** It is assumed that each team member has already done the *Method Questions* for your assigned lab problems.

   (a) Discuss with your team the answers to the Methods Questions.

   (b) Work through the assigned lab problems (as a team), collect data, and analyze your results (3 points). What is the conclusion for this lab problem? Your team will be the "expert" on this lab, and should be able to answer questions from other Tas. If you need help with anything, ask the mentor TA working with you.

   © When you have finished (b), ask your mentor TA for the *Lab Instructor's Guide* for these problems. This manual was written by former Tas to help you prepare for and teach each lab problem.

   (d) Discuss the following questions with your team. How does the data you collected and analyzed compare with the example data in the Instructor's Guide? What other information is included in the Instructor's Guide? How will this information help you prepare to teach these lab problems?

   (e) Photocopy your results and analysis for each lab problem (one per "student"). These will be handed out to your "students" at the end of each lab practice teaching session.

3. **Discussion Session Preparation:** It is assumed that each team member has already solved the assigned group problem in a logical, organized manner.

   (a) Discuss with your team your individual solutions to the discussion problem.

   (b) As a team, write a ***good solution*** for this problem. A good solution must be helpful to undergraduate students who do not know how to solve the problem. A good solution includes:
   - Detailed diagram(s)
   - Definition of all variables
   - Logical progression and complete steps in the solution (working backwards from target variable).
   - Symbolic representation of all equations (both fundamental principles and relationships that apply in certain situations) should be written before substitution of defined variables.
   - Solve the problem mathematically **before** the substitution of quantities (numbers) into the final equation for the target variable.

   9-□ ©Photocopy your solution (one per "student"). This will be handed out to your "students" at the end of the discussion practice teaching session.

Structure of Peer Teaching

As a way of preparing to teach the University of Minnesota's problem-solving labs and discussions sessions, you will have the opportunity to practice-teach either one lab problem or one discussion session to your peers. ***You have already been assigned to a 3-member team, and your team has been assigned two lab problems and one discussion session to prepare***. For four afternoons in the next week, the mentor Tas will supervise the practice teaching of the labs and discussion sessions.

There are two goals for this peer teaching. One is for you to get practice "running through" a lab problem or discussion session, so that you have a sense of what it feels like to keep track of time, supervise a room full of people solving a problem, and lead a discussion. The other goal is for you to become familiar and comfortable with the equipment and typical results for the problem-solving labs.

Each afternoon will be structured as follows:

- The mentor Tas may need to make some brief announcements.
- The "practice teachers" for one afternoon will teach, and the practice teachers for the other three afternoons will act like undergraduate students. This means that you must come to morning class with the *Methods Questions* completed, and be ready to participate in discussions and take data in the afternoon (see Homework #4, #5, #7 and #9 in the Syllabus).
- On the day your team practice teaches:
  - Your team will receive your "students" (peers acting as undergraduates) answers to the Methods Questions during the morning. This will allow you to look over the answers and decide which Method Question(s) you will have your "students" discuss put on the board.
  - Just before lunch, your Mentor TA will tell each team member whether they will teach the assigned discussion session or a lab problem (and which assigned lab problem). So each team member has to be prepared to teach all three.
- Each practice teacher will have about 60 minutes to teach one lab problem, or about 30 minutes to teach a discussion session. The practice teachers for lab will then pass out the data and results that THEY had previously prepared for their lab problem (3 points). The practice teachers for discussion will hand out the solution to the problem (3 points).
- The "students" for this lab or discussion session will give each practice teacher written feedback.
- After all the Tas have practice-taught on a day, they will stay and be mentored by the mentor TA.

These afternoon sessions should run between 3 and 4 hours for the first three days, and about 2 hours for the fourth day.

Each TA will select one free afternoon!

Grading Sheet for Homework #4, #5, #7 or #9
When You Are the Practice Teacher: LAB

What the TA Does	TA Initials:				
Opening Moves:	⓪ Be at the classroom early				
	① Prepare students for group work by showing group/role assignments.				
	② Prepare students for lab by: a) diagnosing difficulties while groups discuss and come to consensus on *Methods Questions*.				
	b) selecting one person from each group to write/draw on board answers to the *Methods Questions*.				
	c) leading a class discussion about the group answers.				
	d) telling students how much time they have to check their predictions; reminding Manager to keep track of time				
Middle Game	③ Coach groups in problem solving (making decisions) by: a) monitoring (diagnosing) progress of all groups				
	b) helping (coaching) groups with the most need, using group roles.				
	④ Grade Lab Procedure (journal).				
	⑤ Prepare students for class discussion by: a) giving students a "10-minute warning." Pass out Group Evaluation Form (if necessary)				
	b) selecting one person from each group to put corrected methods questions and results on board.				
End Game	⑥ Lead a class discussion focusing on what you wanted students to learn from solving the problem.				
	⑦ Discuss group functioning (optional)	*na*	*na*	*na*	*na*
	⑧ Start next lab problem (repeat Steps 1 – 7) if time	*na*	*na*	*na*	*na*
	⑨ End of Lab a) Tell students what lab problems to do Methods Question for next week; if last session, assign students problems for lab report.				
	b) Leave a neat lab room for the next class. Do NOT let the next group of students into the classroom. Write down the comments about equipment that did not work on the lab-room sheet .				
	Total:				
	Grade:				

Total Steps Performed	Grade	Total Steps Performed	Grade
13 – 14	3 points	9 – 10	1 points
11 -12	2points	0 – 8	0 points

Grading Sheet for Homework #4, #5, #7 or #9
When You Are the Practice Teacher: DISCUSSION SESSION

What the TA Does	TA Initials:				
Opening Moves:	⓪ Be at the classroom early				
	① Introduce the problem by telling students: a) what they should learn from solving problem;				
	b) the part(s) of the solution you want groups to put on board				
	② Prepare students for group work by: a) showing group/role assignments and classroom seating map (if necessary);				
	b) passing out Problem (& Useful Information) and one Answer Sheet.				
	c) Tell class the time they need to stop and remind Managers to keep track of the time.				
Middle Game	③ Coach groups in problem solving by: a) Monitoring (diagnosing) progress of all groups. Establish a circulation pattern for periodically listening to groups and *diagnosing difficulties*.				
	b) helping (coaching) groups with the most need. Using group roles.				
	④ Prepare students for class discussion by: a) giving students a "five-minute warning"				
	b) selecting one person from each group to put specified part of solution on the board.				
	c) passing out Group Evaluation Sheet (optional)	*na*	*na*	*na*	*na*
End Game	⑤ Lead a class discussion focusing on what you wanted students to learn from solving the problem.				
	⑥ Discuss group functioning (optional)	*na*	*na*	*na*	*na*
	⑦ Pass out the problem solution as students walk out the door.				
	Total:				
	Grade:				

Total Steps Performed	Grade	Total Steps Performed	Grade
11-12	3 points	7-8	1 points
9-10	2 points	0 – 6	0 points

Teaching Discussion Sessions at UMn

The purpose of this activity is to introduce you to your role as instructors in the discussion section.

PART A: DEMONSTRATION OF A DISCUSSION SESSION (~50 MINUTES)

A Mentor TA will demonstrate how to teach a typical discussion session, with you as the students! Focus on the *process* of collaborative problem solving.

GROUP TASK:

Follow the directions of the Mentor TA.

GROUP PRODUCT:

Your group's problem solution.

GRADING RUBRIC:

The solution will **not** be graded for a correct answer. Instead, the solution will be graded for organization and logical progression.

PART B: CLASS DISCUSSION ABOUT TEACHING DISCUSSION SESSIONS

(1) On the following pages is the *Outline for Teaching a Discussion Session*. Read through this outline and think about the experience you had solving the problem in a group. Write down questions and comments.

(2) The Mentor TA will lead a class discussion about your questions. Write important answers/notes in the space provided.

Preparation Checklist

- ❑ New Group/Role assignments (if necessary, on overhead or written on board)
- ❑ Photocopies of Problem & Useful Information *(one per person)* OR list of useful information to put on board
- ❑ Photocopies of Answer Sheet (optional) or blank sheets of paper *(one per group)*
- ❑ Photocopies of problem solution *(one per person)*
- ❑ Group Evaluation forms (optional one per group) and extra photocopies of Group Roles Sheet

	Instructor Actions	What the Students Do
Opening Moves ~3-5 min.	⓪ Be at the classroom early ① Introduce the problem by telling students: a) what they should learn from solving problem; b) the part of the solution you want groups to put on board ② Prepare students for group work by: a) showing group/role assignments and classroom seating map; b) passing out Problem (& Useful Information) and Answer Sheet.	• Students sitting and listening • Students move into their groups, and begin to read problem. • Checker/Recorder puts names on answer sheet.

QUESTIONS/NOTES:

	Instructor Actions	What the Students Do
Middle Game ~35 min.	③ Coach groups in problem solving by: a) monitoring (diagnosing) progress of all groups b) helping groups with the most need. ④ Prepare students for class discussion by: a) giving students a "five-minute warning" b) selecting one person from each group to put specified part of solution on the board. c) passing out Group Evaluation Sheet (optional)	• Solve the problem: - participate in group discussion, - work cooperatively, - check each other's ideas. • Finish work on problem • Write part of solution on board • Discuss their group effectiveness
End Game ~10 min.	⑤ Lead a class discussion focusing on what you wanted students to learn from solving the problem ⑥ Discuss group functioning (optional) ⑦ Pass out the problem solution as students walk out the door.	• Participate in class discussion

QUESTIONS/NOTES:

Revising an Inappropriate Group Practice Problem

GROUP TASK:

1. Solve the inappropriate group practice problem assigned to your group. Explain why the problem is inappropriate, using the criteria on pages 111-115 of the Instructor's Handbook.
2. Follow the steps on page 120 to revise the problem so it is an acceptable group practice problem. Complete the *Answer Sheet for Activity #13*.
3. Solve the revised problem on the student answer sheet provided.
4. Write your revised problem on a sheet of butcher paper. Post in room 157.

COOPERATIVE GROUP ROLES:

Skeptic: Ask what other possibilities there are, keep the group from superficial analysis by not allowing the group to agree too quickly; ask questions that lead to a deeper analysis; agree when satisfied that the group has explored all possibilities.

Manager: Suggest a plan for answering the questions; make sure everyone participates and stays on task; watch the time.

Checker/Recorder: Ask others to explain their reasoning process so it is clear to all that their suggestions can be discussed; paraphrase, write down, and edit your group's answers to the questions.

TIME: 45 minutes

PRODUCTS:

1. Revised problem on butcher paper.
2. Activity #13 Answer Sheet (revised problem, difficulty characteristics, and your decision.
3. Solution to problem written on student answer sheet.

Manager:____________________________
Recorder:____________________________
Skeptic:____________________________
Summarizer:____________________________

Manager:____________________________
Recorder:____________________________
Skeptic:____________________________
Summarizer:___________________________

Assume that students are just finishing studying the concepts needed to solve the inappropriate group practice problem below.

Original Problem: A merry-go-round has a circular platform which turns at a rate of one full rotation every 10 seconds. A passenger holds himself on the surface with a pair of very sticky shoes with a coefficient of static friction of 0.4. Determine how far away from the center he can go before falling down to the platform.

1. Solve the problem. Explain why the problem is an inappropriate group practice problem. Refer to the *Characteristics of a Good Group Problem* (Instructor's Handbook pages 111 to 115).

2. Revised Problem:

Analysis
______ 1. Choice of principle
______ 2. Two principles
______ 3. Excess data
______ 4. Numbers required
______ 5. Assumptions
______ 6. Special constraints
______ 7. Diagrams
______ 8. Vectors

Mathematical Solution
______ 9. No numbers
______ 10. Unknown(s) cancel
______ 11. Simultaneous eqns.
______ 12. Calc/vector algebra
______ 13. Lengthy algebra

Check difficulty characteristics at right.

3. Explain why you think that your revised problem is now an appropriate group practice problem. Use the Decision Table (IH page 117) and the *Characteristics of a Good Group Problem* (IH pages 111 to 115).

Manager:____________________________
Recorder:____________________________
Skeptic:____________________________
Summarizer:____________________________

Assume that students are just finishing studying the concepts needed to solve the inappropriate group practice problem below.

Original Problem: A ball starts from rest and accelerates at 0.500 m/s^2 while moving down an inclined plane 9.00 m long. When it reaches the bottom, the ball rolls up another plane, where, after moving 15.0 m, it comes to rest.

(a) What is the speed of the ball at the bottom of the first plane?
(b) How long does it take to roll down the first plane?
(c) What is the acceleration along the second plane?
(d) What is the ball's speed 8.00 m along the second plane?

1. Solve the problem. Explain why the problem is an inappropriate group practice problem. Refer to the *Characteristics of a Good Group Problem* (Instructor's Handbook pages 111 to 115).

2. Revised Problem:

Analysis
______ 1. Choice of principle
______ 2. Two principles
______ 3. Excess data
______ 4. Numbers required
______ 5. Assumptions
______ 6. Special constraints
______ 7. Diagrams
______ 8. Vectors

Mathematical Solution
______ 9. No numbers
______ 10. Unknown(s) cancel
______ 11. Simultaneous eqns.
______ 12. Calc/vector algebra
______ 13. Lengthy algebra

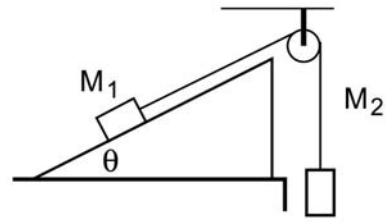
Check difficulty characteristics at right.

3. Explain why you think that your revised problem is now an appropriate group practice problem. Use the Decision Table (IH page 117) and the *Characteristics of a Good Group Problem* (IH pages 111 to 115).

Manager:____________________________
Recorder:____________________________
Skeptic:____________________________
Summarizer:____________________________

Assume that students are just finishing studying the concepts needed to solve the inappropriate group practice problem below.

Original Problem: As shown on the diagram, mass M_1 rests on an inclined plane with a rope tied to it. The rope goes through a frictionless, massless pulley, and is connected to another mass, M_2, which hangs off the edge of the table. There is a coefficient of friction, μ_k, between the mass M_1 and the inclined plane. The angle of the inclined plane is θ.



(a) Draw a free body diagram showing all forces (solid lines) and the acceleration (dotted line).
(b) Write a general solution for the acceleration of the masses in terms of the variables given plus any other that you need to define.
(c) What is the expression for the acceleration if μ_k goes to zero?
(d) What is the expression for the acceleration if $\theta = 0$?
(e) What is the acceleration if $M_1 = 10$ kg, $M_2 = 4$ kg, $\mu_k = 0.2$, and $\theta = 30$ degrees?

1. Solve the problem. Explain why the problem is an inappropriate group practice problem. Refer to the *Characteristics of a Good Group Problem* (Instructor's Handbook pages 111 to 115).

2. Revised Problem:

Analysis
______ 1. Choice of principle
______ 2. Two principles
______ 3. Excess data
______ 4. Numbers required
______ 5. Assumptions
______ 6. Special constraints
______ 7. Diagrams
______ 8. Vectors

Mathematical Solution
______ 9. No numbers
______ 10. Unknown(s) cancel
______ 11. Simultaneous eqns.
______ 12. Calc/vector algebra
______ 13. Lengthy algebra

Check difficulty characteristics at right.

3. Explain why you think that your revised problem is now an appropriate group practice problem. Use the Decision Table (IH page 117) and the *Characteristics of a Good Group Problem* (IH pages 111 to 115).

Evaluating Sample Laboratory Report from Laboratory Manual

We've redefined the quality of writing based on the general writing factors, and how these factors relate to the rubric used to grade physics laboratory reports. The laboratory manual for the students includes, at the beginning, information about what is to be expected of their laboratory reports. There is also a sample report that further model what is expected. In this activity you will evaluate this sample laboratory report for its quality based on the grading rubric, all the while keeping in mind the qualities as described and defined by the general writing factors.

Individual Tasks:

1. *Individually* read through the sample laboratory report (the double-barred sections are descriptions and explanations on what is expected in each section of the report).

2. *Individually* evaluate the sample laboratory report – mark down any and all comments about the quality of the paper, both good and bad.

Whole Group Discussion:

Follow along with the overhead presentation as it points out certain segments that related to the writing factors. Participate in discussing various aspects of the quality of the sample laboratory report.

Time: 45 minutes.

SAMPLE COVER SHEET

PHYSICS ____ LABORATORY REPORT
LABORATORY I

Name and ID#: ______________________________________

Date performed: ____________ Day/Time section meets: ___________

Lab Partners' Names: ___________________________________

____

____

Problem # and Title: ___________________________________

Lab Instructor Initials: _________

Grading Checklist	Points
LABORATORY JOURNAL:	
PREDICTIONS (individual predictions completed in journal before each lab session)	
LAB PROCEDURES (measurement plan recorded in journal, tables and graphs made in journal as data is collected, observations written in journal)	
PROBLEM REPORT:	
ORGANIZATION (clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	
TOTAL (incorrect or missing statement of physics will result in a maximum of 60% of the total points achieved; incorrect grammar or spelling will result in a maximum of 70% of the total points achieved)	
BONUS POINTS FOR TEAMWORK (as specified by course policy)	

* An "R" in the points column means to rewrite that section only and return it to your lab instructor within two days of the return of the report to you.

Appendix E: Sample Laboratory Report

There is no set length for a problem report but experience shows the good reports are typically three pages long. Graphs and photocopies of your lab journal make up additional pages. Complete reports will include the terminology and the mathematics relevant to the problem at hand. Your report should be a clear, concise, logical, and honest interpretation of your experience. You will be graded based on how well you demonstrate your understanding of the physics. Because technical communication is so important, neatness, and correct grammar and spelling are required and will be reflected on your grade.

> Note: As with Problem 1 of Lab 1, the double vertical bars indicate an explanation of that part of the report. These comments are not part of the actual report.

Statement of the problem

> In a complete sentence or two, state the problem you are trying to solve. List the equipment you will use and the reasons for selecting such equipment.

