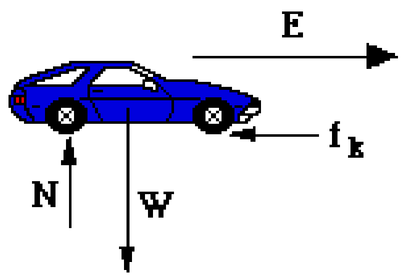
# Cooperative Group Problem Solving – The Workshop




$$\sum F = ma$$
$$f_k = \mu N$$
$$W = mg$$

**"I understand the concepts, I just can't solve the problems."**

**Ken Heller, Qing Xu**
School of Physics and Astronomy
University of Minnesota

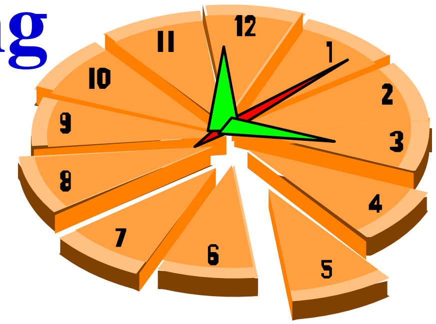
**Details at http://groups.physics.umn.edu/physed/**

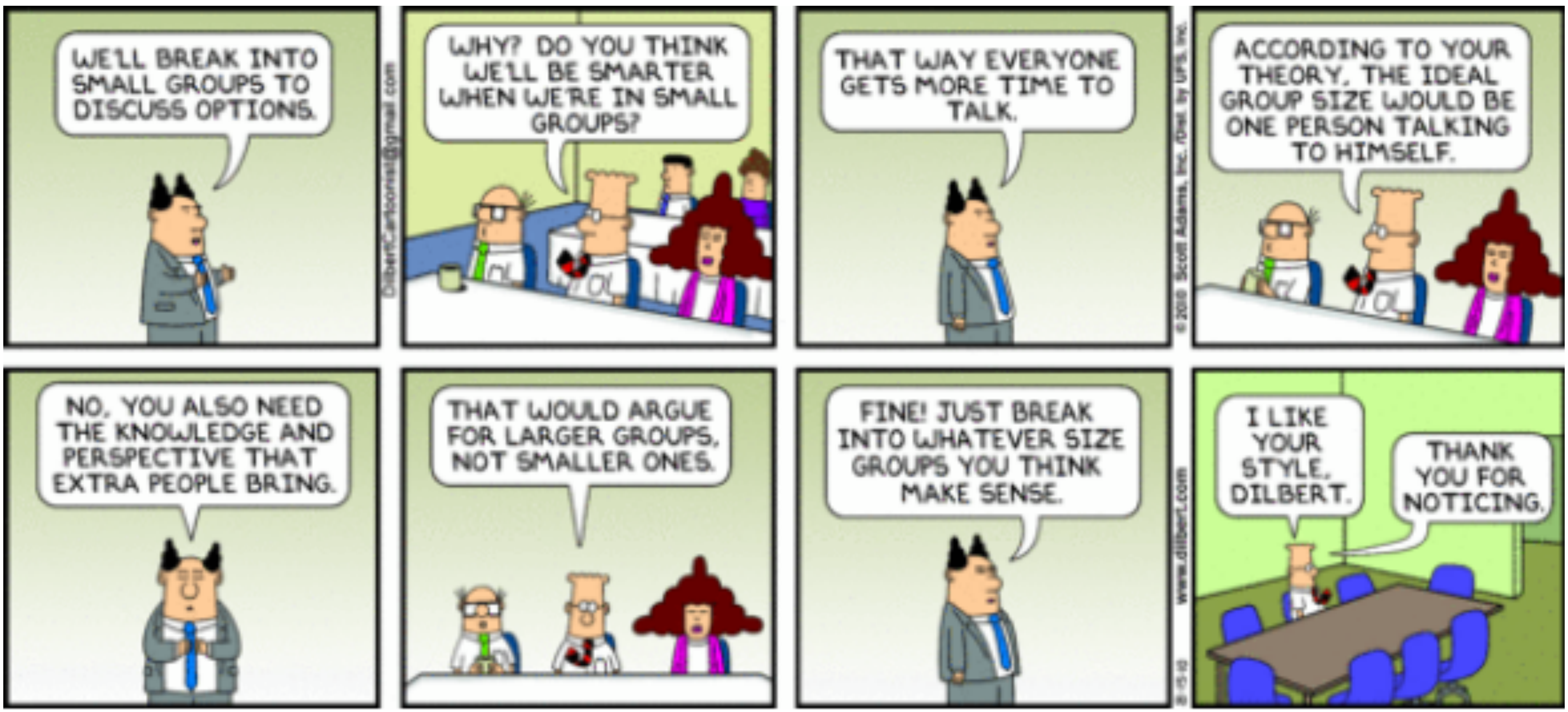
Supported in part by Department of Education (FIPSE), NSF,
and the University of Minnesota

