LABORATORY V
ENERGY

In this lab, you will begin to use the principle of *conservation of energy* to determine the motion resulting from interactions that are difficult to analyze using force concepts alone. Keep in mind that **energy is always conserved**, it but it is sometimes difficult to calculate the value of all of the energy terms for an interaction.

Not all of the initial energy of a system ends up as visible energy of motion. Some energy is transferred into or out of the system, and some may be transformed to internal energy of the system. Since this energy is not observable in the macroscopic motion of objects, we sometimes say that the energy is "dissipated" in the interaction.

The first three problems explore the application of conservation of energy to collisions. The fourth problem deals with conservation of energy, power output, and the human body.

OBJECTIVES:

Successfully completing this laboratory should enable you to:

- Use the conservation of energy to predict the outcome of interactions between objects.
- Choose a useful system when using conservation of energy.
- Identify different types of energy when applying energy conservation to real systems.
- Decide when conservation of energy is not useful to predict the outcome of interactions between objects.

PREPARATION:

Read Serway & Vuille Chapter 5. You should also be able to:

- Analyze the motion of an object from videos.
- Calculate the kinetic energy of a moving object.
- Calculate the work done on a system by an external force.
- Calculate the gravitational potential energy of an object with respect to the earth.
- Calculate the total energy of a system of objects.
- Calculate the mechanical power output of a system.

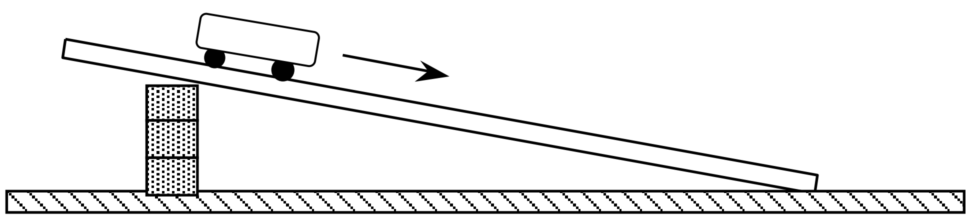
PROBLEM #1:
KINETIC ENERGY AND WORK

You have been hired as a technical adviser for an upcoming western film. In the script, a wagon containing boxes of gold has been cut loose from the horses by an outlaw. The wagon starts from rest near the top of a hill. The outlaw plans to have the wagon roll down the hill, across a flat section of ground, and over a cliff face into a canyon. The outlaw stations some of his gang in the canyon to collect the gold from the demolished wagon. Little do they know, the Lone Ranger sees the outlaw's action from his lookout post near the base of the hill, and quickly races on horseback to intercept the wagon before it plummets into the canyon. The Lone Ranger must match the speed of the wagon at the base of the hill to hook a strong cord onto the wagon, and then lasso the other end to a large rock.

The director asks you to determine how the velocity of the stagecoach near the bottom of the hill depends on its initial release height up the hill, to coordinate a reasonable required speed for the Lone Ranger's interception. You decide to model the situation using a cart released from rest on an inclined track.

EQUIPMENT

For this problem you will have a meter stick, a stopwatch, wood blocks, an aluminum track, a PASCO cart, a video camera, a triple-beam balance, and a computer with video analysis applications written in LabVIEW™ (VideoRECORDER and VideoTOOL).



PREDICTION

For a cart rolling down an inclined track, write an expression for the final velocity in terms of the initial (vertical) release height. Does the final velocity depend on the steepness (angle) of the incline?

Use your expression to sketch a graph of the final velocity versus the initial release height.

WARM-UP

Read: Serway & Vuille Chapter 5, Sections 5.1 to 5.2

1. Draw two pictures, one showing the cart at rest at the top of the incline, and another when it is rolling at the bottom of the incline. Draw velocity vectors on your sketch. Define your system. Label the distances, mass of the cart, and the kinetic energy of all objects in your system for both pictures.