The problem was to determine the dependence of the time of flight of a projectile on its initial horizontal velocity. We rolled an aluminum ball down a ramp and off the edge of a table starting from rest at two different positions along the ramp. Starting from the greater height up the ramp meant the ball had a larger horizontal velocity when it rolled along the table. Since the table was horizontal, that was the horizontal velocity when it entered the air. See Figure 1 from my lab journal for a picture of the set-up.

We made two movies with the video equipment provided, one for a fast rolling ball and one for a slower one. These movies were analyzed with LabVIEW™ to study the projectile's motion in the horizontal and vertical directions.

Prediction

> Next comes your prediction. Notice that the physical reason for choosing the prediction is given. In this case there is a theoretical relationship between Δt and v_o. There is a reference to real life experience: the example of the bullets. Also, **note that this prediction is wrong**. That is all right. The prediction does not need to be correct, it needs to be what you really thought before doing the lab; that is why it is called a prediction. The prediction is supposed to be a complete and reasonable attempt by your group to determine the outcome of the problem.

Our group predicted that the time the ball took to hit the ground once it left the table would be greater if the horizontal velocity were greater. We have observed that the faster a projectile goes initially, the longer its trajectory. Since the gravitational acceleration is constant, we reasoned that the ball would take more time to travel a larger distance.

Mathematically, we start from the definition of acceleration:

$$a = \frac{d}{dt}\left(\frac{dy}{dt}\right)$$

and integrate twice with respect to time to see how a change in time might be related to initial velocity. We found that:

$$y - y_o = v_o\Delta t + 0.5a\Delta t^2 \qquad (1)$$

With the y-axis vertical and the positive direction up, we know the acceleration is -g. We also know that v_o is the initial velocity, and $y_o - y$ is h, the height of the table. Solving for Δt one finds:

$$\Delta t = \frac{vo \pm \sqrt{(vo^2 + 2hg)}}{g} \qquad (2)$$

Faced with a choice in sign, our group chose the solution with the positive sign, deciding that a possible negative value for elapsed time does not correspond with our physical situation. From equation (2), we deduced that if v_o increased, then the time of fall also increases. This coincided with our prediction that a projectile with fastest horizontal velocity would take the most time to fall to the ground. For a graph of our predicted time of flight versus initial horizontal velocity, see Graph A from the lab journal.

LabVIEW™ generated graphs of x and y positions as functions of time. Our prediction for the vertical direction was equation (1). Since the ball only has one acceleration, we predicted that equation (1) would also be true for the horizontal motion:

$$x - x_o = v_o\Delta t + 0.5a\Delta t^2$$

The dotted lines on the printed graphs represent these predictions.

The Example of Two Bullets

Our TA asked us to compare a bullet fired horizontally from a gun to a bullet dropped vertically. Our group decided the bullet that is fired horizontally will take longer to hit the ground than the one that is simply dropped from the same height.

Data and results

This section describes your experimental method, the data that you collected, any problems in gathering the data, and any crucial decisions you made. Your actual results should show you if your prediction was correct or not.

To ensure the ball's velocity was completely horizontal, we attached a flat plank at the end of the ramp. The ball rolls down the ramp and then goes onto the horizontal plank. After going a distance (75 cm) along the plank, the ball leaves the edge of the table and enters projectile motion.

We measured the time of flight by simply counting the number of video frames that the ball was in the air. The time between frames is 1/30 of a second since this is the rate a video camera takes data. This also corresponds to the time scale on the LabVIEW™ graphs. We decided to compare the times of flight between a ball with a fast initial velocity and one with a slow initial velocity. To get a fast velocity we started the ball at the top of the ramp. A slower velocity was achieved by starting the ball almost at the bottom of the ramp.

During the time the ball was in the air, the horizontal velocity was a constant, as shown by the velocity in the x-direction graphs for slow and fast rolling balls. From these graphs, the slowest velocity we used was 1.30 m/s, and the fastest was 2.51 m/s.

After making four measurements of the time of flight for these two situations, we could not see any correspondence between time of flight and initial horizontal velocity (see table 1 from lab journal). As a final check, we measured the time of flight for a ball that was started approximately halfway up the ramp and found it was similar to the times of flight for both the fast and the slow horizontal velocities (see table 2 from lab journal).

A discussion of uncertainty should follow all measurements. No measurement is exact. Uncertainty must be included to indicate the reliability of your data.

Most of the uncertainty in recording time of flight came from deciding the time for the first data point when the ball is in the air and the last data point before it hit the ground. We estimated that we could be off by one frame, which is 1/30 of a second. To get a better estimate of this uncertainty, we repeated each measurement four times. The average deviation served as our experimental uncertainty (see Table 1 from lab journal). This uncertainty matched our estimate of how well we could determine the first and the last frame of the projectile trajectory.

Conclusions

This section summarizes your results. In the most concise manner possible, it answers the original question of the lab.

Our graph indicates that the time of flight is independent of the ball's initial horizontal velocity (see lab journal, Graph A). We conclude that there is no relationship between these two quantities.

A good conclusion will always compare actual results with the predictions. If your prediction was incorrect, then you must discuss where your reasoning went wrong. If your prediction was correct, then you should review your reasoning and discuss how this lab served to confirm your knowledge of the basic physical concepts.

Our prediction is contradicted by the apparent independence of the time of flight and initial horizontal velocity. We thought that the ball would take longer to fall to the floor if it had a greater initial horizontal velocity. After some discussion, we determined the error in our prediction. We did not understand that the vertical motion is completely independent of the horizontal motion. Thus, in the vertical direction the equation

$$y - y_o = v_o\Delta t + 0.5a\Delta t^2$$

means that the v_o is the only the y-component of initial velocity. Since the ball rolls horizontally at the start of its flight, v_o in this equation always equals zero.

The correct equation for the time of flight, with no initial vertical component of velocity, is actually:

$$y - y_o = 0.5a\Delta t^2$$

In this equation, there is no relationship between time of flight and initial horizontal velocity.

Furthermore, the graphs we generated with LabVIEW™ showed us that velocity in the y-direction did not change when the initial horizontal velocity changed. Velocity in the y-direction is always approximately zero at the beginning of the trajectory. It is not exactly zero because of the difficulty our camera had determining the position when the projectile motion begins. We observed that the y-velocity changed at the same rate (slope of v_y plots, graphs 1 and 2) regardless of the horizontal velocity. In other words, the acceleration in the y-direction is constant, a fact that confirms the independence of vertical and horizontal motion.

After you have compared your predictions to your measured results, it is helpful to use an alternative measurement to check your theory with the actual data. This should be a short exercise demonstrating to yourself and to your TA that you understand the basic physics behind the problem. Most of the problems in lab are written to include alternative measurements. In this case, using the time of fall and the gravitational constant, you can calculate the height of the table.

The correct equation for the horizontal motion is

$$x - x_o = v_o \Delta t$$

The horizontal acceleration is always zero, but the horizontal distance that the ball covers before striking the ground does depend on initial velocity.

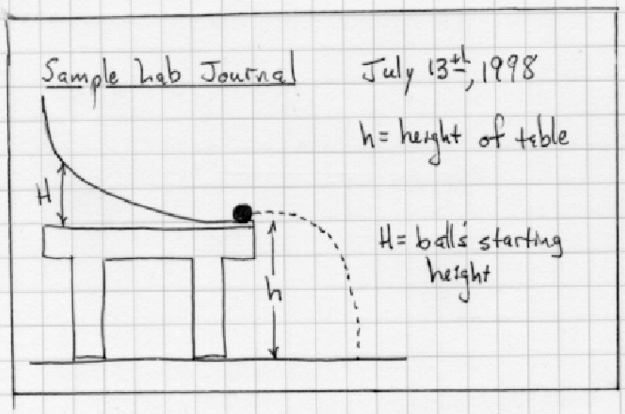
** Alternative Analysis**

Since $y_o - y = h$ and $a = -g$ we can check to see if our measured time of flight gives us the height of the table. From our graph, we see that the data overlaps in a region of about 0.41 sec. With this as our time of flight, the height of the table is calculated to be 82.3 cm. Using a meter stick, we found the height of the table to be 80.25 cm. This helped convince us that our final reasoning was correct.

The example of the two bullets discussed in the Prediction section was interpreted incorrectly by our group. Actually, both bullets hit the ground at the same time. One bullet travels at a greater speed, but both have the same time of flight. Although this seems to violate "common sense" it is an example of the independence of the horizontal and vertical components of motion.

APPENDIX E: SAMPLE LAB REPORT

The following are pages photocopied from my lab journal:



Equipment: ramp, aluminum ball, video camera, computer, meterstick

Purpose: Determine if Time of flight depends on initial horizontal velocity

Method: One person releases ball, another operates video camera. Count frames with ball in the air to find time of flight.

Exploration: Larger H results in larger horizontal $\vec{v}$.

Table 1

Fast Ball, $H \simeq 35cm$, $v_0 = 2.51\ m/s$

Trial	Frames with ball in air	Deviation from ave.
1	13	0.25
2	13	0.25
3	12	0.75
4	13	0.25
Average	12.75	0.4

Time of flight:
$12.75\ \text{frames} \times \frac{1}{30} \frac{sec}{frame} =$

0.42 sec

Uncertainty:
$\pm 0.4\ \text{frames} \times \frac{1}{30} \frac{sec}{frame} =$

± 0.014 sec

Slow Ball, $H \simeq 10cm$, $v_0 = 1.3\ m/s$

1	12	0.5
2	13	0.5
3	13	0.5
4	12	0.5
Average	12.5	0.5

Time of flight:
$12.5\ \text{frames} \times \frac{1}{30} \frac{sec}{frame} =$

0.41 sec

Uncertainty
$\pm 0.5 \times \frac{1}{30} \frac{sec}{frame} =$

± 0.018 sec

Table 2

Medium Ball, $H \simeq 20$, $v_0 = 1.8\ m/s$

Trial	# frames	Deviation
1	12	0.5
2	12	0.5
3	13	0.5
4	13	0.5
Average	12.5	0.5

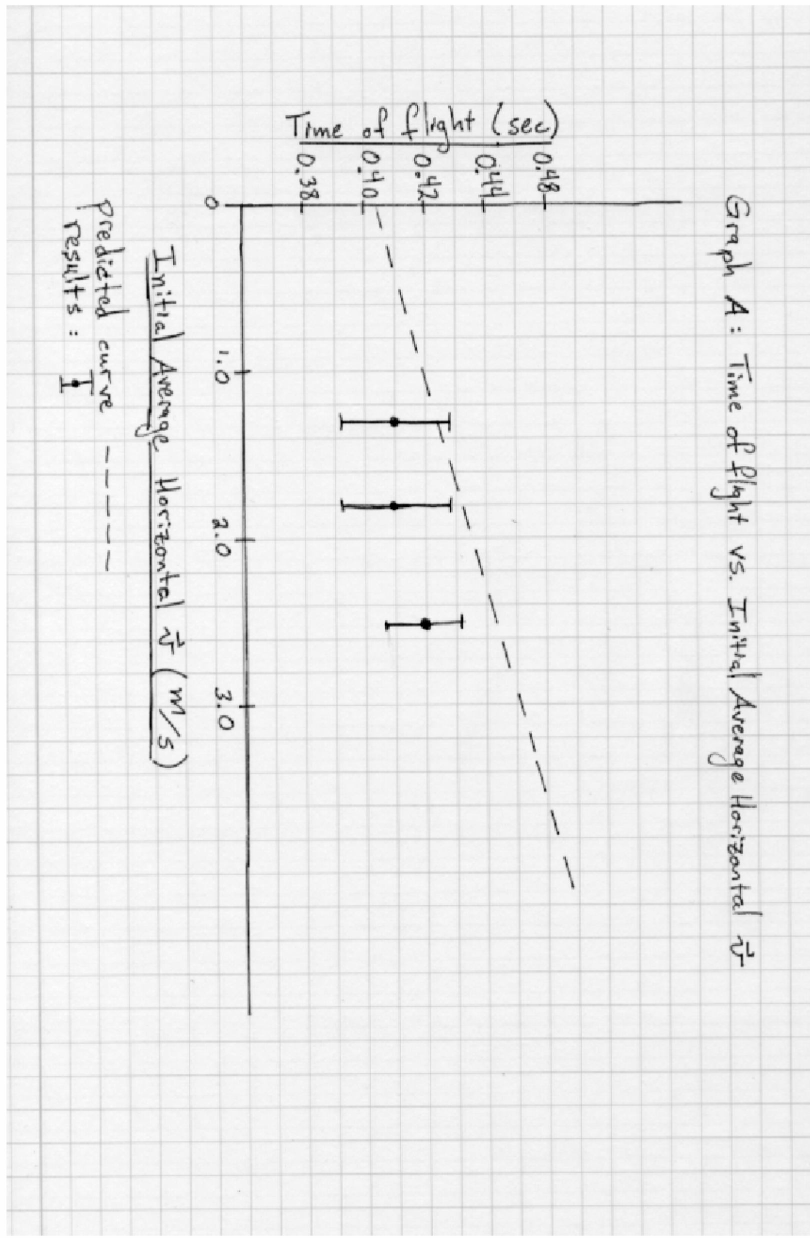
Time of flight:
$12.5\ \text{frames} \times \frac{1}{30} \frac{sec}{frames} =$

0.41 sec

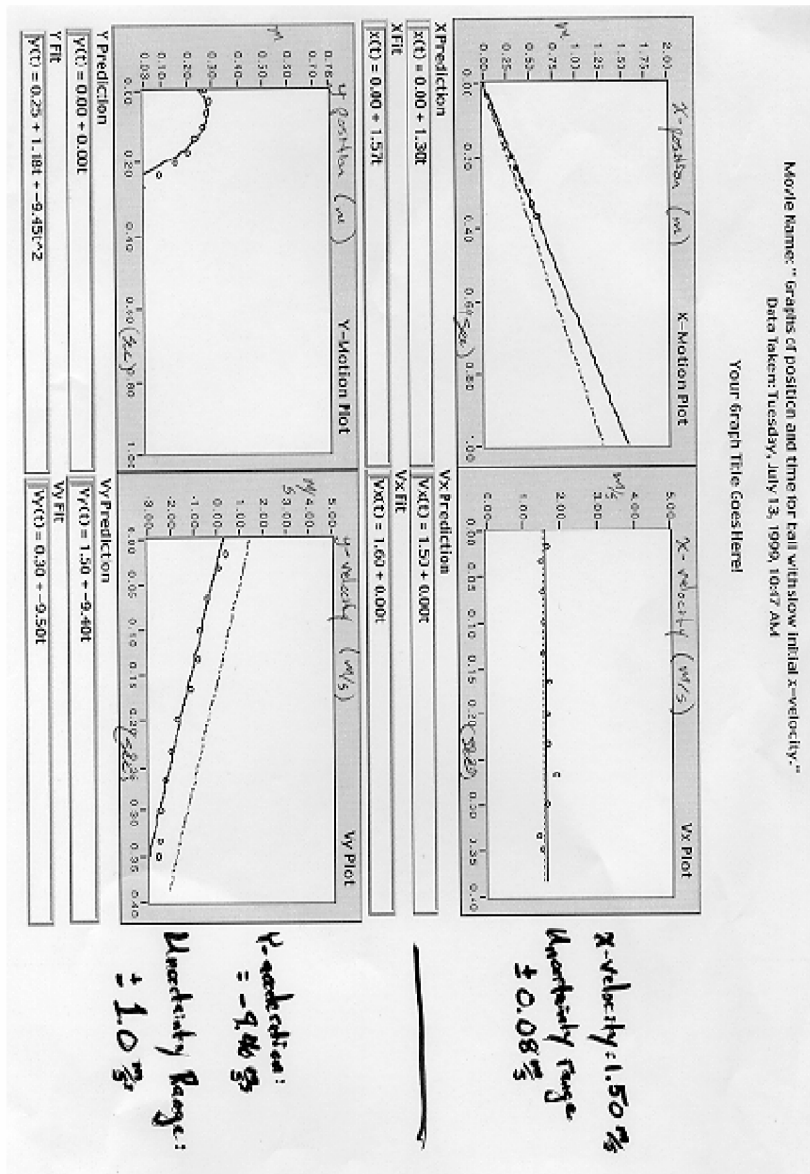
Uncertainty: $\pm 0.5 \times \frac{1}{30} \frac{sec}{frame} =$

±0.018 sec

APPENDIX E: SAMPLE LAB REPORT

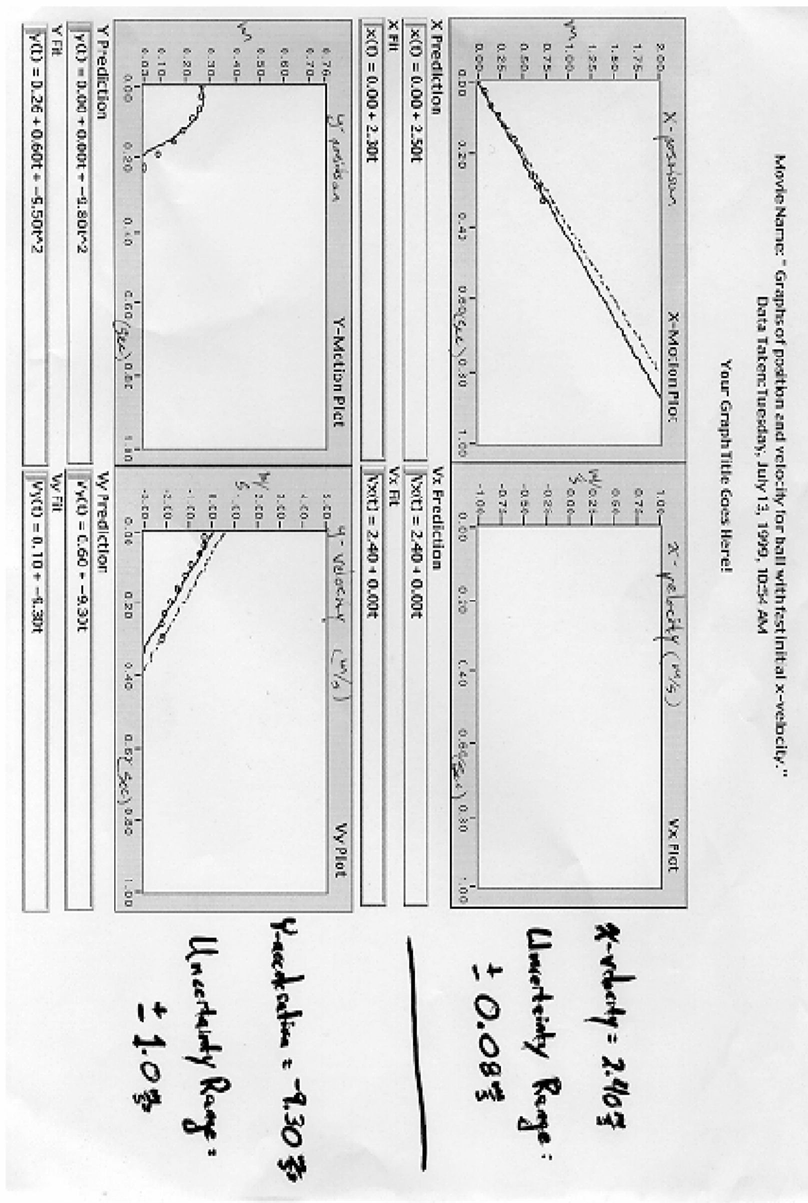


APPENDIX E: SAMPLE LAB REPORT



E - 9

APPENDIX E: SAMPLE LAB REPORT



How to Grade a Student Laboratory Report

We've redefined the quality of writing based on the general writing factors, and how these factors relate to the rubric used to grade physics laboratory reports. We've also evaluated the sample laboratory report from the laboratory manual. Now we will go through an example of how to grade a student laboratory report.