# Cooperative Group Problem Solving

## Goals, Motivation, and Procedure

## It's Your Agenda





# What Do Other Faculty Want?

**Goals: Calculus-based Course (88% engineering majors) 1993**

- 4.5 Basic principles behind all physics
- 4.5 General qualitative problem solving skills
- 4.4 General quantitative problem solving skills
- 4.2 Apply physics topics covered to new situations
- 4.2 *Use with confidence*

**Goals: Algebra-based Course (24 different majors) 1987**

- 4.7 Basic principles behind all physics
- 4.2 General qualitative problem solving skills
- 4.2 *Overcome misconceptions about physical world*
- 4.0 General quantitative problem solving skills
- 4.0 Apply physics topics covered to new situations

**Goals: Biology Majors Course 2003**


- 4.9 Basic principles behind all physics
- 4.4 General qualitative problem solving skills
- 4.3 *Use biological examples of physical principles*
- 4.2 *Overcome misconceptions about physical world*
- 4.1 General quantitative problem solving skills
- 4.0 *Apply physics topics covered to real world situations*
- 4.0 *Know range of applicability of physics principles*

**Modified survey in response to CBS Curriculum Committee**

**Scaffolding**

# Grading Rubric

**This is a closed book, closed notes quiz. Calculators are permitted. The ONLY formulas that may be used are those given below. Define all symbols and justify all mathematical expressions used. Make sure to state all of the assumptions used to solve a problem. Credit will be given only for a logical and complete solution that is clearly communicated with correct units. Partial credit will be given for a well communicated problem solving strategy based on correct physics. MAKE SURE YOUR NAME, ID #, SECTION #, and TAs NAME ARE ON EACH PAGE!! START EACH PROBLEM ON A NEW PAGE. Each problem is worth 25 points:**

**In the context of a unified solution, partial credit will be awarded as follows:**

- **a useful picture, defining the question, and giving your approach is worth 6 points;**
- **a complete physics diagram defining the relevant quantities, identifying the target quantity, and specifying the relevant equations with reasons is worth 6 points;**
- **planning the solution by constructing the mathematics leading to an algebraic answer and checking the units of that answer is worth 7 points;**
- **calculating a numerical value with correct units is worth 3 points; and**
- **evaluating the validity of the answer is worth 3 points.**

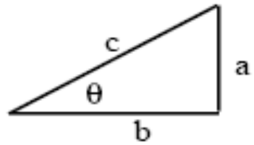
**The multiple choice questions are each worth 1.5 points.**

**Scaffolding**

# Control of Equations that are Allowed

**Equation sheet on the final exam: Calculus Based Physics for Biology Majors**

**Useful Mathematical Relationships:**




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

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

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

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

$\frac{d(z^n)}{dz} = nz^{n-1}$, $\frac{d(\cos z)}{dz} = -\sin z$, $\frac{d(\sin z)}{dz} = \cos z$, $\frac{d(e^{az})}{dz} = ae^{az}$, $\frac{d(\ln z)}{dz} = \frac{1}{z}$,

$\frac{df(z)}{dt} = \frac{df(z)}{dz}\frac{dz}{dt}$,

**Fundamental Concepts, Principles, and Definitions:**

| | | | | | |
|---|---|---|---|---|---|
| $\sum \vec{F} = m\vec{a}$ | $\rho = \frac{m}{V}$ | $E_f - E_i = E_{in} - E_{out}$ | $KE = \frac{1}{2}mv^2$ | $P = \frac{F}{A}$ | $e = \frac{E_{desired}}{E_{input}}$ |
| $\tau = rF_{\perp}$ | $\frac{dW}{d\ell} = F_{\ell}$ | $f = \frac{1}{T}$ | $\frac{dU}{dx} = -F_{internal}$ | $S = k\ln\Omega$ | $\theta = \frac{\delta C}{r}$ |
| $F = U - TS$ | $\frac{dx}{dt} = v_x$ | $\frac{dv_x}{dt} = a_x$ | $s_{av} = \frac{distance}{\Delta t}$ | $v_{x\,av} = \frac{\Delta x}{\Delta t}$ | $a_{x\,av} = \frac{\Delta v_x}{\Delta t}$ |