2. What is the work done by gravity on the cart from its initial position to when it reaches the bottom of the hill? Hint: remember that to calculate work, you need to multiply the magnitude of the force and the displacement *in the same direction* as the force. You can choose to use either the vertical displacement of the cart, or the distance traveled along the incline.

3. Use the work-kinetic energy theorem to write an equation that relates the work done by gravity on the cart to the change in kinetic energy between its initial release and when it reaches the base of the hill. Assume energy dissipation is small enough to be neglected. Solve your equation for the final velocity of the cart in terms of the vertical release height. (If your equation is in terms of the distance traveled along the incline, use trigonometry to relate this distance to the vertical height of the hill.) Does your equation depend on the steepness of the hill, as measured by the angle of the incline?

EXPLORATION

Practice releasing the cart from rest on the inclined aluminum track. Try a variety of different track angles, release heights, and cart masses. Record your observations of the cart's motion for each practice run. Do you observe a difference in the final velocity of the cart if you release it from the same height, but with a steeper incline? BE SURE TO CATCH THE CART AT THE BOTTOM OF THE TRACK!

Choose a single angle of incline for the aluminum track, the cart mass you will use, and several release heights for the cart. Set up the camera and tripod to give you the best video of the cart's motion down the incline. *Hint: Your video may be easier to analyze if the motion on the video screen is purely horizontal. Why? It could be useful to rotate the camera!*

What will you use for a calibration object in your videos? What quantities in your prediction equation do you need to measure with the video analysis software, and what quantities can be measured without the video?

Write down your measurement plan.

MEASUREMENT

Follow your measurement plan from the Exploration section. Record a video of the cart's motion down the incline for the first release height you have chosen. What is the total distance through which the cart rolls? How much time does it take? These measurements will help you set up the graphs for your computer data taking.

Open your video in VideoTOOL and follow the instructions to acquire data. As a lab group, decide how you will acquire the value for the final velocity of the cart when it is at the bottom of the hill.

Repeat the data acquisition and analysis for different cart release heights. How many different heights do you need to adequately verify your prediction?

If you have time, try acquiring data to compare two videos with the same vertical release height for the cart, but a steeper incline (different track angle).

ANALYSIS

Determine the fit functions that best represent the position vs. time graphs for the cart in the x and y directions. (If you are having trouble, review your notes from Lab I Problem 2: Motion Down an Incline.) How can you estimate the values of the constants of each function from the graph? You can waste a lot of time if you just try to guess the constants. What kinematic quantities do these constants represent? Be sure to record all of the fit equations into your lab journal in an organized manner.

Do the same for the velocity vs. time graphs in the x and y directions. Compare these functions with the position vs. time functions.

What quantity or quantities are you interested in acquiring from the graphs of position and velocity in VideoTOOL? Are the fit functions helpful in this case, or do you need to look at the raw data?

For each cart release height, use your predicted expression from the Warm-up and Prediction to calculate the predicted final velocity of the cart. Have you measured all of the quantities that you need for this expression? If not, be sure to take the measurements before you leave the lab. Make a data table in your lab journal that lists the predicted (calculated) final velocity and the measured final velocity from VideoTOOL for each release height.

Make a graph of the final velocity versus the release height for your predicted and measured data (plot the measured and predicted velocities on the same graph, but with different colors or symbols.)

CONCLUSION

How did your measurements compare to your prediction? What are the limitations on the accuracy of your measurements and analysis? What were the sources of your uncertainties?

For a cart rolling down an inclined track, how does the final velocity depend on the initial release height? Does the final velocity depend on the steepness (angle) of the incline? (If you did not try different angles for measurements or in the Exploration, compare notes with another lab group.)

PROBLEM #2:
ENERGY EFFICIENCY OF COLLISIONS

You are working at a company that designs pinball machines and have been asked to devise a test to determine the efficiency of some new magnetic bumpers. You know that when a normal pinball rebounds off traditional bumpers, some of the initial energy of motion is "dissipated" in the deformation of the ball and bumper, thus slowing the ball down. The lead engineer on the project assigns you to determine if the new magnetic bumpers are more efficient. The engineer tells you that the efficiency of a collision is the ratio of the final kinetic energy to the initial kinetic energy of the system.