Individual Tasks:

3. *Individually* read through the example student laboratory report.

4. Follow closely as we go over the grading of the example student laboratory report.

5. Mark down any and all comments made during the presentation on the example student laboratory report.

Time: 30 minutes

Note: This activity is to show you how to grade student laboratory reports, so follow along closely.

SAMPLE COVER SHEET

PHYSICS ____ LABORATORY REPORT
LABORATORY I

Name and ID#: ____

Date performed: ______________ Day/Time section meets: ____________

Lab Partners' Names: ____

____

____

Problem # and Title: ____

Lab Instructor Initials: __________

Grading Checklist	Points
LABORATORY JOURNAL:	
PREDICTIONS (individual predictions completed in journal before each lab session)	
LAB PROCEDURES (measurement plan recorded in journal, tables and graphs made in journal as data is collected, observations written in journal)	
PROBLEM REPORT:	
ORGANIZATION (clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	
TOTAL(incorrect or missing statement of physics will result in a maximum of 60% of the total points achieved; incorrect grammar or spelling will result in a maximum of 70% of the total points achieved)	
BONUS POINTS FOR TEAMWORK (as specified by course policy)	

* An "R" in the points column means to rewrite that section only and return it to your lab instructor within two days of the return of the report to you.

88\

Lab report of lab 2 problem #1

312

MASS AND THE ACCELERATION OF A FALLING BALL

The purpose of this lab is to determine if the acceleration of an object depend on its mass. We use a baseball and a plastic orange ball (1/3 mass of baseball). These two objects have different mass but almost the same size. They are use to be dropped so we can calculate the acceleration for each of them. A camcorder is used to record the different intervals of the balls. From the information received, we can determine the change of distance and the change of time of each interval. The software program "Lab View" guides us in our analysis of the change of velocity of each interval as it goes down the screen.

Prediction

It is understand that any object regardless of its mass will be pull towards the earth at a constant acceleration of 9.8 m/s2. This is only true in a vacuum room. We predicted that the acceleration of an object would have a factor from its mass. The free-fall acceleration of an object will increase as the mass of the object increase. This change of acceleration is depending on the air acting on the ball. If the object has more mass then the object is able to reduce the pressure acting upon it but if the object is light, air will be a factor and it will not accelerate as fast.

Data and Results

We use a meter stick to ensure a vertical path for the ball to follow. The ball is being dropped from the top of the meter stick to the floor (bottom). We use the video camera to record a movie of the free-fall. The movie capture individual intervals of the fall, each time frame if capture every 1/30 sec. We then use the intervals to determine the change of distance over change of time.

The starting time for the baseball was 0.80sec and ended at 1.02 sec. The total time is 0.22 seconds to travel 100 cm. The average velocity is 454 cm/sec. The weight of this ball (baseball) is 140 grams and 7cm in diameter.

The starting time for the orange ball is at 0.6 seconds and ends at 0.9 seconds. The total time is 0.3 seconds over a distance of 100 cm. The average velocity of the free-fall is 333.33 m/s. The weight of the ball is 47.7 grams and a diameter of 6.5 cm.

From the data above, we can see that the velocity of the baseball is higher then the Orange ball.

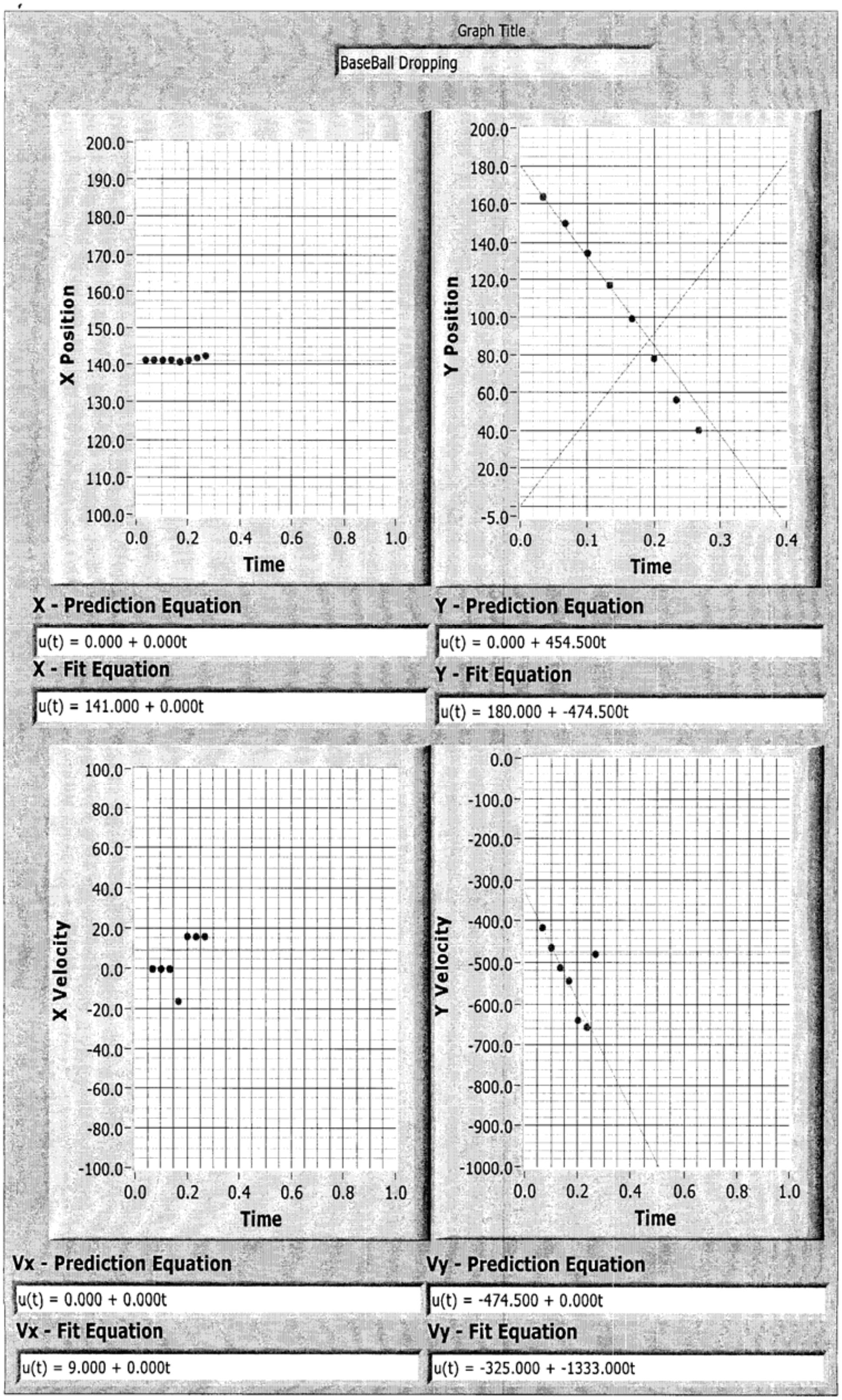
Baseball:
(Interval 2) 140cm/ 0.26sec = 538 m/s
(Interval 1) 125cm/ 0.24sec = 520 m/s
18.46 m/s / 0.02 sec = 923 cm/s = **9.23 m/s2**

Orange Ball:
(Interval 2) 330cm/ 0.22sec = 1500m/s
(Interval 1) 140cm/ 0.10sec = 1400m/s
100m/s / 0.12 sec = 833.33 cm/s = **8.33m/s2**

Difference of acceleration:
9.23 m/sec2 – 8.33 m/sec2 = 1.10 m/sec2

Conclusion

In conclusion, it took 0.08seconds longer for the orange ball to reach the ground then the baseball and baseball is acceleration 1.10 m/sec2 faster then the orange ball. We predict that if the balls were being evaluated in a vacuum room, the acceleration would be the same even if they have different mass.


Graph Title
BaseBall Dropping
X Position
Time
Y Position
Time
X - Prediction Equation
u(t) = 0.000 + 0.000t
X - Fit Equation
u(t) = 141.000 + 0.000t
Y - Prediction Equation
u(t) = 0.000 + 454.500t
Y - Fit Equation
u(t) = 180.000 + -474.500t
X Velocity
Time
Y Velocity
Time
Vx - Prediction Equation
u(t) = 0.000 + 0.000t
Vx - Fit Equation
u(t) = 9.000 + 0.000t
Vy - Prediction Equation
u(t) = -474.500 + 0.000t
Vy - Fit Equation
u(t) = -325.000 + -1333.000t

Grading Two Example Student Laboratory Reports

Now it's your chance to grade student laboratory reports. Please keep in mind the information from Activities **17** & **#18a** as you go through the following 2 student laboratory reports.

INDIVIDUAL TASKS:

1. *Individually* read through the 2 example student laboratory reports and grade them using the grading rubric for physics laboratory reports.

2. Mark down any and all comments on the example student laboratory reports as you grade them.

3. Assign points for each student laboratory report on the grading rubric.

GROUP DISCUSSION

TIME: 30 minutes

PRODUCT

Grading rubric; comments and feedback on each student laboratory report.

Activity 18b. Grading Two Example Lab Reports

SAMPLE COVER SHEET

PHYSICS ____ LABORATORY REPORT
LABORATORY I

Name and ID#: ____

Date performed: ______________ Day/Time section meets: ____________

Lab Partners' Names: ____________________________________

____

____

Problem # and Title: _____________________________________

Lab Instructor Initials: __________

Grading Checklist	Points
LABORATORY JOURNAL:	
PREDICTIONS (individual predictions completed in journal before each lab session)	
LAB PROCEDURES (measurement plan recorded in journal, tables and graphs made in journal as data is collected, observations written in journal)	
PROBLEM REPORT:	
ORGANIZATION (clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	
TOTAL(incorrect or missing statement of physics will result in a maximum of 60% of the total points achieved; incorrect grammar or spelling will result in a maximum of 70% of the total points achieved)	
BONUS POINTS FOR TEAMWORK (as specified by course policy)	

* An "R" in the points column means to rewrite that section only and return it to your lab instructor within two days of the return of the report to you.

Example #1

n

Lab Report 2 – Lab 3, Problem 1

Statement of the problem:

I am a volunteer in the city's children's summer program. One suggested activity is for the children to build and race model cars along a level surface. To ensure that each car has a fair start, my co-worker recommends a special launcher be built. The launcher uses a string attached to the car at one end and, after passing over a pulley, the other end of the string is tied to a block hanging straight down. The car starts from rest and the block is allowed to fall, launching the car along the track. After the block hits the ground, the string no longer exerts a force on the car and the car continues moving along the track. I want to know how the launch speed of the car depends on the parameters of the system that you can adjust. I decide to calculate how the launch velocity of the car depends on the mass of the car, the mass of the block, and the distance the block falls. My ultimate goal was to find the answer to the question – "What is the velocity of the car after being pulled for a known distance?"

Prediction:

I predicted that, using the equation $V=\sqrt{(2M_a gh)/(M_a+M_c)}$

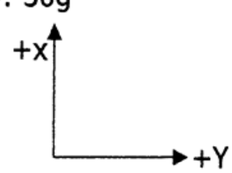
and with the data collected during setup, that the velocity at the time the block hit the floor would be 60.5cm/s.
(Prediction graphs are attached.)

Procedure:

First, we gathered supplies. We used a cart, a flat track with a pulley attached, a mass hanger with a mass set to simulate the wooden block, string, and a video camera attached to a computer with video analysis software. We massed the cart and the block, and began to set up the experiment. We placed the cart on the track, and ran the string through the pulley. We hooked our mass onto the end of the string, and held it to a height that we measured and marked. We began recording video and let the mass go. We made 3 runs like this to obtain the best video. When we were satisfied we analyzed the video and came up with a good measurement of the cart's velocity. We printed our graphs and made conclusions based on our data.

Data and Results:

Mass of Cart (Mc): 753.8g
Mass of Block (Ma): 50g
Height (H): 30cm
Coordinate Axis:



(Graphs of data analysis are attached)

Discussion:

The results from the lab were pretty close to the prediction made by plugging the masses of the cart and block and the height of the drop into the equation I wrote in my lab journal.

In the lab, there were a few sources of obvious error. The first major source was the method of getting data. The computer software is a bit inaccurate in measuring the velocity with the method of selecting points in the video frames. The camera we used has a curved lens, which distorts the video. This all leads to data that is off from the expected return. Another possible source of error is the equipment. The set-up we used was not entirely perfect in the fact that we were not taking friction into account, yet there was most likely friction in the cart's wheels. This would matter most during the time after the block has hit the ground, which is the situation we are modeling.

We could have made a few improvements. The main improvement would be to more accurately analyze the data within the computer software to compensate for any distortion in the video. We also could have made sure the cart was properly lubricated before performing the experiment.

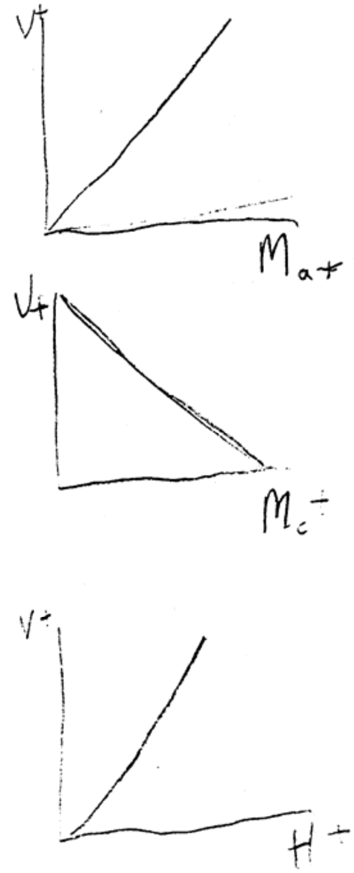
Conclusions:

In our lab, we discovered the velocity of the car after being pulled a known distance was around 55cm/s. This was close to our initial prediction, so we were satisfied with our results.

The launch velocity of the car does depend on its mass, as well as the mass of the block and the distance the block falls. This is due to the fact that they all affect the forces acting on the car. There are some instances where the mass would not really affect the launch velocity. If the distance dropped were very close to zero, the launch velocity would be near zero no matter what the mass of the block was.

If the same block falls the same distance, the force exerted by the block on the cart would not change, no matter the mass of the cart. The force of the block on the cart is always equal to the block's weight.