**Under Certain Conditions:**

| | | | | | |
|---|---|---|---|---|---|
| $F = mg$ | $F = kx$ | $F = \mu_k n$ | $F \le \mu_s n$ | $F = G\frac{m_1 m_2}{r^2}$ | $F = k_e\frac{q_1 q_2}{r^2}$ |
| $\sum\tau = 0$ | $\Delta E_{internal} = mL$ | $\Delta E_{internal} = Cm\Delta T$ | $PV = NkT$ | $PV = nRT$ | $\frac{dW}{dV} = P$ |
| $U = mgh$ | $U = \frac{1}{2}kx^2$ | $W = -T\Delta S$ | $\Delta S = \frac{Q}{T}$ | $F = bv$ | $a = \frac{v^2}{r}$ |
| $x = A\cos(2\pi ft + \phi)$ | $x = \frac{1}{2}at^2 + v_o t + x_o$ | $\frac{1}{2}\rho v^2 + \rho gy + P = constant$ | | | |

**Useful constants:** 1 mile = 5280 ft, $g = 9.8\ m/s^2 = 32\ ft/s^2$, $k_B = 1.4 \times 10^{-23}$ J/K, $N_{av} = 6 \times 10^{23}$ , $R = 8.3$ J/(mol K), $\rho_{water} = 1\ g/cm^3$

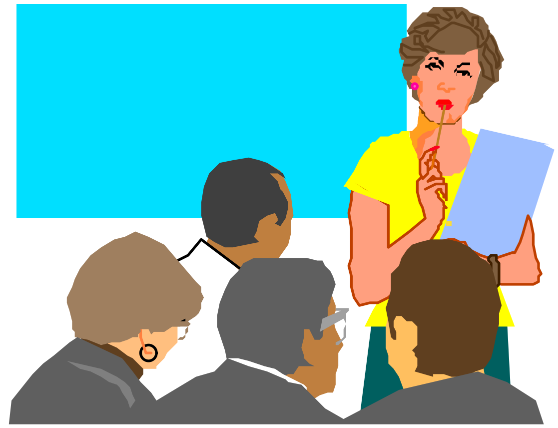
**40 equations**

## TASK

Discuss why you assign problems in your courses.

List the common goals of the problems.

Report the single most important goal



## TIME ALLOTTED

10 minutes

## PROCEDURES

**Form a group of 3 people**
**Choose one person as a recorder**

*Formulate* a response individually.
*Discuss* your response with your partners.
*Listen* to your partners' responses.
*Create* a new group response through discussion.

# The Monotillation of Traxoline

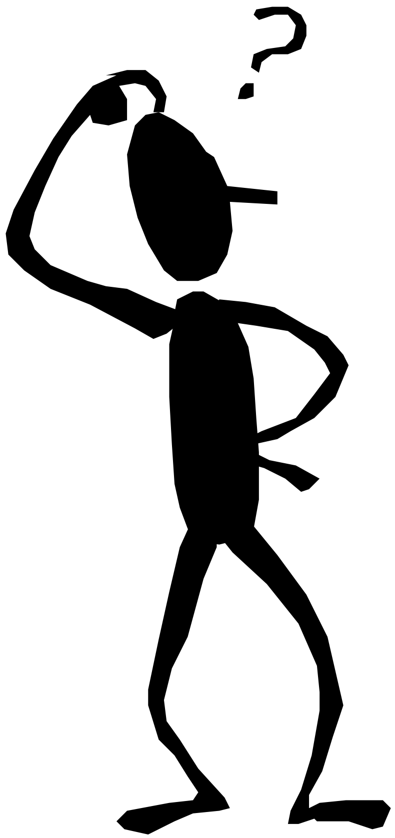
**(attributed to Judy Lanier)**

**It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then brachter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.**

## Answer the following questions.

1. What is traxoline?
2. Where is traxoline montilled?
3. How is traxoline quasselled?
4. Why is it important to know about traxoline?

# Textbook Problem



A block starts from rest and accelerates for 3.0 seconds. It then goes 30 ft. in 5.0 seconds at a constant velocity.

a. What was the final velocity of the block?

b. What was the acceleration of the block?