Since you want to measure the efficiency of the bumper (not the ball), you decide to compare the collision efficiency of a cart with a magnet colliding with a magnetic bumper to the cart colliding with a nonmagnetic bumper.

EQUIPMENT

For this problem you will have a meter stick, a stopwatch, wood blocks, an aluminum track, a magnetic bumper (end stop), a PASCO cart, a video camera, a triple-beam balance, and a computer with video analysis applications written in LabVIEW™ (VideoRECORDER and VideoTOOL).

PREDICTION

For a level track, write an expression for the energy efficiency of the collision between the cart and the bumper in terms of the least number of quantities that you can easily measure. Write an expression for the energy dissipated during the impact with the bumper in terms of measurable quantities.

Do you expect the cart's collision with a magnetic bumper to have a higher, lower, or equal efficiency to the cart's collision with a nonmagnetic bumper? Use your equations to explain your reasoning.

WARM-UP

Read: Serway & Vuille Chapter 5, Sections 5.2, 5.3, and 5.5

1. Draw two pictures, one showing the situation before the impact with the bumper and the other one after the impact. Draw velocity vectors on your sketch. Define your system. Label the kinetic energy of all objects in your system before and after the impact.

2. According to the engineer's information, what is the efficiency of the bumper in terms of the final and initial kinetic energies of the cart? Write an equation for the efficiency of the collision in terms of quantities you know or can measure. Does your equation depend on the cart mass?

3. Write down a conservation of energy equation for the collision with the bumper (remember to take into account the energy dissipated). Use this to write an expression for the energy dissipated during the impact with the bumper in terms of the cart mass and initial and final velocities. Does the energy dissipated depend on the mass of the cart?

EXPLORATION

Practice giving the cart an initial push along the level track to collide with the magnetic bumper. Repeat for several different initial velocities. How can you ensure that the bumper does not change position during the collision? Try adding more mass to the cart, and observe a collision. Do you notice any change in the cart's motion due to more mass?

Practice giving the cart an initial push along the level track to collide with a nonmagnetic bumper, such as a wood block or a nonmagnetic end stop. Repeat for several different initial velocities. How can you ensure that the bumper does not change position during the collision?

Find a range of initial velocities that do not collide too violently with the bumpers. Set up the camera and tripod to give you the best video of the collision immediately before and after the cart collides with the bumpers. Hint: For a clear comparison of the two bumpers, it is useful to use the same initial velocities for each kind of bumper.

What will you use for a calibration object in your videos? What quantities in your prediction equations do you need to measure with the video analysis software? Is it possible to obtain information before and after the collision with one video analysis, or will you need to analyze each video more than once?

Write down your measurement plan.

MEASUREMENT

Follow your measurement plan from the Exploration section. Record a video of the cart's collision with a magnetic end stop and repeat (for the same initial velocity) with a nonmagnetic end stop, or a wood block. Use a stopwatch and the distance traveled by the cart before impact with the bumper to estimate the initial velocity of the cart for each trial.

Open one of your videos in VideoTOOL and follow the instructions to acquire data. As a lab group, decide how you will acquire data and analyze the collision. (Will you acquire data for the cart's motion before the impact and repeat the process for after the impact, or will you acquire data for the entire motion of the cart in a single analysis?)

If you have time, repeat the measurements for a different initial velocity. If there is not enough time, compare your data with another lab group that used a different initial velocity of the cart.