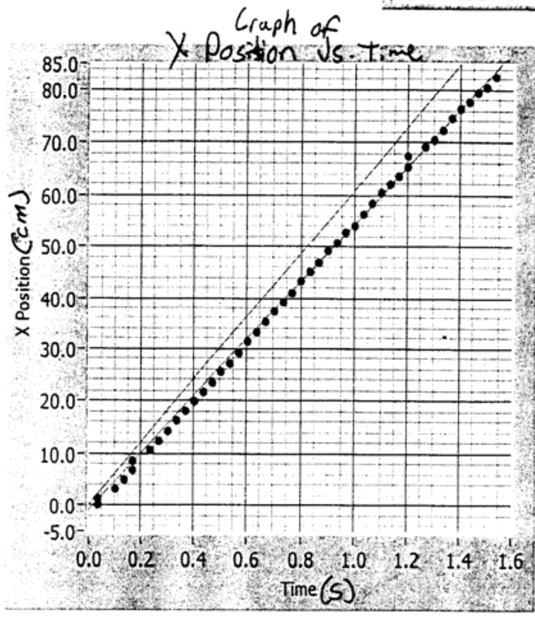
Prediction graphs

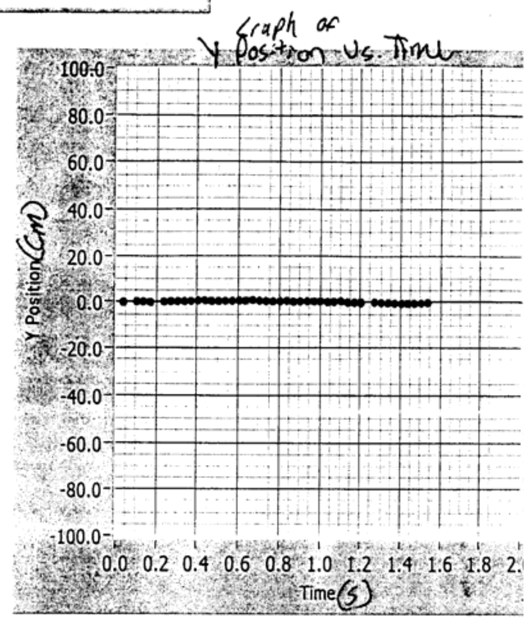


7

Graph Title

Lab 3 Problem 1





X - Prediction Equation

u(t) = 0.000 + 60.500t

X - Fit Equation

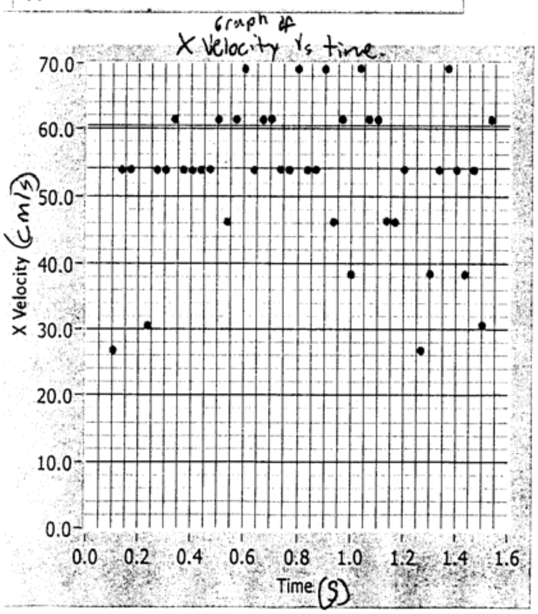
u(t) = -1.000 + 55.000t

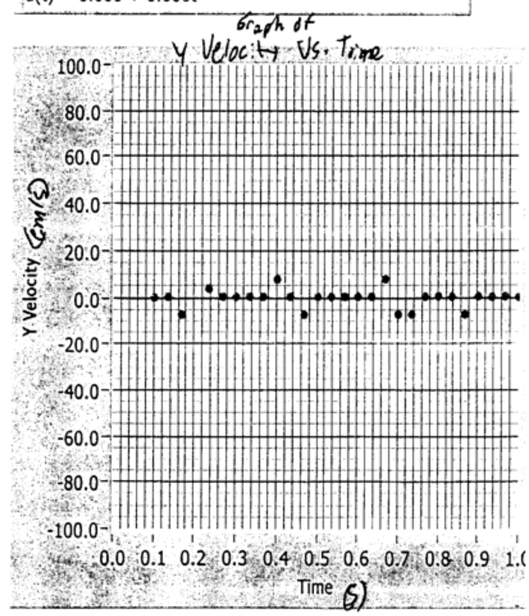
Y - Prediction Equation

u(t) = 0.000 + 0.000t

Y - Fit Equation

u(t) = 0.000 + 0.000t





Vx - Prediction Equation

u(t) = 60.500 + 0.000t

Vx - Fit Equation

u(t) = 54.000 + 0.000t

Vy - Prediction Equation

u(t) = 0.000 + 0.000t

Vy - Fit Equation

u(t) = 0.000 + 0.000t

SAMPLE COVER SHEET

PHYSICS ____ LABORATORY REPORT
LABORATORY I

Name and ID#: ____

Date performed: ____________ Day/Time section meets: ____________

Lab Partners' Names: ____

____

____

Problem # and Title: ____

Lab Instructor Initials: __________

Grading Checklist	Points
LABORATORY JOURNAL:	
PREDICTIONS (individual predictions completed in journal before each lab session)	
LAB PROCEDURES (measurement plan recorded in journal, tables and graphs made in journal as data is collected, observations written in journal)	
PROBLEM REPORT:	
ORGANIZATION (clear and readable; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	
TOTAL (incorrect or missing statement of physics will result in a maximum of 60% of the total points achieved; incorrect grammar or spelling will result in a maximum of 70% of the total points achieved)	
BONUS POINTS FOR TEAMWORK (as specified by course policy)	

* An "R" in the points column means to rewrite that section only and return it to your lab instructor within two days of the return of the report to you.

Example #2

uist

109

002

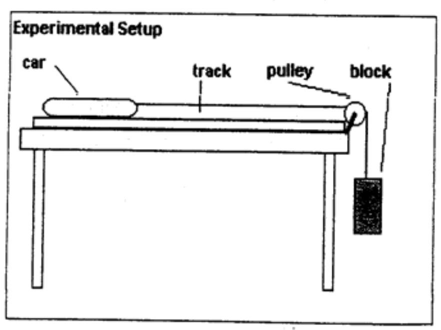
Lab III Problem 1: Force and Motion

1. Statement of the Problem -- According to the lab manual, my group members and I were asked to test the velocity of a toy car launched down a track. The car is attached to a string at the end of the track, which goes over a pulley and is then attached to a block. When the block is released, the string pulls the car down the track. After the block hits the ground, the car is no longer pulled but keeps going. We were asked to find how the cars speed after the block hits the ground depends on the mass of the car, the mass of the block, and the distance the block falls before hitting the ground. The question we answered in this lab is:

What is the velocity of the car after being pulled a known distance?

We used a toy car with a string attached to it, a block, a pulley, and a track to conduct our experiment. We recorded the motion of the car and the block using a video analysis application written in LabVIEW™, then analyzed the video to find the position, velocity and acceleration of the car while it was being pulled by the falling block and after the black reached the ground.

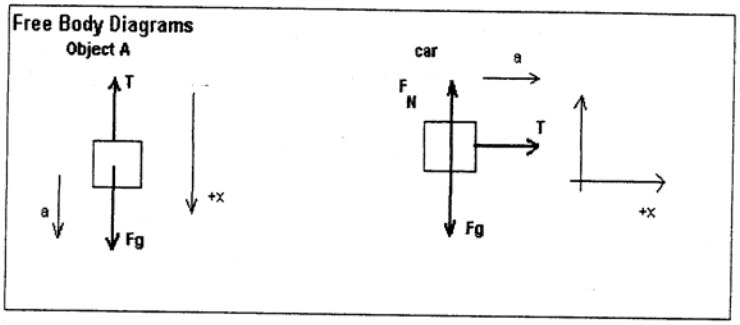
The block (called object A) has a significantly shorter distance to fall than the car has to travel along its track. In this experiment, we ignored the friction between the car and the track and between the pulley and the string. We also ignored the mass of the string.



2. Prediction --

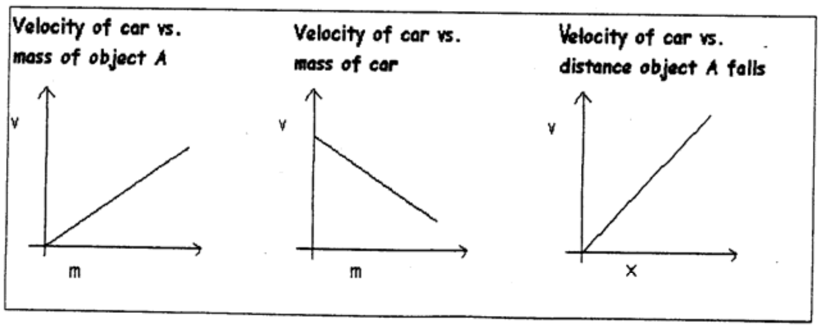
The first question asked me to calculate the cart's velocity after the block had hit the ground. I predicted that $\mathbf{v_c} = \sqrt{\mathbf{2xg[m_a/(m_c + m_a)]}}$. I solved the first kinematics equation, $\mathbf{x_c = x_{0c} + v_{0c}t + 1/2at^2}$ **for t**, assuming that x_0 =O, v_0 =0 and $a_c = a_A$, and that the magnitude of the car's displacement was the same as the magnitude of the block's, (since the string did not stretch), yielding $\mathbf{t = 2x/a}$. Since v= at, $\mathbf{v = a\sqrt{(2x/a)}}$ and $v^2 = 2ax$. Solving for a gives $\mathbf{a = v^2/2x}$.

Variables	
x	position
xo	initial position
v	velocity
vo	initial velocity
a	acceleration
t	time
m	mass of object A
m	mass of car
F	Force
g	gravity
N	Normal Force
T	tension force



Since the objects are attached to the same string, the tension forces acting upon them are equal to each other. The sum of the forces acting on Object A in the x direction is $\mathbf{\Sigma F_A = Fg - T}$. The sum of the forces acting on the car in the x direction is $\mathbf{\Sigma F_c = T}$. Since F= ma, $\mathbf{M_A a = M_A g - T}$ and $\mathbf{M_c a = T}$. Using $\mathbf{a = v^2/2x}$, $\mathbf{M_A(v^2/2x) = M_A g - T}$, and $\mathbf{M_c(v^2/2x) = T}$. Combining these equations gives $\mathbf{M_A(v^2/2x) = M_A g - M_c(v^2/2x)}$, and solving for v gives $\mathbf{v_c} = \sqrt{\mathbf{2xg[m_a/(m_c + m_a)]}}$.

The next three prediction problems asked us to draw a graph of the car's velocity vs. time as a function of the mass of object A, mass of the car, and distance object A falls, respectively. The other two variables are kept constant in each graph.



Sonah 4

The velocity would increase as the mass of object A or the distance object A falls increased, and would decrease as the mass of the car increased. The velocity would increase at a greater rate with the increase in distance than it would with the increase in mass of object A. Another way this could be said is that the graph of velocity vs. distance would have a greater slope than the graph of velocity vs. mass of object A.

3. Procedure – We set up the experiment according to the experimental setup picture above. The mass of the car we used was 252 g, and the mass of object A was 50 g. The distance form object A to the ground was 0.41m and the total distance the car was able to travel was 1m. There was 0.59m for the car to travel after object A hit the ground. We placed the camera about 1.5m away from the table holding the track so that the entire length of the track could be seen as well as object A. We recorded the car's motion and then analyze it in LabVIEW™. We divided the motion of the car into two parts -- motion before object A hit the ground and motion after object A hit the ground -- and analyzed each part separately. We predicted the equations for the position vs. time graphs, plotted data points of both the horizontal and vertical motion of the graphs, and then found the best-fit equations for them. We did the same for the car's velocities.

4. Data and Results – SEE ATTACHED GRAPHS

We predicted that there would be no motion, and hence no velocity, in the y direction for any of the graphs, and our prediction was correct.

<u>Before object A hit the ground</u> --When we predicted the equation for the x position vs. time of the car before object A hit the ground, we didn't really know what we were doing. We should have used the equation $x = x_0 + v_0t + 1/2at^2$ to make our prediction. The values for x_0 and v_0t would both have been equal to zero and we could have predicted the acceleration using $a = v^2/2x$: $(\sqrt{2xg[m_a/(m_c + m_a)]})^2/2x = [m_a/(m_c + m_a)]g = a$. This would have given us an acceleration of 1.49 m/s*s, and a predicted equation of $x = 0 + 0(t) + 0.75\text{m/s*s}(t^2)$. The value of 0.897 m/s*s in the best-fit equation is reasonably close to this. Since the slope of a velocity vs. time graph is equal to the acceleration and since 0.897 m/s*s was equal to ½ a, we predicted that the slope of the acceleration vs. time graph would be equal to 1.80 m/s*s, and our prediction fit the actual value of 1.70 m/s*s well.

<u>After object A hit the ground</u>—We predicted that the car would have zero acceleration during this portion of its motion and that its velocity would be equal to its final velocity, just as object A hit the ground. Again, we used the equation $x = x_0 + v_0t +$

$1/2at^2$ to describe the predicted motion, with x_0 and a both equal to zero. We predicted the velocity to be $v=\sqrt{2xg[m_a/(m_c+m_a)]}$, or 1.167m/s. This prediction was very close to the actual value. We predicted that for the velocity vs. time graph, the velocity would stay constant at 0.167m/s, and our prediction was very close to the actual best-fit line equation.

5. Discussion--

Results- The acceleration of the car in the experiment is dependant on the block falling. Before the block hits the ground, the car accelerates because of the falling block. The acceleration of the block and the car is the same because the same tension force acts them upon. Their accelerations are equal to $[m_a/(m_c+m_a)]g$, where m_a is the mass of object a (the block), m_c is the mass of the car, and g is the acceleration due to gravity, 9.8m/s*s. The velocity of the car and of object a at the time when object a hits the ground is equal to $\sqrt{2xg[m_a/(m_c+m_a)]}$.

After the block hit the ground there would no longer be any tension in the string and the sum of the forces on the car would be equal, (since T=0 and $F_g=-F_N$). Because F=ma, the car would have no acceleration. Its velocity would continue to be equal to $\sqrt{2xg[m_a/(m_c+m_a)]}$.

Error- Error resulted from our collection of data points again. It is difficult to click on exactly the same point of the car each time and to click on the same y value along the track each time as well. This results in distortion of the position measurements and velocities calculated. There is not much that can be done about this, except that we should try to be very precise in future collection of data points. Also, the camera could have caused a slight distortion of the collected data values. In this experiment, we neglected the friction between the car and the track and between the pulley and the string. This made the calculations a lot easier, but it caused our predicted value for the acceleration of the car and the block to be different than the actual value.

Improvements- It would be optimal to do many trials of this experiment, using different values for m_c, m_a and x, to check that the equations really fit, but time is an issue. With more precise data collection, we could have eliminated some of the movement and velocity seen along the y-axis.

6. Conclusions-- Using physics principles and equations, we predicted that the velocity of car pulled a known distance by a falling object would be equal to $\sqrt{2xg[m_a/(m_c+m_a)]}$, where x is equal to the distance the object falls, g is equal to gravity (9.8m/s*s), m_a is the mass of the object falling and m_c is equal to the mass of the car being pulled. Since the tension forces on each object are the same, they have the same acceleration and this can be predicted using Newton's second law and kinematics equations. The results of our experiment confirmed this.

In each case but one, the predicted values for the components of the equations of the graphs were the same or close to the actual ones. When we predicted the value for acceleration of the car before the block hit the ground, we didn't figure any friction into the calculations. We based all of our future predictions off of the actual values we got for this graph's equation and they all matched the actual values well.

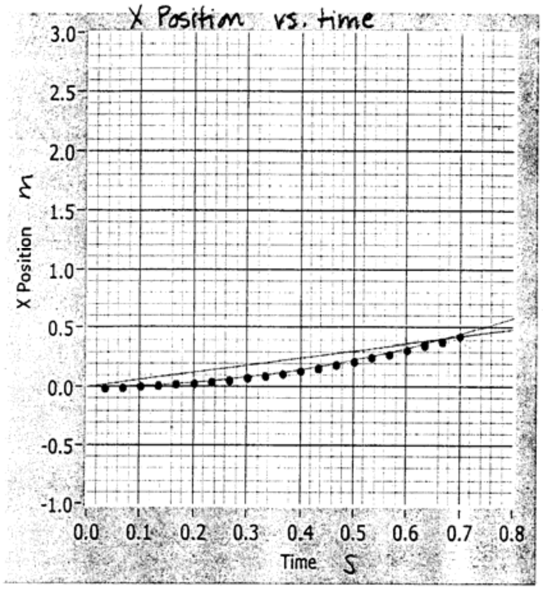
The launch velocity of the car does depend on the mass of the car, the mass of the block and the distance the block falls, according to $v = \sqrt{2xg[m_a/(m_c + m_a)]}$. For values of m_a that are much larger than m_c, m_c does not affect v very much, since $[m_a/(m_c + m_a)]$ becomes very close to 1.

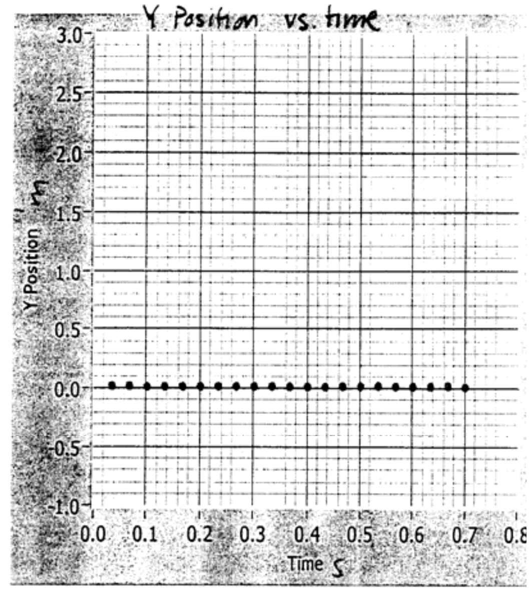
The tension force upon the car and the block is dependent on the masses of both objects. Changing the mass of either one will change the tension force exerted on both. The tension force on the block is equal to its weight if the block has no net acceleration; in other words, when $T = F_g$. This would happen if the mass of the block was zero, and since it could never have zero mass, it would never happen in a frictionless system. It may come close to zero though, and would reach zero in a system with friction. We could test this experimentally by using a car with a very large mass and using blocks of decreasing masses. The acceleration of the car should go toward zero as the mass of the blocks decrease.