# A Complex Process

**The procedure is quite simple but you may have to go somewhere else if the facilities are not adequate. Before the process begins, you form different groups. Of course, one group may be sufficient depending on how much there is to do.**

**Next you get started. Be careful, a mistake can be costly. It is important not to overdo things. It is usually better to do too few things than too many. This is especially important when issues of compatibility arise. At first, the whole procedure might seem complicated since timing can be crucial. With practice, it can all become routine.**

**After the procedure is completed, form groups again to complete the process. This whole cycle will need to be repeated often.**

## Answer the following questions.

1. **What is the process being discussed?**
2. **What facilities are needed?**
3. **What are some compatibility issues?**
4. **Why is it important to form groups?**

**Household task**

**Laundry**

# Improving "Standard" Problems

A block of mass m = 2.5 kg starts from rest and slides down a frictionless ramp that makes an angle of $\theta = 25^o$ with respect to the horizontal floor. The block slides a distance *d* down the ramp to reach the bottom. At the bottom of the ramp, the speed of the block is measured to be *v* = 12 m/s.

(a) Draw a diagram, labeling θ and d. [5 points]

(b) What is the acceleration of the block, in terms of g? [5 points]

(c) What is the distance *d*, in meters? [15 points]

From a test

## Better

A 2.5 kg block starts from rest and slides down a frictionless ramp at $25^o$ to the horizontal floor. At the bottom of the ramp, the speed of the block is measured to be 12 m/s.

(a) Draw a diagram, with appropriate labeling. [5 points]

(b) What is the acceleration of the block, in terms of g? [5 points]

(c) What is the distance the block slides, in meters? [15 points]

Allow students to practice making simple decisions.

## Better

A 2.5 kg block starts from rest and slides down a frictionless ramp at $25^o$ to the horizontal floor. At the bottom of the ramp, the speed of the block is measured to be 12 m/s. How far did the block slide?

Allow students to practice making decisions about structuring their solution and connecting physics concepts.

## Better

A 2.5 kg block starts from the top and slides down a slippery ramp reaching 12 m/s at the bottom. How long is the ramp? The ramp is at $25^o$ to the horizontal floor .

Allow students to practice making assumptions.

## Original

**A block of mass m = 2.5 kg starts from rest and slides down a frictionless ramp that makes an angle of θ= 25º with respect to the horizontal floor. The block slides a distance *d* down the ramp to reach the bottom. At the bottom of the ramp, the speed of the block is measured to be *v* = 12 m/s.**
**(a) Draw a diagram, labeling θ and d. [5 points]**
**(b) What is the acceleration of the block, in terms of g? [5 points]**
**(c) What is the distance *d*, in meters? [15 points]**

## Better

**A 2.5 kg block starts from the top and slides down a slippery ramp reaching 12 m/s at the bottom. How long is the ramp? The ramp is at 25º to the horizontal floor .**

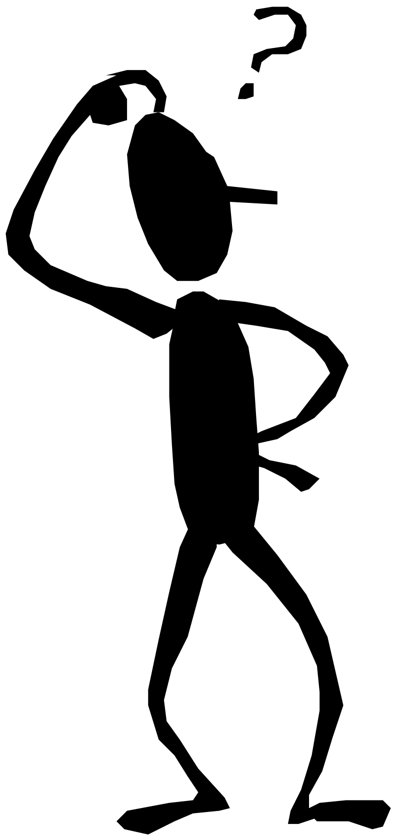
## Better

**You have been asked to design a simple system to transport boxes from one part of a warehouse to another. The design has boxes placed on the top of the ramp so that they slide to their destination. A box slides easily because the ramp is covered with rollers. Your job is to calculate the maximum length of the ramp if the heaviest box is 25 kg and the ramp is at 5.0º to the horizontal. To be safe, no box should go faster than 3.0 m/s when it reaches the end of the ramp.**

## Context Rich Problem

**Allows student decisions.**
**Practice making assumptions.**
**Connects to student reality.**
**Has a motivation (why should I care?).**

# Textbook Problem



A block starts from rest and accelerates for 3.0 seconds. It then goes 30 ft. in 5.0 seconds at a constant velocity.