ANALYSIS

Using VideoTOOL, determine the fit functions that best represent the position vs. time graphs for the cart in the x and y directions. If you acquired data separately for before and after the collision, you will have separate fit functions for each time you analyze the video. If you acquired data for the entire motion of the cart, look at the data and decide what fit function you think best matches the graphs. How can you estimate the values of the constants of each function from the graph? You can waste a lot of time if you just try to guess the constants. What kinematic quantities do these constants represent? Be sure to record all of the fit equations into your lab journal in an organized manner.

Do the same for the velocity vs. time graphs in the x and y directions. Compare these functions with the position vs. time functions.

For each collision, use your predicted expressions from the Warm-up and Prediction to calculate the energy efficiency and energy dissipated with appropriate units. Have you measured all of the quantities that you need for these expressions? If not, make sure you measure them before you leave the lab.

CONCLUSION

What was the efficiency of each collision? How much energy was dissipated in the impact? What are the limitations on the accuracy of your measurements and analysis? What were the sources of your uncertainties?

Did a magnetic bumper have a higher, lower, or same efficiency as the nonmagnetic bumper? Did the efficiency of a bumper depend on the initial velocity you gave the cart?

PROBLEM #3:
ENERGY IN COLLISIONS WHEN OBJECTS STICK TOGETHER

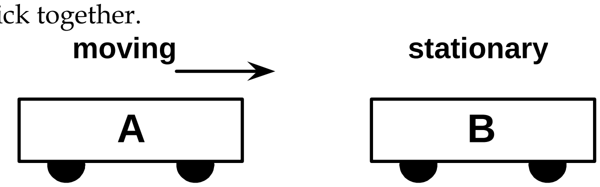
You have a summer job with the Minnesota Traffic Safety Board. You are helping to write a report about the damage done to vehicles in different kinds of traffic accidents. Your boss wants you to concentrate on the damage done when a moving vehicle hits a stationary vehicle and they stick together.

You know that in a traffic collision, as with any interaction, some of the initial energy of motion is transformed or "dissipated" in the deforming (damaging) of the vehicles. Your boss believes that the amount of damage done in such a collision depends only on the total combined mass of the two vehicles and the initial kinetic energy of the moving vehicle. Is your boss correct?

To resolve the issue, you decide to model the collision with carts of different masses and measure the energy efficiency of three different cart collisions: one in which the moving cart is more massive, one in which the stationary cart is more massive, and one in which the moving and stationary carts are equally massive. You define efficiency as the ratio of the final kinetic energy of the system to the initial kinetic energy.

EQUIPMENT

For this problem you will have several cart weights, a meter stick, a stopwatch, an aluminum track, two PASCO carts, a video camera, and a computer with video analysis applications written in LabVIEW™ (VideoRECORDER and VideoTOOL). The carts have Velcro pads on one side, which will allow the carts to stick together.



PREDICTION

Consider the following three cases in which the total mass of the carts is the same ($m_A + m_B$ = constant), where m_A is the moving cart, and m_B is the stationary cart:

(a) $m_A = m_B$ (b) $m_A > m_B$ (c) $m_A < m_B$

Write an expression for the efficiency of the collision between moving cart A and stationary cart B. Rank the collision situations a, b, and c from most efficient to least efficient. (Make an educated guess and explain your reasoning.)

Write an expression for the energy dissipated in a collision in which the carts stick together, as a function of the mass of each cart, the initial kinetic energy of the system, and the energy efficiency of the collision. If you assume the kinetic energy of an incoming vehicle is the same in the three cases, which situation will cause the most damage?

WARM-UP

Read: Serway & Vuille Chapter 5, Sections 5.2, 5.3, and 5.5.

1. Draw two pictures, one showing the situation before the collision and the other one after the collision. Is it reasonable to neglect friction? Label the mass of each cart, and draw velocity vectors on each sketch. Define your system. If the carts stick together after the collision, what must be true about their final velocities? Write down expressions for the kinetic energy of the system before and after the collision.