7

Graph Title

Lab III Problem 1: Before [A] hit the ground





X - Prediction Equation

u(t) = 0.000 + 0.600t

X - Fit Equation

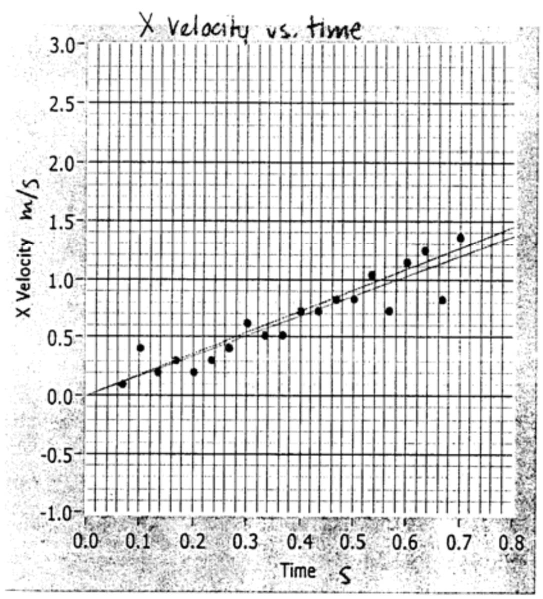
u(t) = 0.000 + 0.000 t + 0.897 t^2

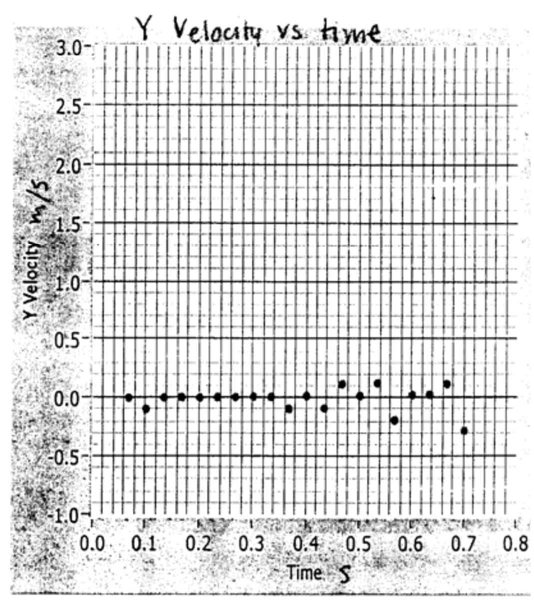
Y - Prediction Equation

u(t) = 0.000 + 0.000t

Y - Fit Equation

u(t) = 0.000 + 0.000t





Vx - Prediction Equation

u(t) = 0.000 + 1.800t

Vx - Fit Equation

u(t) = 0.000 + 1.700t

Vy - Prediction Equation

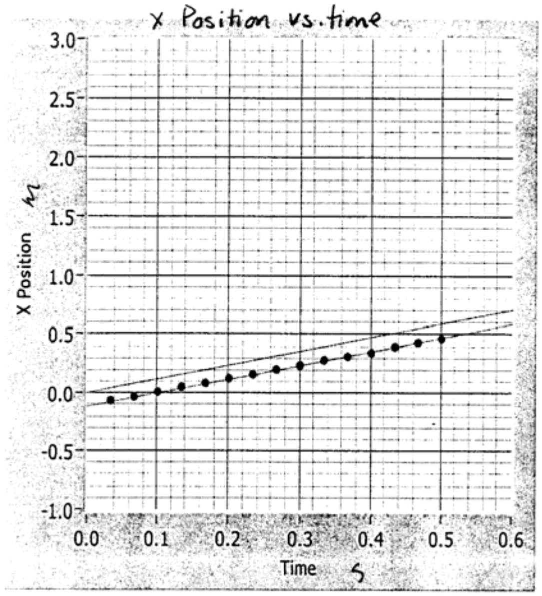
u(t) = 0.000 + 0.000t

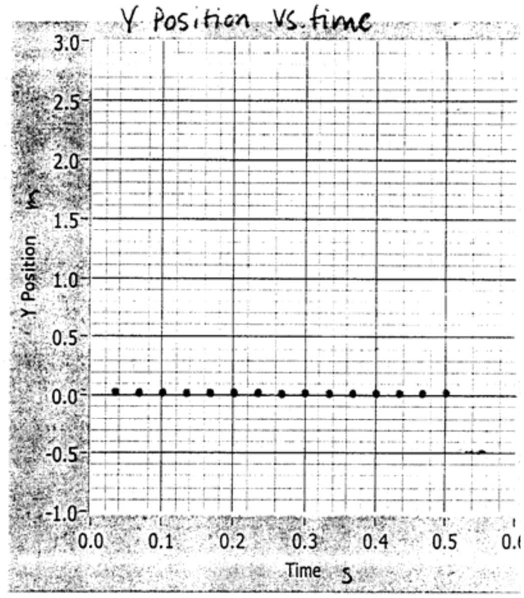
Vy - Fit Equation

u(t) = 0.000 + 0.000t

Graph Title

Lab III Problem 1: After [A] hit the ground





X - Prediction Equation

u(t) = 0.000 + 1.167t

X - Fit Equation

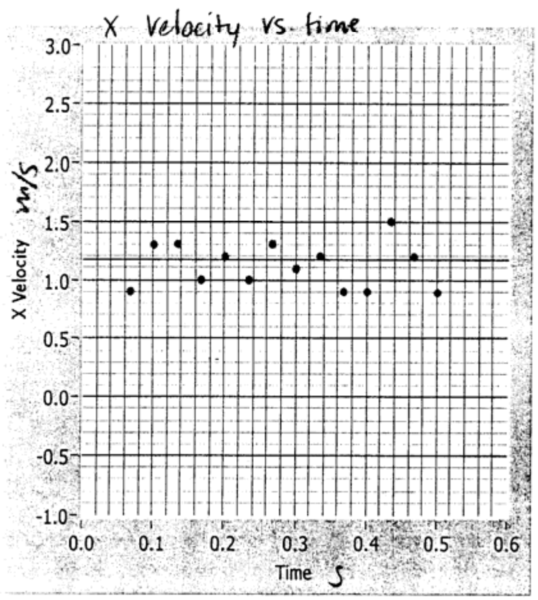
u(t) = -0.120 + 1.167t

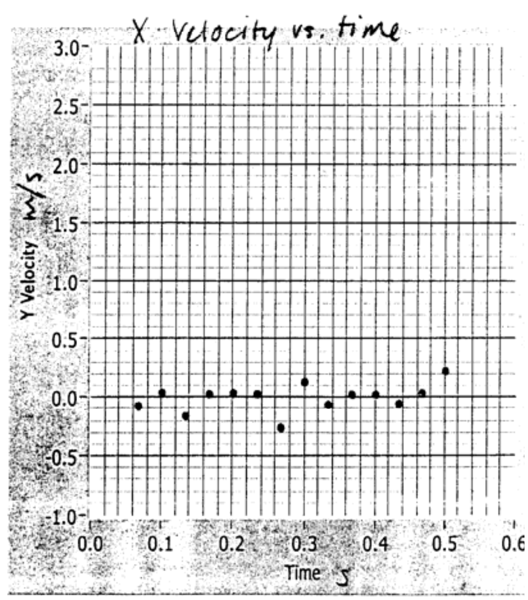
Y - Prediction Equation

u(t) = 0.000 + 0.000t

Y - Fit Equation

u(t) = 0.000 + 0.000t





Vx - Prediction Equation

u(t) = 1.167 + 0.000t

Vx - Fit Equation

u(t) = 1.170 + 0.000t

Vy - Prediction Equation

u(t) = 0.000 + 0.000t

Vy - Fit Equation

u(t) = 0.000 + 0.000t

Campus Resources for Writing Support

Writing Support Network. The Writing Support Network is a web page that lists support services for students in writing classes. All writing centers home pages are listed.

See: http://www.writinghelp.umn.edu/

Center for the Interdisciplinary Studies of Writing. CISW offers workshops for TAs and faculty teaching writing-intensive courses. You can also find on their website sources for sample courses, syllabi, and assignments that are writing-intensive.

See: http://CISW.cla.umn.edu/

Writing-Intensive Resources for Scientific and Technical Disciplines. This web site provides information for faculty and students in scientific and technical disciplines. Faculty information includes suggestions for evaluating written reports, integrating writing in assignments, and incorporating revision and peer review. Student information provides a number of online handouts on writing topics such as writing and revising, editing, oral presentations, and student collaboration. Student can also find helpful links to other resources about writing such as other writing centers and sources for documentation.

See: http://www.agricola.umn.edu/writingintensive/

Classroom Climate

A positive Classroom Climate can play an important role in determining academic misconduct and sexual harassment.

In your groups:

1. **Recall examples of positive/negative classroom climates.**
2. **Brainstorm factors that contributed to the positive/negative classroom climate**

Scholastic Dishonesty is ...

Directions: Circle **T** if the statement accurately completes the above sentence; Circle **F** if the statement does not accurately complete the above sentence.

T / F 1. The act of passing off someone else's work as your own.

T / F 2. Extensive assistance from other people on an assignment without recognition.

T / F 3. Using sections of someone else's homework assignment.

T / F 4. Looking at another student's examination during a testing situation.

T / F 5. Conferring with fellow students during an examination period.

T / F 6. Allowing another student to copy from your examination.

T / F 7. Using notes stored on a calculator during a closed-book examination.

T / F 8. Using another person's idea without acknowledging that person.

T / F 9. Allowing another student to copy sections of your paper.

T / F 10. Signing another student's name on an attendance sheet.

T / F 11. Permitting another student to sign your name on an attendance sheet.

T / F 12. Collaborating with a fellow student on a take home exam.

T / F 13. Copying an answer to a problem line-for-line from a textbook or solution manual without identifying where it came from.

T / F 14. An act that can result in expulsion from the University.

Adapted with permission from the Teaching Enrichment Program at the University of Minnesota.

Case Studies: Diversity and Gender Issues

GROUP TASK

This exercise uses "critical incidents" derived from encounters among and between teachers and students at the University of Minnesota. The critical incidents are, as the name implies, incidents or situations that are of importance in understanding the behavior, values, and cultural differences of those described in the incident. Case Studies #1 through #6 deal with incidents you might encounter as a graduate teaching assistant. Case Studies #7 and #8 describe encounters between people from the U.S. and international scholars. Case Studies #9 through #11 deal with incidents with fellow graduate students.

The incidents are open-ended, with no absolute right answer to be guessed or learned. In our discussion of the incidents, several explanations, alternatives, or solutions could be proposed depending on the personality, style, or culture of the individuals.

Discuss the four critical incidents assigned to your group. Use the guidelines listed under each critical incident to begin the discussion. There is no need to limit your discussion to just the questions provided.

GROUP ROLES

Skeptic: Ask what other possibilities there are, keep the group from superficial analysis by not allowing the group to agree too quickly; ask questions that lead to a deeper analysis; agree when satisfied that the group has explored all possibilities.

Manager: Suggest a plan for discussing each incident and answering the questions; make sure everyone participates and stays on task; watch the time.

Checker/Recorder: Ask others to explain their reasoning process so it is clear to all that their suggestions can be discussed; paraphrase, write down, and edit your group's response to each incident.

TIME: 25 minutes

The *Checker/Recorder* will be asked to make the opening comments about **one** of the assigned case studies when we return to the larger group.

GROUP PRODUCT

Answer Sheets for assigned Case Studies.

Name : ________________________________

Case Study #1*

One of your physics students is a highly achieving undergraduate who is very bright, personable, and attractive. You enjoy working with this student, but are not otherwise interested in a relationship. Unexpectedly, the student leaves you a note, professing an interest in establishing a close relationship, along with a bouquet of flowers.

*Adapted from University-wide sexual harassment training

1. What are your responsibilities in this situation?
2. How can you maintain the kind of teaching relationship you want?

NOTES:

Name : ____

Case Study #2*

One day, as you are waiting for students to come in and settle down for your discussion session, you notice that one of the students enters wearing a T-shirt which is emblazoned with a sexually obscene and violent slogan. The student sits down as the bell rings for the class to begin. Just as you are about to begin your opening game, another student states loudly that he cannot sit in the class and attempt to learn if that T-shirt is allowed to stay there. The two students then engage in a shouting match.

*Taken from University-wide sexual harassment training

1. What are your responsibilities in this situation?
2. What are some possible solutions?

NOTES:

Name : ________________________________

Case Study #3

You are discussing with your class the physics of sound, specifically why longer musical instruments make deeper sounds. To provide a quick demonstration, you have one male student and then one female student stand up and say "oooh." After the session, the female student goes to the professor and says that she felt singled out since she is the only woman in the class. Further, she was upset and embarrassed since saying "oooh" loudly in a room full of men seemed to her to be too sexual a thing to do.

1. What could you have done to prevent the situation?
2. What could you do to resolve the situation?
3. What could your professor have done to prevent the situation?
4. What could the professor do to resolve the situation?

NOTES:

Name : ______________________________

Case Study #4

Jose, a student in your section, is in a wheelchair. His brother Pedro is in the same section, and is very protective of Jose. (Pedro registered for all the same classes as Jose on purpose so that he can help him out.) The brothers want to be in the same group, but you want to have diverse groups so that students can get to know one another. However, because of Jose's disability you give in to the brothers and put them in a group with two other people. When there is a group test problem, the brothers surprise you by speaking Spanish to one another. You ask them to speak English so that everyone in the group can understand. They tell you that they don't think they read English as well as other people in the class and are just talking to each other in Spanish to be sure that they understand the quiz problem.

1. What could you have done to prevent the situation?
2. What can you do to resolve the situation?

NOTES:

Name : ______________________________________

Case Study #5

You are a relaxed TA, often chatting and laughing with students in your section before you start class. One day before lab, you discover that you share an interest in racquetball with one of your students and you make an appointment to play. Soon you are meeting every Wednesday at lunch for a racquetball game with this student and becoming friends. The other students in your section know about this and are upset about it. You think it's no big deal, since it's not as though you are romantically involved with your student.

1. What are your responsibilities in this situation?
2. What can you do to resolve the situation?

NOTES:

Name : ____

Case Study #6

Early in the spring semester, one of your fellow team members stops by your lab section and starts chatting and visiting with one of your students during the lab. It is soon obvious that the two are in a relationship. After lab, you find out that this student was in the TA's lab last term.

1. What are your responsibilities in this situation?
2. What can you do to resolve the situation?

NOTES:

Case Study #7*

Abdelkader, Mohammed and Naji, students from the same country, are close to completing their first semester at the University. When they first met at the new student orientation program and discovered they were all in the same engineering department, they arranged their schedules so they could take most of their classes together. Every day before their physics class they met to study each other's notes and to discuss the assigned reading and homework they had done the night before.

Their physics professor noticed that the three students made nearly the same errors in the first exam of the semester. At the time, he assumed it was because they were from the same educational background. However, when he noticed that all three students had exactly the same problems incorrect on their second test, he decided they had to be cheating. The professor called the students into his office and explained that this type of behavior was unacceptable. He told them that he was going to call the foreign-student advisor to see what action could be taken because of their cheating.

*Adapted from Florence A. Funk's "Intercultural Critical Incidents"

1. What happened? (Describe the situation.)
2. Why? (Give causes/interpretation of the situation.)
3. Alternatives/Solutions:
   a. What could have been done to prevent the situation?
   b. What can be done to resolve the situation?

NOTES:

 Name : ________________________________

Case Study #8*

Chong, a new international student at the University of Minnesota, arrived on campus two weeks before classes began so he could find housing, register for classes and become familiar with the St. Paul-Minneapolis area. During this two week period everything went well. He found an apartment to share with a U.S. student from his department, was able to register for all the classes he needed, and made the acquaintance of a few other students. Once classes began Chong discovered that he was thrilled with the discussion that took place between the students and professors in his classes, he enjoyed the company of his roommate's friends and he enjoyed the easy access to movies, shopping, and fast food establishments.

About three weeks into the term, Chong began to find the endless classroom discussions a waste of time. He was frustrated with the ridiculous antics of his roommate's friends and it seemed that everything he needed cost too much. He found that he was now seeking the company of his countrymen and that their discussions most often centered on how "screwed-up" everything was in the States. He ate lunch in a local ethnic restaurant and avoided contact with students from the U.S. unless it was required to fulfill classroom assignments.

*Taken from Florence A. Funk's "Intercultural Critical Incidents"

1. What happened? (Describe the situation.)
2. Why? (Give causes/interpretation of the situation.)
3. Alternatives/Solutions:
    a. What could have been done to prevent the situation?
    b. What can be done to resolve the situation?

NOTES:

Name : ______________________________

Case Study #9

Boris is a first year physics graduate student from Russia. Although he speaks English with a heavy accent, he is fluent and is given his own discussion and lab sections to teach. After a few weeks he becomes puzzled by his students' behavior. Even though he can tell from their test scores that they are confused about physics, they never ask questions or come to his office hours. They come to class late and have to be asked two or three times before they will respond when he asks them to go to the board. Boris comes to you and asks what he should do.

1. What happened? (Describe the situation.)
2. Why? (Give causes/interpretation of the situation.)
3. Alternatives/Solutions:
   a. What could have been done to prevent the situation?
   b. What can you do to help resolve the situation?

NOTES:

Name : ________________________________

Case Study #10

Mary was having some difficulty in one of her 5000-level physics classes. She had trouble with the homework assignments and then scored below the median on the first two exams. About halfway through the term, Mary went to see the professor to ask him for help. He told Mary that she should really be ashamed at her performance in the class and that she would probably fail. He refused to help her and told her that she should drop out of school, since it was unlikely that she would ever be a physicist. After meeting with him, the student was so upset that she went to the top of a tall building and considered killing herself.

1. What happened? (Describe the situation.)
2. Why? (Give causes/interpretation of the situation.)
3. Alternatives/Solutions:
    a. What could Mary have done to prevent the situation?
    b. What can Mary do to resolve the situation?
    c. What could the professor have done to prevent the situation?
    d. What could you (as one of Mary's classmates) do to prevent or resolve the situation?

NOTES:

Name : ______________________________

Case Study #11

In one of her sections Susan had a male student, Joe, who was very self-assured. During her office hours, he often sat very close to her and put his arm around the back of her chair. One day in lab, as Susan helped a group at the next table, Joe reached behind him and stroked her leg. She said, "Don't do that," and asked to speak to him after class. When the other students had gone, Susan said, "I don't know what you thought you were doing when you touched my leg in class." Joe said that it had been an accident, and Susan ended the conversation. Immediately after that, she went to see the lecturer for Joe's class and told him the whole story. The professor laughed.