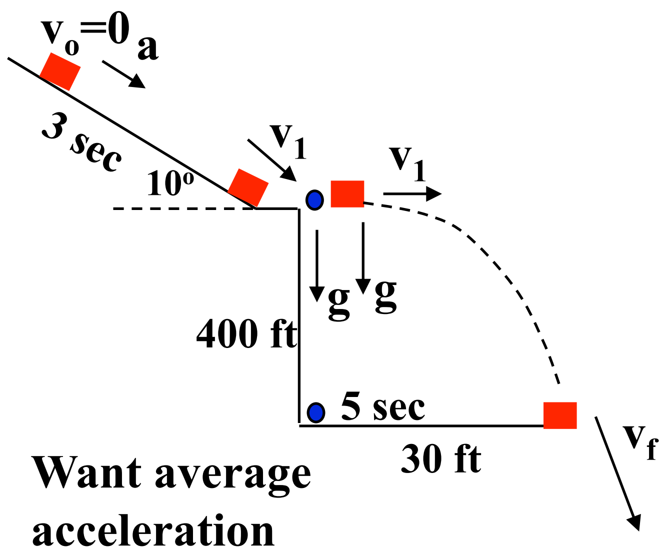
a. What was the final velocity of the block?

b. What was the acceleration of the block?

# Context-Rich Problem

**You are working with an insurance company to help investigate a tragic accident. At the scene, you see a road running straight down a hill 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.**

# Visualize




Want average acceleration down the hill.

## Principles

- Average acceleration = (velocity change / time for change)
- Final velocity = initial horizontal velocity of flight
- Vertical & horizontal motion are independent

In flight

- Horizontal velocity is constant
- Vertical acceleration is constant & same for everything

You are working with an insurance company to help investigate a tragic accident. At the scene, you see a road running straight down a hill 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.

# Beginning Context-Rich Problem

**You are working with an insurance company to help investigate a tragic accident. At the scene, you see a road running straight down a hill 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.**

**Gives a motivation – allows some students to access their mental connections.**
**Gives a realistic situation – allows some students to visualize the situation.**
**Does not give a picture – students must practice visualization.**
**Uses the character "you" –more easily connects to student's mental framework.**

**Decisions must be made**

# Decisions

**You are working with an insurance company to help investigate a tragic accident. At the scene, you see a road running straight down a hill 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.**

**What is happening? – you need a picture.**

**What is the question? – it is not in the last line.**

**What quantities are important and what should I name them? – choose symbols.**

**What physics is important? – difference between average and instantaneous.**

**What assumptions are necessary? – should friction be ignored?**

**Is all the information necessary? – the angle? The vertical drop? The time?**

# Stop surface feature pattern matching

**You are working with an insurance company to help investigate a tragic accident. At the scene, you see a road running straight down a hill 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.**

**Not an inclined plane problem**

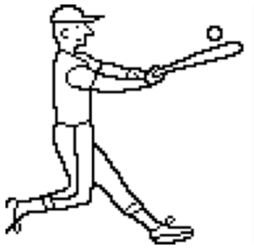
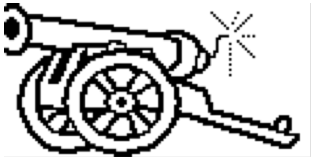
**Not a projectile motion problem**

**Same as the following textbook question except students must engage with the content**

**A block starts from rest and accelerates for 3.0 seconds. It then goes 30 ft. in 5.0 seconds at a constant velocity.**

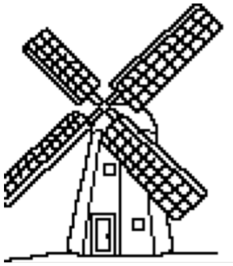
**a. What was the final velocity of the block?**
**b. What was the acceleration of the block?**

# Context-rich Problems

- Each problem is a short story in which the major character is the student. That is, each problem statement uses the personal pronoun "you."


- The problem statement includes a plausible motivation or reason for "you" to calculate something.
- The objects in the problems are real (or can be imagined) -- the idealization process occurs explicitly.




- No pictures or diagrams are given with the problems. Students must visualize the situation by using their own experiences.
- The problem can not be solved in one step by plugging numbers into a formula.