2. Write down an energy conservation equation for this collision. (Remember to take into account the energy dissipated.)

3. Write an equation for the efficiency of the collision in terms of the final and initial kinetic energy of the carts, and then in terms of the cart masses and their initial and final speeds. How do you expect the final velocities to compare for situations a, b, and c? If the initial kinetic energy of cart A remains the same for all three situations, which situation is most efficient? Least efficient? Or do you expect them to be equally efficient? Explain your reasoning.

4. Solve your equation from question 2 for the energy dissipated in the collision. Solve your equation from question 3 for the final kinetic energy in terms of the efficiency and initial kinetic energy, and substitute this into the equation for energy dissipated. Your equation should now be only in terms of the efficiency and the initial kinetic energy of cart A.

5. How is the energy dissipated related to efficiency? For a constant initial kinetic energy, does a collision with a low efficiency have high or low energy dissipation? Based on your rankings of efficiency from question 3, which collision will cause the most damage (have the most energy dissipated)?

6. Use the simulation “Lab3Sim” (See Appendix F for a brief explanation of how to use the simulations) to explore the conditions of this problem. For this problem you will want to set the elasticity to zero.

EXPLORATION

Practice setting the cart into motion so the carts stick together with Velcro after the collision. Try various initial velocities and observe the motion of the carts.

Vary the masses of the carts so that the mass of the initially moving cart covers a range from greater than the mass of the stationary cart to less than the mass the stationary cart while keeping the total mass of the carts the same. Be sure the carts still move freely over the track.

To keep the initial kinetic energy approximately the same for different masses of cart A, how should you change the initial velocity of the moving cart? Try it out.

Select the cart masses you will use for $m_A = m_B$, $m_A > m_B$, and $m_A < m_B$ for the same total mass. Determine an initial velocity for each case that will give you approximately the same initial kinetic energy for cart A. Use a stopwatch and meter stick to practice giving cart A these initial velocities.

Set up the camera and tripod to give you the best video of the collision immediately before and after the carts collide. What will you use for a calibration object in your videos? What quantities in your prediction equations do you need to measure with the video analysis software? Is it possible to obtain information before and after the collision with one video analysis, or will you need to analyze each video more than once?

Write down your measurement plan.

MEASUREMENT

Follow your measurement plan from the Exploration section. Record a video of one collision situation. Use a stopwatch and the distance traveled by the cart before impact with the bumper to estimate the initial velocity of the cart.

Open one your video in VideoTOOL and follow the instructions to acquire data. As a lab group, decide how you will acquire data and analyze the collision. (Will you acquire data for the cart A's motion before the impact and repeat the process for cart A and B after the collision, or will you acquire data for the entire motion of the carts in a single analysis?) Repeat this process for the remaining two collision situations.

Measure and record the masses of the two carts for each situation. Analyze your data as you go along (before making the next video), so you can determine if your initial choice of masses and speeds is sufficient. Collect enough data to convince yourself and others of your conclusions about the efficiency of the collision.

Save all of your data and analysis. You can use it again for Laboratory VI.

ANALYSIS

From your videos, determine the velocities of the carts before and after the collision. Use your equations from the Warm-up and Prediction questions to calculate the initial and final kinetic energy, efficiency, and energy dissipated for each case.

Record the measured and calculated values in an organized data table in your lab journal.

CONCLUSION

Given the same initial energy, in which case(s) ($m_A = m_B$, $m_A > m_B$, or $m_A < m_B$) was the energy efficiency the largest? In which case was it the smallest?

Was a significant portion of the energy dissipated? Was it the same for each collision situation? Into what other forms of energy do you think the cart's initial kinetic energy is most likely to transform?

Was your boss right? Is the same amount of damage done to vehicles when (1) a car hits a stationary truck and they stick together as when (2) a truck hits the stationary car (given the same initial kinetic energies)? State your results that support this conclusion.