1. What happened? (Describe the situation.)
2. Why? (Give causes/interpretation of the situation.)
3. Alternatives/Solutions
   a. What could the TA (Susan) have done to prevent the situation?
   b. What could Susan do to resolve the situation?
   c. What could the professor have done to prevent the situation?
   d. What could the professor do to resolve the situation?

Name : ______________________________

Homework

Homework #1: Analyzing Students' Alternative Conceptions

Part A. Analyzing Force Concept Inventory Questions:

The top of each attached page shows a question from the Force Concept Inventory. The "Pre" and "Post" columns show the percentage of students in the calculus-based course that selected each of the possible answers on the pretest (given at the beginning of the term) and the posttest (at the end of ten weeks of instruction).

For each question:

a. Describe briefly how a student might be thinking who selected each incorrect answer. (Hint: Review the alternative conceptions from the McDermott and Wandersee et. al., articles.)

b. Which of the possible "alternative conceptions" were successfully addressed by instruction? Which were not?

1.

Question 30

Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands on her opponent's court.

Consider the following forces:

1. A downward force of gravity.
2. A force by the "hit".
3. A force exerted by the air.

Which following force(s) is (are) acting on the tennis ball after it has left contact with the racquet and before it touches the ground?

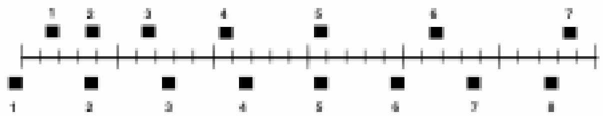
	Pre	Post
(A) 1 only	2	10
(B) 1 and 2	4	7
(C) 1 and 3	18	46
(D) 2 and	3	11
(E) 1, 2, and 3	75	36

a. Describe briefly how a student might be thinking who gives each incorrect answer.

b. Which of these "alternative conceptions" were successfully addressed by instruction? Which were not?

2.

Question 19



Do the blocks ever have the same speed?

	Pre	Post
(A) No.1	6	8
(B) Yes, at instant 2.	4	2
(C) Yes, at instant 5.	9	6
(D) Yes at instant 2 and 5.	20	20
(E) Yes at some time during interval 3 to 4.	51	65

a. Describe briefly how a student might be thinking who gives each incorrect answer.

b. Which of these “alternative conceptions” were successfully addressed by instruction? Which were not?

3.

Question 4

A large truck collides head-on with a small compact car. *<u>During the collision,</u>*

		Pre	Post
(A)	the truck exerts a greater amount of force on the car than the car exerts on the truck	79	46
(B)	the car exerts a greater amount of force on the truck than the truck exerts on the car.	2	1
(C)	neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.	0	0
(D)	the truck exerts a force on the car, but the car doesn't exert a force on the truck.	0	0
(E)	the truck exerts the same amount of force on the car as the car exerts on the truck.	19	53

6

a. Describe briefly how a student might be thinking who gives each incorrect answer.

b. Which of these "alternative conceptions" were successfully addressed by instruction? Which were not?

Part B. Analyzing Open-Ended Questions:

The attached sheets contain student responses to two open-ended questions given to students in the calculus-based course as a **posttest** (after ten weeks of instruction).

1. First read through the responses of Students #1, #2 and #3. These students wrote fairly good and complete answers to the questions.

2. Now read through the remainder of the student answers.
   - What is one thing that surprised you about these responses? Why?
   - What is one thing that did not surprise you? Why?

3. Read through the responses again, and answer the first three questions on the next page.

4. Imagine you were tutoring the student assigned to your group. What example situation, reference to a common experience students are likely to have, or set of questions do you think might help move the student away from their alternative conception(s)? Discuss.

Answer Sheet

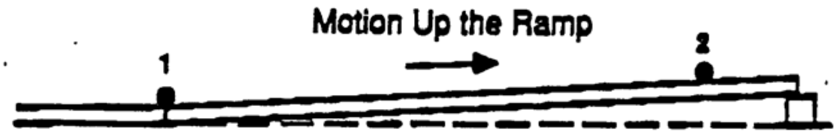
1. What conceptual difficulties do Students #4, #5 and #6 have with the concept of acceleration? (Hint: You may want to look at the McDermott article, page 27).

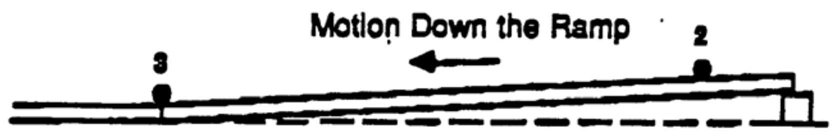
2. Which students' responses to the passenger/car questions indicate a **forward** force on the passenger or car which is a "pseudo-force" or non-Newtonian force (i.e., not caused by the interaction of the passenger or car with real objects). What might these students be thinking to indicate these non-Newtonian forces? What is your evidence?

3. Which students' responses to the passenger/car questions indicate a **backward** force on the passenger or car which is a "pseudo-force" or non-Newtonian force (i.e., not caused by the interaction of the passenger or car with real objects). What might these students be thinking to indicate these non-Newtonian forces? What is your evidence?

4. What example situation, reference to a common experience students are likely to have, or set of questions do you think might help move Student # ____ away from their alternative conception(s)?

The following questions are for course evaluation purposes only and will not be graded. They will help us evaluate how well we met your learning needs this course.





1. A steel ball is launched with some initial velocity, slows down as it travels up a gentle incline, reverses direction, and then speeds up as it returns to its starting point. Assume friction is negligible.

(a) Suppose we calculated the acceleration of the ball as it's moving *up* the ramp (from 1 to 2), and the acceleration as it's moving *down* the ramp (from 2 to 3). How would these two accelerations compare? (i.e., Are the accelerations the same size? The same direction?) Explain your reasoning.

The acceleration of the ball as it moves up the ramp would be an acceleration of the same direction as it moved down the ramp. They would also be of the same size, because the slope of the ramp is constant throughout the event.

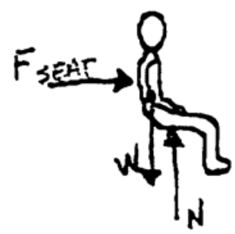
(b) Does the ball have an acceleration at it's highest point on the incline (at position 2)? Explain your reasoning.

Yes, at its highest point the acceleration is still the same as before, the velocity however is 0.

Student #1

3. You are a passenger in a car which is traveling on a straight road while it is increasing speed from 30 mph to 55 mph. You wonder what forces cause you and the car to accelerate. When you pull over to eat, you decide to figure it out.

(a) On the left side of the table below, draw and label arrows representing all the forces acting on *you* (passenger) while the car is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

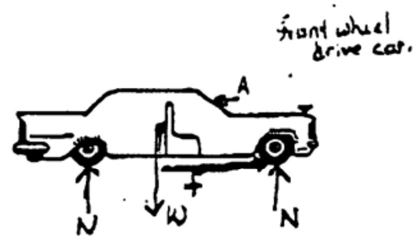
You (Passenger)	Description of Each Force
	F_{SEAT} = FORCE OF THE SEAT PUSHING YOU AS THE CAR ACCELERATES. PUSH W = GRAVITATIONAL FORCE OF EARTH ON YOU. PULL N = NORMAL FORCE OF SEAT PUSHING ON YOU.

(b) Which force(s) cause you (passenger) to accelerate? Explain your reasoning.

F_{SEAT} CAUSES YOU TO ACCELERATE BECAUSE IT IS NOT COUNTERACTED BY ANY OTHER FORCES.

Student #2

(c) On the left side of the table below, draw and label arrows representing all the forces acting on the *car* while it is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

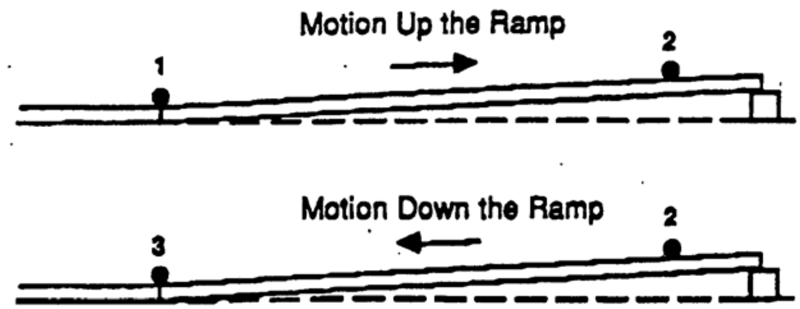
Car	Description of Each Force
	W = the gravitational pull of the earth on the car N = the support force of the road on the car, distributed evenly on all four tires. A = the drag force of the air on the car as it moves forward. f = the frictional force of the road on the tires causing forward motion.

(d) Which force(s) cause the car to accelerate? Explain your reasoning.

The frictional force of the road on the tires causes the car to accelerate. The tires are moving in that direction and if there where no friction, they would just spin. Since there is friction between the road and tires it acts in → this direction causing the car to move forward. This is static friction.

Student #3

The following questions are for course evaluation purposes only and will not be graded. They will help us evaluate how well we met your learning needs this course.



1. A steel ball is launched with some initial velocity, slows down as it travels up a gentle incline, reverses direction, and then speeds up as it returns to its starting point. Assume friction is negligible.

(a) Suppose we calculated the acceleration of the ball as it's moving *up* the ramp (from 1 to 2), and the acceleration as it's moving *down* the ramp (from 2 to 3). How would these two accelerations compare? (i.e., Are the accelerations the same size? The same direction?) Explain your reasoning.

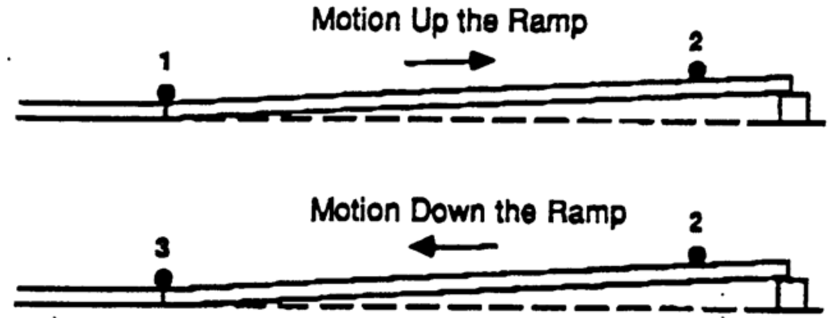
The acceleration of the ball from 2 to 3 would be larger than the acceleration of the ball from 1 to 2 because it takes more work for the ball to go up the ramp than to go down th ramp. The accelerations would be in the same direction.

(b) Does the ball have an acceleration at it's highest point on the incline (at position 2)? Explain your reasoning.

No it does not, it must stop, at least for a second, so it can reverse its direction.

Student #4

The following questions are for course evaluation purposes only and will not be graded. They will help us evaluate how well we met your learning needs this course.



1. **A steel ball is launched with some initial velocity, slows down as it travels up a gentle incline, reverses direction, and then speeds up as it returns to its starting point. Assume friction is negligible.**

(a) Suppose we calculated the acceleration of the ball as it's moving *up* the ramp (from 1 to 2), and the acceleration as it's moving *down* the ramp (from 2 to 3). How would these two accelerations compare? (i.e., Are the accelerations the same size? The same direction?) Explain your reasoning.

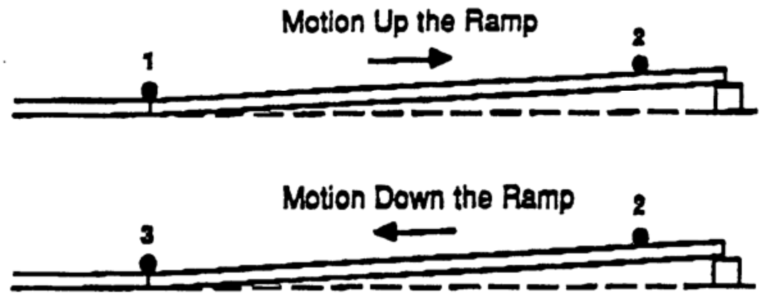
The accelerations are in opposite directions. One is positive by going down the ramp and gaining speed, but the other is negative by going up the ramp and then slowing down.

(b) Does the ball have an acceleration at it's highest point on the incline (at position 2)? Explain your reasoning.

At the point the ball turns around, there will be no acceleration since at this point v=0. The acceleration will start once again as the ball starts moving down the incline

Student # 5

The following questions are for course evaluation purposes only and will not be graded. They will help us evaluate how well we met your learning needs this course.



1. A steel ball is launched with some initial velocity, slows down as it travels up a gentle incline, reverses direction, and then speeds up as it returns to its starting point. Assume friction is negligible.

(a) Suppose we calculated the acceleration of the ball as it's moving *up* the ramp (from 1 to 2), and the acceleration as it's moving *down* the ramp (from 2 to 3). How would these two accelerations compare? (i.e., Are the accelerations the same size? The same direction?) Explain your reasoning.

To compare the two accelerations we would find the magnitudes to be approximately the same, to give the acceleration direction you must consider which way the motion is in relation to acceleration. So from one to two there is a negative acceleration because the acceleration is in the opposite direction of motion. From two to three acceleration is positive because it is the same direction as the motion.

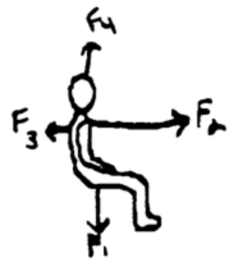
(b) Does the ball have an acceleration at it's highest point on the incline (at position 2)? Explain your reasoning.

The magnitude of the ball at point 2 is zero. With the ball at this point, the direction of motion is changing so acceleration doesn't exist at that instantaneous position.

Student # 6

3. You are a passenger in a car which is traveling on a straight road while it is increasing speed from 30 mph to 55 mph. You wonder what forces cause you and the car to accelerate. When you pull over to eat, you decide to figure it out.

(a) On the left side of the table below, draw and label arrows representing all the forces acting on *you* (passenger) while the car is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

You (Passenger)	Description of Each Force
	F_1 = force of gravity by earth (Pull) F_2 = force from accoloration of car (Pull) F_3 = force of inertia pulling back F_4 = Normal force from seat (Push)

(b) Which force(s) cause you (passenger) to accelerate? Explain your reasoning.

The force from the car causes you to accelorate, becase it is loger than the iertial force

Student # 7

3. You are a passenger in a car which is traveling on a straight road while it is increasing speed from 30 mph to 55 mph. You wonder what forces cause you and the car to accelerate. When you pull over to eat, you decide to figure it out.

(a) On the left side of the table below, draw and label arrows representing all the forces acting on *you* (passenger) while the car is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

You (Passenger)	Description of Each Force
	The push force from the back of the car seat is equal to the push force from your back while the car accelerates. The the force of gravity pulls is equal to the normal force of the seat bottom pushing up on you

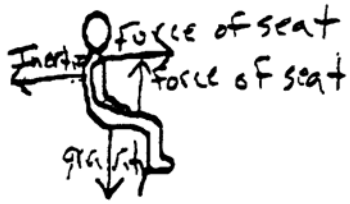
(b) Which force(s) cause you (passenger) to accelerate? Explain your reasoning.

The force of the car seat pushing you along with the car.

Student #8

3. You are a passenger in a car which is traveling on a straight road while it is increasing speed from 30 mph to 55 mph. You wonder what forces cause you and the car to accelerate. When you pull over to eat, you decide to figure it out.

(a) On the left side of the table below, draw and label arrows representing all the forces acting on *you* (passenger) while the car is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

You (Passenger)	Description of Each Force
	Inertia - the car is accelerating forward, but your body wants to stay in its original position, and you are pushed into the seat. Gravity - gravity pushes you into the seat and holds you in the car Force of seat - seat pushing back on you as you try to resist motion

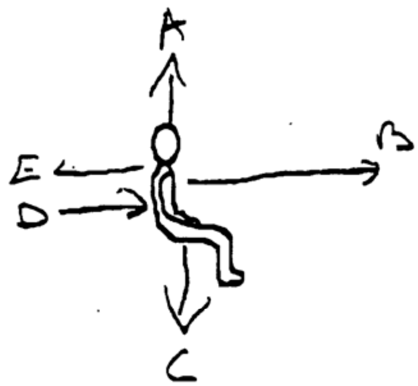
(b) Which force(s) cause you (passenger) to accelerate? Explain your reasoning.

The force of the seat propels you forward
The force of the accelerating car is transferred to the seat, which is part of the car

Student # 9

3. You are a passenger in a car which is traveling on a straight road while it is increasing speed from 30 mph to 55 mph. You wonder what forces cause you and the car to accelerate. When you pull over to eat, you decide to figure it out.

(a) On the left side of the table below, draw and label arrows representing all the forces acting on *you* (passenger) while the car is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

You (Passenger)	Description of Each Force
	A: force of earth on seat B: Force of the engine C. Force of gravity D. Force of seat E. Force you exert on seat

(b) Which force(s) cause you (passenger) to accelerate? Explain your reasoning.

E, D, A, C they keep you in the seat

Student #10

3. You are a passenger in a car which is traveling on a straight road while it is increasing speed from 30 mph to 55 mph. You wonder what forces cause you and the car to accelerate. When you pull over to eat, you decide to figure it out.

(a) On the left side of the table below, draw and label arrows representing all the forces acting on *you* (passenger) while the car is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

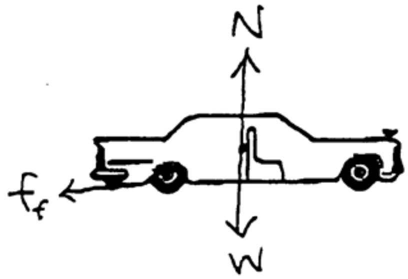
You (Passenger)	Description of Each Force
	F_g = force of gravity F_N = Normal force F_R = Force of resistance (inertia) F_F = Force Forward from engine.

(b) Which force(s) cause you (passenger) to accelerate? Explain your reasoning.

F_f ⇒ the force of the engine, transmitted via the car.