# Context-rich Problems

**In addition, more difficult context-rich problems can have one or more of the following characteristics:**

- **The unknown variable is not explicitly specified in the problem statement (e.g., Will this design work?).**
- **More information may be given in the problem statement than is required to solve the problems, or relevant information may be missing.**
- **Assumptions may need to be made to solve the problem.**
- **The problem may require more than one fundamental principle for a solution (e.g., Newton's Laws and the Conservation of Energy).**
- **The context can be very unfamiliar (i.e., involve the interactions in the nucleus of atoms, quarks, quasars, etc.)**

# Design of a Problem

| Difficulty | Symptom | Design feature |
|---|---|---|
| Visualizing a physical situation | Physically impossible results. No pictures or diagrams drawn | No pictures given. Situation not trivial. |
| Connection to reality | “Fragile” knowledge. Difficulty applying to slightly different situations. | Reasonable motivation. Realistic situation described. Avoid “physics’ words. |
| Gender or cultural bias | Lack of interest or intellectual involvement. Difficulty visualizing. | Actors are “you” & unnamed acquaintances |
| “Idealizing” a situation | Difficulty applying to slightly different situations. | A realistic situation reduces in a straightforward way to a simple one after visualization. |

| Difficulty | Symptom | Design feature |
|---|---|---|
| Integrating correct conceptual knowledge | Misconceptions remain | Realistic situation described. Misconception will prevent correct solution. |
| Applying knowledge | Difficulty applying to slightly different situations. | Realistic situation described. Decisions necessary for applicable concept or technique. |
| Solving “wrong” problem. Pattern matching. | Oversimplification or misreading of problem. | Realistic situation which must be interpreted in terms of physics. |
| Mathematical rigor. | Math “magic”. | Problem can be solved in a straightforward way using basic concepts. |
| Logical analysis. | Random equations. | Problem requires more than one mathematical/ logical step. |

# Build A Context-Rich Problem

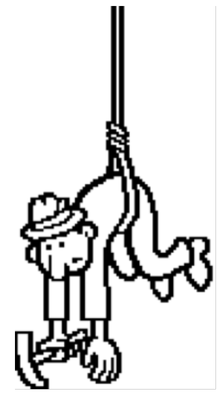
- Choose Basic Physics Principle(s)
- Decide on Difficulty Level
- Address a Misconception?
- Involve a Special Technique?
- Choose a Context
- Decide on a Motivation
- Choose Target and Input Quantities
- Decide on Decisions to be Made
- Check Solution (more than 1-step, no subtle insights)
- Check Evaluation Possibilities

# How to Change a Textbook "Problem"

1. Choose a textbook exercise or problem.
2. If the problem does not have one, determine a context (real objects with real motions or interactions) for the problem. Use an unfamiliar context for a very difficult group problem.
3. Decide on a motivation -- Why would "you" want to calculate something in this context?
4. Determine if you need to change the target quantity to
   (a) make the problem more than a one-step exercise, or
   (b) make the target quantity fit your motivation.
5. Write the problem like a short story. Edit to reduce word count.
6. If you want to create a more difficult individual or group problem,
   (a) determine extra information that someone in the situation would be likely to have, or leave out common-knowledge information (e.g, the boiling temperature of water).
   (b) write the story so the target quantity is not explicitly stated, or
   (c) think of different information that could be given, so two approaches would be needed to solve the problem instead of one approach.

# Some Common Contexts

- physical work (pushing, pulling, lifting objects vertically, horizontally, or up ramps)
- suspending objects, falling objects



- sports situations (falling, jumping, running, throwing, etc. while diving, bowling, playing golf, tennis, football, baseball, etc.)
- situations involving the motion of bicycles, cars, boats, trucks, planes, etc.
- astronomical situations (motion of satellites, planets)

cooling of objects (cooking,
ning, etc.)

# Some Motivations

1. You are . . . . (everyday situation) and need to figure out . . . .
2. You are watching . . . . (an everyday situation) and wonder . . . .
3. You are on vacation and observe/notice . . . . and wonder . . . .
4. You are watching TV or reading an article about . . . . and wonder . . .
5. Because of your knowledge of physics, your friend asks you to help him/her . . . .
6. You are writing a science-fiction or adventure story for your English class about . . . . and need to figure out . . . .
7. Because of your interest in the environment and your knowledge of physics, you are a member of a Citizen's Committee (or Concern Group) investigating . . . .
8. You have a summer job with a company that . . . . Because of your knowledge of physics, your boss asks you to . . . .
9. You have been hired by a College research group that is investigating . . . . Your job is to determine . . . .
10. You have been hired as a technical advisor for a TV (or movie) production to make sure the science is correct. In the script . . . ., but is this correct?
11. When really desperate, use motivation of an artist friend designing a kinetic sculpture!