Student #11

(c) On the left side of the table below, draw and label arrows representing all the forces acting on the *car* while it is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

Car	Description of Each Force
	N= normal force f_f= frictional force between road + tire. W= gravitational pull of earth on the car.

(d) Which force(s) cause the car to accelerate? Explain your reasoning.

The frictional force and gravitational pull cause the car to accelerate. The frictional force between the tires and the road allow the car to move forward and accelerate.

Student #12

(c) On the left side of the table below, draw and label arrows representing all the forces acting on the *car* while it is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

Car	Description of Each Force
	FF - the force of friction the car & the road exert. F - the force caused by the cars mass and acceleration

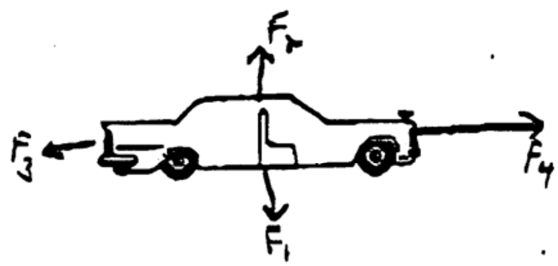
(d) Which force(s) cause the car to accelerate? Explain your reasoning.

The force of motion causes the car to accelerate

Because of the force of motion & the mass of the car, it accelerates.

Student #13

(c) On the left side of the table below, draw and label arrows representing all the forces acting on the *car* while it is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

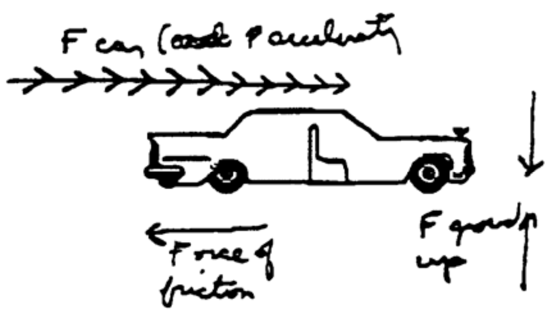
Car	Description of Each Force
 	F_1 = Force of gravity from earth (Pull) F_2 = Normal force from road (Push) F_3 = Force of friction from road + tires (Pull) F_4 = accelerating force from car's motor (Pull)

(d) Which force(s) cause the car to accelerate? Explain your reasoning.

The force from the motor because it exceeds the force of friction.

Student #14

(c) On the left side of the table below, draw and label arrows representing all the forces acting on the *car* while it is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

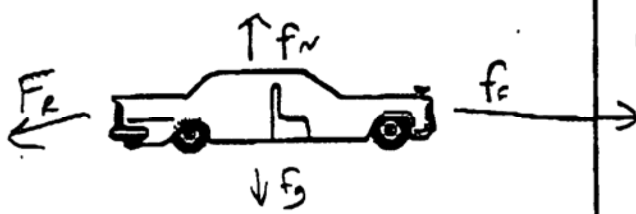
Car	Description of Each Force
	The force of car increase as the car accelerate. F car down = F ground up Force of friction = F ground up but act against F(car) accelerating.

(d) Which force(s) cause the car to accelerate? Explain your reasoning.

Force of friction + F car down + F ground up (normal force) all helps the car to accelerate because the F of friction acts in the opposite direction which gives the car a means of accelerating.

Student #15

(c) On the left side of the table below, draw and label arrows representing all the forces acting on the *car* while it is accelerating. The length of the arrows should indicate the relative sizes of the forces (i.e., a larger force should be represented by a clearly longer arrow, equal forces by arrows of equal length). On the right side of the table, describe each force in words (i.e., What kind of force is it? Is the force a push or a pull? What object, if any, is exerting the force? What object is being affected by the force?).

Car	Description of Each Force
	F_N ⇒ normal, opposite to F_g F_g ⇒ force of gravity F_f ⇒ force forward from engine F_R ⇒ force of resistance (air, friction)

(d) Which force(s) cause the car to accelerate? Explain your reasoning.

F_f, force forward no other choice.

Student #16

Homework #3: Solving Problems Using Your Problem Solving Framework

Note: Before you do this homework, complete the reading assignments:

Competent Problem Solver. Read/skim the brief descriptions and examples:

- Pictures and motion diagrams: pages 1-4 to 1-5; pages 1-8 to1-9; pages 2-4 and 2-12; pages 2-6 and 2-14; and pages 3-6 to 3-13 (17 pages)
- Free-body and force diagrams: pages 4-1 through 421 (21 pages)

Instructor's Handbook. Teaching a Discussion Session

- Overview of Teaching a Discussion Section (2 pages)
- Outline for Teaching Discussion Sessions (1 page)
- Detailed Advice for Teaching Discussion Sessions (4.5 pages)
- Some Teaching Tools

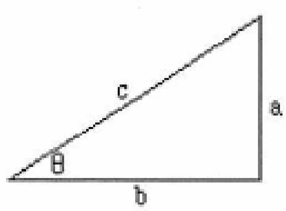
Imagine that you have been asked by your professor to write solutions for the five discussion session problems on the following pages. The solutions will be photocopied and passed out to all the students in the course at the end of each discussion session.

Solve each problem **by following the problem-solving framework** you designed in TA Orientation last Friday. Write your solutions on the answer sheets that you designed. Be sure to include motion diagrams and/or both free-body and force diagrams. Use the agent-object notation for the forces (in *Readings*, Hughes, 2002).

You can use only the fundamental concepts and equations for special conditions that your students would know at the time you give them each problem to solve. You would write these equations on the board (or they would be included with the problem) before your groups started solving the problem. Imagine also that you want to model solving problems based on *principles and concepts,* instead of the memorized plug-and-chug or pattern-matching "formulas." So you decide to limit the kinematics equations to three, independent equations.

You may find the following information useful in solving the problems.

Useful Mathematical Relationships:



For a right triangle: $\sin\theta = \frac{a}{c}$, $\cos\theta = \frac{b}{c}$, $\tan\theta = \frac{a}{b}$,

$a^2 + b^2 = c^2$, $\sin^2\theta + \cos^2\theta = 1$, $\sin 2\theta = 2\sin\theta\cos\theta$

For a circle: $C = 2\pi R$, $A = \pi R^2$

For a sphere: $A = 4\pi R^2$, $V = \frac{4}{3}\pi R^3$

If $Ax^2 + Bx + C = 0$, then $x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$

Useful constants: 1 mile = 5280 ft, 1km = 5/8 mile, $g = 9.8\ m/s^2 = 32\ ft/s^2$

1. **Runner Problem.** Chris and Alex are practicing for their next competition race. Chris runs at a constant speed of 3 meters/second down a long straight road. After 5 minutes, Alex starts from the same place and runs at a faster constant speed of 4 meters/second. How far from the starting point will the runners be when Alex catches up to Ken?

   Remember to use only the equation shown below.

   Fundamental Concept: $v_{x\ av} = \dfrac{\Delta x}{\Delta t} = \dfrac{x_f - x_o}{t_f - t_o}$

2. **Traffic Accident Problem:** You have a summer job with an insurance company and are helping to investigate a tragic "accident." At the scene, you see a road running straight down a hill that is at 10° to the horizontal. At the bottom of the hill, the road widens into a small, level parking lot overlooking a cliff. The cliff has a vertical drop of 400 feet to the horizontal ground below where a car is wrecked 30 feet from the base of the cliff. A witness claims that the car was parked on the hill and began coasting down the road, taking about 3 seconds to get down the hill. Your boss drops a stone from the edge of the cliff and, from the sound of it hitting the ground below, determines that it takes 5.0 seconds to fall to the bottom. You are told to calculate the car's average acceleration coming down the hill based on the statement of the witness and the other facts in the case. Obviously, your boss suspects foul play.

   Remember to use only the equations shown below.

   Fundamental Concepts: $v_{x\ av} = \dfrac{\Delta x}{\Delta t} = \dfrac{x_f - x_o}{t_f - t_o}$ $\quad a_{x\ av} = \dfrac{\Delta v_x}{\Delta t} = \dfrac{v_{xf} - v_{xo}}{t_f - t_o}$

   Under Certain Conditions: $x_f = \dfrac{1}{2}a_x(\Delta t)^2 + v_{xo}(\Delta t) + x_o$

3. **Ice Skating Problem:** You are taking care of two small children, Sarah and Rachel, who are twins. On a nice cold, clear day, you decide to take them ice skating on Lake of the Isles. To travel across the frozen lake you have Sarah hold your hand and Rachel's hand. The three of you form a straight line as you skate, and the two children just glide. Sarah must reach up at an angle of 60 degrees to grasp your hand, but she grabs Rachel's hand horizontally. Since the children are twins, they are the same height and the same weight, 50 lbs. To get started you accelerate at 2.0 m/s^2. You are concerned that the force on the children's arms might cause shoulder damage. So you calculate the force Sarah exerts on Rachel's arm, and the force you exert on Sarah's other arm. You assume that the frictional forces of the ice surface on the skates are negligible.

   Remember to use only the equations shown at the top of the next page.

Fundamental Concepts:

$$v_{x\ av} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_o}{t_f - t_o} \qquad a_{x\ av} = \frac{\Delta v_x}{\Delta t} = \frac{v_{xf} - v_{xo}}{t_f - t_o}$$

$$\sum F_x = ma_x \qquad F_{12} = F_{21}$$

Under Certain Conditions:

$$x_f = \frac{1}{2}a_x(\Delta t)^2 + v_{xo}(\Delta t) + x_o \qquad F = mg \qquad F = \mu_{sliding}N \qquad F \le \mu_{static}N$$

4. A 20-Kg block is pulled along a horizontal table by a light cord that extends horizontally from the block over a pulley attached to the end of the table, and then down to a hanging 10-Kg block. The coefficient of static friction between the 20-Kg block and the table surface is 0.80, and the coefficient of kinetic friction is 0.40. Determine the speed of the blocks after moving 2 meters. They start at rest.

   Remember to use only the equations shown at the top of this page.

5. You have taken a summer job at a warehouse and have designed a method to help get heavy packages up a 15° ramp. A package is attached to a thin cable that runs parallel to the ramp and over a pulley at the top of the ramp. After passing over the pulley, the other end of the cable is attached to a counterweight that hangs straight down. In your design, the mass of the counterweight is always adjusted to be twice the mass of the package, so the packages will accelerate up the ramp. Your boss is worried that the thin cable will break, so she asks you to calculate the tension in the cable for the maximum mass of a package, 50 kg. You run some tests and determine that the coefficient of kinetic friction for a package on the ramp is 0.51, and the coefficient of static friction is 0.85.

   Remember to use only the equations shown at the top of this page.

Initial Evaluation of Example Student Laboratory Reports

Before you start this homework, read the article by S. Allie, A. Buffler, L. Kunda, and M. Inglis, Writing Intensive Physics Laboratory Reports: Tasks and Assessment (Selected Readings). In this homework you will you will go through 2 examples of student laboratory reports and evaluate their quality.

Homework Tasks:

1. Come up with words and characteristics that describe what you consider to be "good" and "bad" writing.

2. Using the descriptions that you came up with in step 1, evaluate the following 2 example student laboratory reports.

3. Mark down any and all comments on the example student laboratory reports, and indicate whether it is "good" or "bad" based on your description.

Note: This homework is to elicit your initial ideas on how to evaluate student laboratory reports. In class we will discuss, model, and coach grading lab reports.

Defining "Good" & "Bad" Writing

What words or characteristics come to mind when trying to define "good" writing?

What words or characteristics come to mind when trying to define "bad" writing?

Example #1

Lab Report 2 – Lab 3, Problem 1

Statement of the problem:

I am a volunteer in the city's children's summer program. One suggested activity is for the children to build and race model cars along a level surface. To ensure that each car has a fair start, my co-worker recommends a special launcher be built. The launcher uses a string attached to the car at one end and, after passing over a pulley, the other end of the string is tied to a block hanging straight down. The car starts from rest and the block is allowed to fall, launching the car along the track. After the block hits the ground, the string no longer exerts a force on the car and the car continues moving along the track. I want to know how the launch speed of the car depends on the parameters of the system that you can adjust. I decide to calculate how the launch velocity of the car depends on the mass of the car, the mass of the block, and the distance the block falls. My ultimate goal was to find the answer to the question – "What is the velocity of the car after being pulled for a known distance?"

Prediction:

I predicted that, using the equation $V=\sqrt{(2M_agh)/(M_a+M_c)}$

and with the data collected during setup, that the velocity at the time the block hit the floor would be 60.5cm/s. (Prediction graphs are attached.)

Procedure:

First, we gathered supplies. We used a cart, a flat track with a pulley attached, a mass hanger with a mass set to simulate the wooden block, string, and a video camera attached to a computer with video analysis software. We massed the cart and the block, and began to set up the experiment. We placed the cart on the track, and ran the string through the pulley. We hooked our mass onto the end of the string, and held it to a height that we measured and marked. We began recording video and let the mass go. We made 3 runs like this to obtain the best video. When we were satisfied we analyzed the video and came up with a good measurement of the cart's velocity. We printed our graphs and made conclusions based on our data.

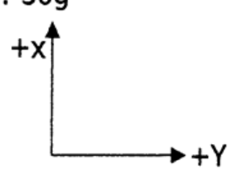
Data and Results:

Mass of Cart (Mc): 753.8g

Mass of Block (Ma): 50g

Height (H): 30cm

Coordinate Axis:



(Graphs of data analysis are attached)

Discussion:

The results from the lab were pretty close to the prediction made by plugging the masses of the cart and block and the height of the drop into the equation I wrote in my lab journal.

In the lab, there were a few sources of obvious error. The first major source was the method of getting data. The computer software is a bit inaccurate in measuring the velocity with the method of selecting points in the video frames. The camera we used has a curved lens, which distorts the video. This all leads to data that is off from the expected return. Another possible source of error is the equipment. The set-up we used was not entirely perfect in the fact that we were not taking friction into account, yet there was most likely friction in the cart's wheels. This would matter most during the time after the block has hit the ground, which is the situation we are modeling.

We could have made a few improvements. The main improvement would be to more accurately analyze the data within the computer software to compensate for any distortion in the video. We also could have made sure the cart was properly lubricated before performing the experiment.

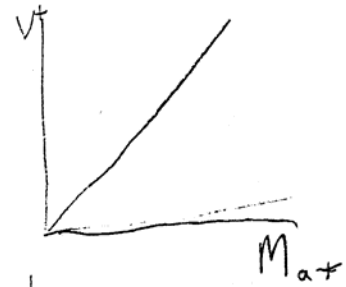
Conclusions:

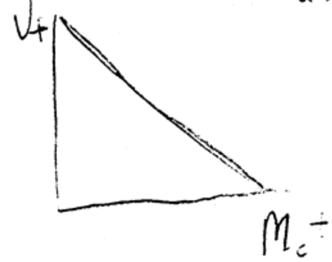
In our lab, we discovered the velocity of the car after being pulled a known distance was around 55cm/s. This was close to our initial prediction, so we were satisfied with our results.

The launch velocity of the car does depend on its mass, as well as the mass of the block and the distance the block falls. This is due to the fact that they all affect the forces acting on the car. There are some instances where the mass would not really affect the launch velocity. If the distance dropped were very close to zero, the launch velocity would be near zero no matter what the mass of the block was.

If the same block falls the same distance, the force exerted by the block on the cart would not change, no matter the mass of the cart. The force of the block on the cart is always equal to the block's weight.

Prediction graphs

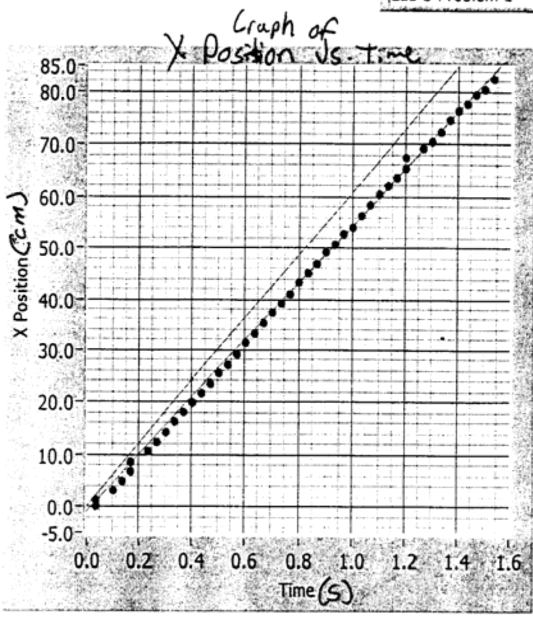


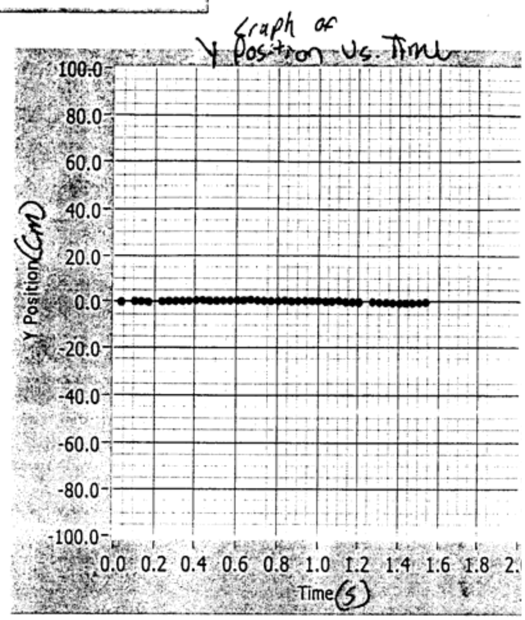


7

Graph Title

Lab 3 Problem 1





X - Prediction Equation

u(t) = 0.000 + 60.500t

X - Fit Equation

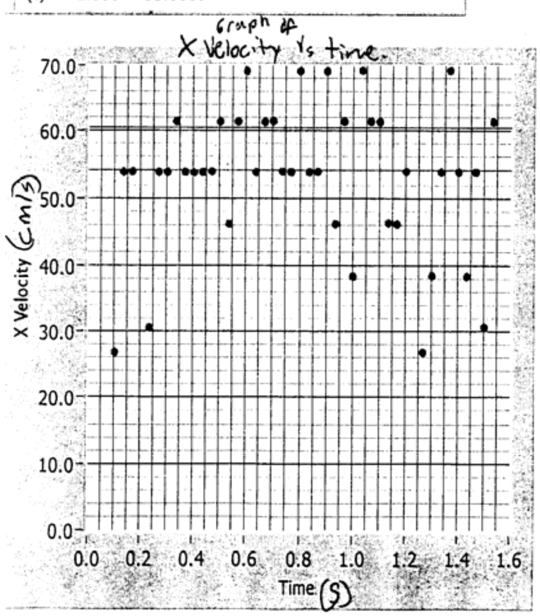
u(t) = -1.000 + 55.000t

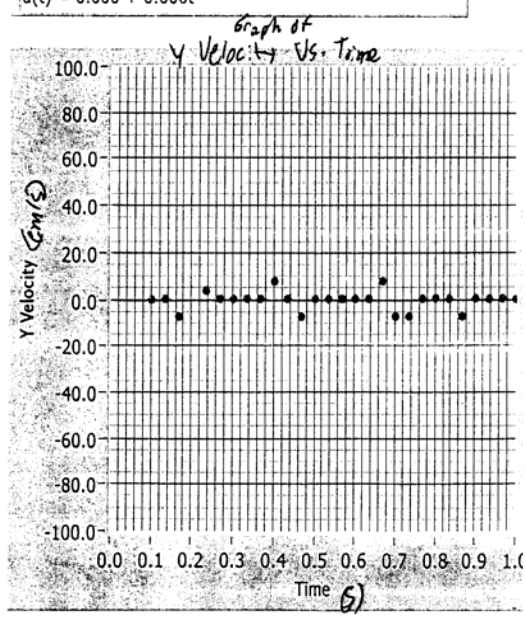
Y - Prediction Equation

u(t) = 0.000 + 0.000t

Y - Fit Equation

u(t) = 0.000 + 0.000t





Vx - Prediction Equation

u(t) = 60.500 + 0.000t

Vx - Fit Equation

u(t) = 54.000 + 0.000t

Vy - Prediction Equation

u(t) = 0.000 + 0.000t

Vy - Fit Equation

u(t) = 0.000 + 0.000t

Example #2

uist
109
002

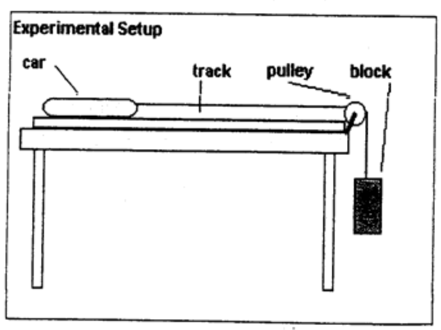
Lab III Problem 1: Force and Motion

1. Statement of the Problem -- According to the lab manual, my group members and I were asked to test the velocity of a toy car launched down a track. The car is attached to a string at the end of the track, which goes over a pulley and is then attached to a block. When the block is released, the string pulls the car down the track. After the block hits the ground, the car is no longer pulled but keeps going. We were asked to find how the cars speed after the block hits the ground depends on the mass of the car, the mass of the block, and the distance the block falls before hitting the ground. The question we answered in this lab is:

What is the velocity of the car after being pulled a known distance?

We used a toy car with a string attached to it, a block, a pulley, and a track to conduct our experiment. We recorded the motion of the car and the block using a video analysis application written in LabVIEW™, then analyzed the video to find the position, velocity and acceleration of the car while it was being pulled by the falling block and after the black reached the ground.

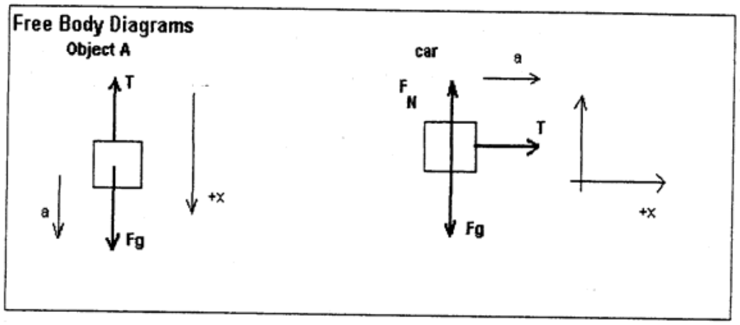
The block (called object A) has a significantly shorter distance to fall than the car has to travel along its track. In this experiment, we ignored the friction between the car and the track and between the pulley and the string. We also ignored the mass of the string.



2. Prediction --

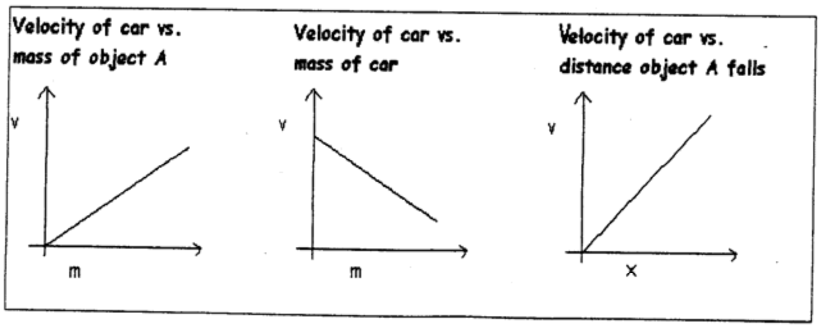
Variables	
x	position
xo	initial position
v	velocity
vo	initial velocity
a	acceleration
t	time
m	mass of object A
m	mass of car
F	Force
g	gravity
N	Normal Force
T	tension force

The first question asked me to calculate the cart's velocity after the block had hit the ground. I predicted that $\mathbf{v_c = \sqrt{2xg[m_a/(m_c + m_a)]}}$. I solved the first kinematics equation, $\mathbf{x_c = x_{0c} + v_{0c}t + 1/2at^2}$ **for t**, assuming that x_0 =O, v_0 =0 and $a_c = a_A$, and that the magnitude of the car's displacement was the same as the magnitude of the block's, (since the string did not stretch), yielding $\mathbf{t = 2x/a}$. Since v= at, $\mathbf{v = a\sqrt{(2x/a)}}$ and v^2 =2ax. Solving for a gives $\mathbf{a = v^2/2x}$.



Since the objects are attached to the same string, the tension forces acting upon them are equal to each other. The sum of the forces acting on Object A in the x direction is $\mathbf{\Sigma F_A = Fg - T}$. The sum of the forces acting on the car in the x direction is $\mathbf{\Sigma F_c = T}$. Since F= ma, $\mathbf{M_A a = M_A g - T}$ and $\mathbf{M_c a = T}$. Using $\mathbf{a = v^2/2x}$, $\mathbf{M_A(v^2/2x) = M_A g - T}$, and $\mathbf{M_c(v^2/2x) = T}$. Combining these equations gives $\mathbf{M_A(v^2/2x) = M_A g - M_c(v^2/2x)}$, and solving for v gives $\mathbf{v_c = \sqrt{2xg[m_a/(m_c + m_a)]}}$.

The next three prediction problems asked us to draw a graph of the car's velocity vs. time as a function of the mass of object A, mass of the car, and distance object A falls, respectively. The other two variables are kept constant in each graph.



The velocity would increase as the mass of object A or the distance object A falls increased, and would decrease as the mass of the car increased. The velocity would increase at a greater rate with the increase in distance than it would with the increase in mass of object A. Another way this could be said is that the graph of velocity vs. distance would have a greater slope than the graph of velocity vs. mass of object A.

3. Procedure – We set up the experiment according to the experimental setup picture above. The mass of the car we used was 252 g, and the mass of object A was 50 g. The distance form object A to the ground was 0.41m and the total distance the car was able to travel was 1m. There was 0.59m for the car to travel after object A hit the ground. We placed the camera about 1.5m away from the table holding the track so that the entire length of the track could be seen as well as object A. We recorded the car's motion and then analyze it in LabVIEW™. We divided the motion of the car into two parts -- motion before object A hit the ground and motion after object A hit the ground -- and analyzed each part separately. We predicted the equations for the position vs. time graphs, plotted data points of both the horizontal and vertical motion of the graphs, and then found the best-fit equations for them. We did the same for the car's velocities.

4. Data and Results – SEE ATTACHED GRAPHS

We predicted that there would be no motion, and hence no velocity, in the y direction for any of the graphs, and our prediction was correct.

Before object A hit the ground --When we predicted the equation for the x position vs. time of the car before object A hit the ground, we didn't really know what we were doing. We should have used the equation $x = x_0 + v_0t + 1/2at^2$ to make our prediction. The values for x_0 and v_0t would both have been equal to zero and we could have predicted the acceleration using $a = v^2/2x$: $(\sqrt{2xg[m_a/(m_c + m_a)]})^2/2x = [m_a/(m_c + m_a)]g = a$. This would have given us an acceleration of 1.49 m/s*s, and a predicted equation of $x = 0 + 0(t) + 0.75\text{m/s*s}(t^2)$. The value of 0.897 m/s*s in the best-fit equation is reasonably close to this. Since the slope of a velocity vs. time graph is equal to the acceleration and since 0.897 m/s*s was equal to ½ a, we predicted that the slope of the acceleration vs. time graph would be equal to 1.80 m/s*s, and our prediction fit the actual value of 1.70 m/s*s well.

After object A hit the ground—We predicted that the car would have zero acceleration during this portion of its motion and that its velocity would be equal to its final velocity, just as object A hit the ground. Again, we used the equation $x = x_0 + v_0t +$

$1/2at^2$ to describe the predicted motion, with x_0 and a both equal to zero. We predicted the velocity to be $v=\sqrt{2xg[m_a/(m_c+m_a)]}$, or 1.167m/s. This prediction was very close to the actual value. We predicted that for the velocity vs. time graph, the velocity would stay constant at 0.167m/s, and our prediction was very close to the actual best-fit line equation.

5. Discussion--

Results- The acceleration of the car in the experiment is dependant on the block falling. Before the block hits the ground, the car accelerates because of the falling block. The acceleration of the block and the car is the same because the same tension force acts them upon. Their accelerations are equal to $[m_a/(m_c+m_a)]g$, where m_a is the mass of object a (the block), m_c is the mass of the car, and g is the acceleration due to gravity, 9.8m/s*s. The velocity of the car and of object a at the time when object a hits the ground is equal to $\sqrt{2xg[m_a/(m_c+m_a)]}$.

After the block hit the ground there would no longer be any tension in the string and the sum of the forces on the car would be equal, (since T=0 and $F_g=-F_N$). Because F=ma, the car would have no acceleration. Its velocity would continue to be equal to $\sqrt{2xg[m_a/(m_c+m_a)]}$.

Error- Error resulted from our collection of data points again. It is difficult to click on exactly the same point of the car each time and to click on the same y value along the track each time as well. This results in distortion of the position measurements and velocities calculated. There is not much that can be done about this, except that we should try to be very precise in future collection of data points. Also, the camera could have caused a slight distortion of the collected data values. In this experiment, we neglected the friction between the car and the track and between the pulley and the string. This made the calculations a lot easier, but it caused our predicted value for the acceleration of the car and the block to be different than the actual value.

Improvements- It would be optimal to do many trials of this experiment, using different values for m_c, m_a and x, to check that the equations really fit, but time is an issue. With more precise data collection, we could have eliminated some of the movement and velocity seen along the y-axis.

6. Conclusions-- Using physics principles and equations, we predicted that the velocity of car pulled a known distance by a falling object would be equal to $\sqrt{2xg[m_a/(m_c+m_a)]}$, where x is equal to the distance the object falls, g is equal to gravity (9.8m/s*s), m_a is the mass of the object falling and m_c is equal to the mass of the car being pulled. Since the tension forces on each object are the same, they have the same acceleration and this can be predicted using Newton's second law and kinematics equations. The results of our experiment confirmed this.

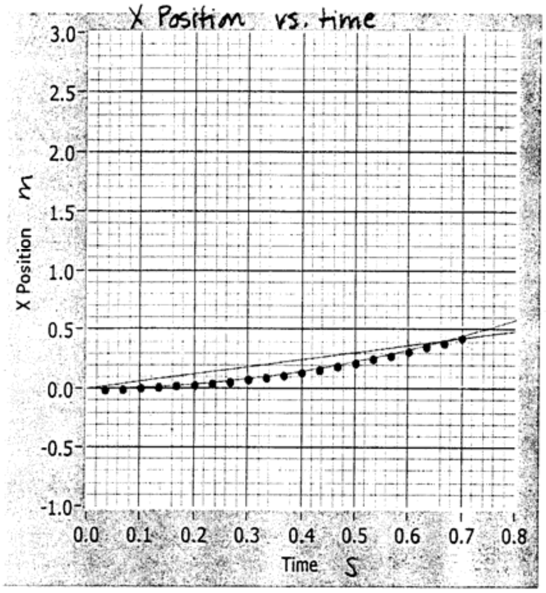
In each case but one, the predicted values for the components of the equations of the graphs were the same or close to the actual ones. When we predicted the value for acceleration of the car before the block hit the ground, we didn't figure any friction into the calculations. We based all of our future predictions off of the actual values we got for this graph's equation and they all matched the actual values well.

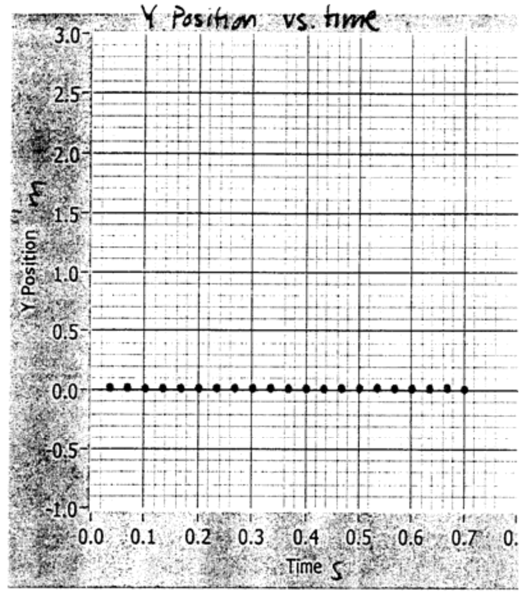
The launch velocity of the car does depend on the mass of the car, the mass of the block and the distance the block falls, according to $v = \sqrt{2xg[m_a/(m_c + m_a)]}$. For values of m_a that are much larger than m_c, m_c does not affect v very much, since $[m_a/(m_c + m_a)]$ becomes very close to 1.

The tension force upon the car and the block is dependent on the masses of both objects. Changing the mass of either one will change the tension force exerted on both. The tension force on the block is equal to its weight if the block has no net acceleration; in other words, when $T = F_g$. This would happen if the mass of the block was zero, and since it could never have zero mass, it would never happen in a frictionless system. It may come close to zero though, and would reach zero in a system with friction. We could test this experimentally by using a car with a very large mass and using blocks of decreasing masses. The acceleration of the car should go toward zero as the mass of the blocks decrease.

Graph Title

Lab III Problem 1: Before [A] hit the ground





X - Prediction Equation

u(t) = 0.000 + 0.600t

X - Fit Equation

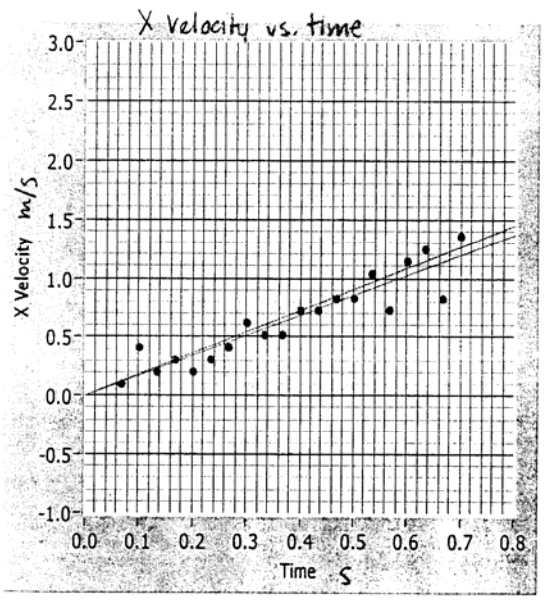
u(t) = 0.000 + 0.000 t + 0.897 t^2

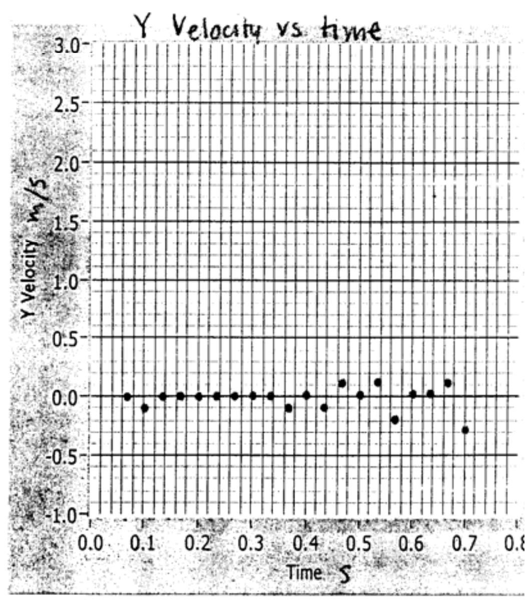
Y - Prediction Equation

u(t) = 0.000 + 0.000t

Y - Fit Equation

u(t) = 0.000 + 0.000t





Vx - Prediction Equation

u(t) = 0.000 + 1.800t

Vx - Fit Equation

u(t) = 0.000 + 1.700t

Vy - Prediction Equation

u(t) = 0.000 + 0.000t

Vy - Fit Equation

u(t) = 0.000 + 0.000t