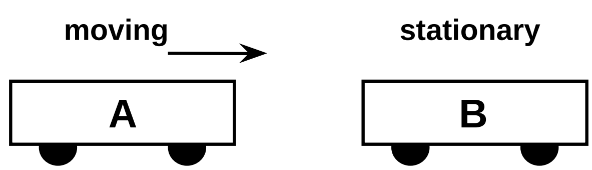
PROBLEM #4:
ENERGY IN COLLISIONS WHEN OBJECTS BOUNCE APART

You still have your summer job with the Minnesota Traffic Safety Board investigating the damage done to vehicles in different kinds of traffic accidents. Your boss now wants you to concentrate on the damage done in low speed collisions when a moving vehicle hits a stationary vehicle and they bounce apart. Even with new improved bumpers, your boss believes that, given the same initial energy, the damage to the vehicles in a collision when cars bounce apart will be less when the moving vehicle has a smaller mass than the stationary vehicle (e.g., a compact car hits a van) than for other situations.

To resolve the issue, you decide to model the collision with carts of different masses and measure the energy efficiency of three different cart collisions: one in which the moving cart is more massive, one in which the stationary cart is more massive, and one in which the moving and stationary carts are equally massive. You define efficiency as the ratio of the final kinetic energy of the system to the initial kinetic energy.

EQUIPMENT

For this problem you will have several cart weights, a meter stick, a stopwatch, an aluminum track, two PASCO carts, a video camera, and a computer with video analysis applications written in LabVIEW™ (VideoRECORDER and VideoTOOL). The carts have magnets on one side which will allow them to repel each other.



PREDICTION

Consider the following three cases in which the total mass of the carts is the same ($m_A + m_B$ = constant), where m_A is the moving cart, and m_B is the stationary cart:

(a) $m_A = m_B$ (b) $m_A > m_B$ (c) $m_A < m_B$

Write an expression for the efficiency of the collision between moving cart A and stationary cart B. Rank the collision situations a, b, and c from most efficient to least efficient. (Make an educated guess and explain your reasoning.)

Write an expression for the energy dissipated in a collision in which the carts bounce apart, as a function of the mass of each cart, the initial kinetic energy of the system, and the energy efficiency of the collision. If you assume the kinetic energy of an incoming vehicle is the same in the three cases, which situation will cause the most damage?

WARM-UP

Read: Serway & Vuille Chapter 5, Sections 5.2, 5.3, and 5.5

1. Draw two pictures, one showing the situation before the collision and the other one after the collision. Is it reasonable to neglect friction? Label the mass of each cart, and draw velocity vectors on each sketch. Define your system. Write down expressions for the kinetic energy of the system before and after the collision.

2. Write down an energy conservation equation for this collision. (Remember to take into account the energy dissipated.)

3. Write an equation for the efficiency of the collision in terms of the final and initial kinetic energy of the carts, and then in terms of the cart masses and their initial and final speeds. How do you expect the final velocities for carts A and B to compare for situations a, b, and c? If the initial kinetic energy of cart A remains the same for all three situations, which situation is most efficient? Least efficient? Or do you expect them to be equally efficient? Explain your reasoning.

4. Solve your equation from question 2 for the energy dissipated in the collision. Solve your equation from question 3 for the final kinetic energy in terms of the efficiency and initial kinetic energy, and substitute this into the equation for energy dissipated. Your equation should now be only in terms of the efficiency and the initial kinetic energy of cart A.

5. How is the energy dissipated related to efficiency? For a constant initial kinetic energy, does a collision with a low efficiency have high or low energy dissipation? Based on your rankings of efficiency from question 3, which collision will cause the most damage (have the most energy dissipated)?

6. Use the simulation "Lab3Sim" (See Appendix F for a brief explanation of how to use the simulations) to explore the conditions of this problem. For this problem you will want to set the elasticity to something other than zero.

EXPLORATION

Practice setting the cart into motion so the carts bounce apart from the magnetic bumpers. Try various initial velocities and observe the motion of the carts.

Vary the masses of the carts so that the mass of the initially moving cart covers a range from greater than the mass of the stationary cart to less than the mass the stationary cart while keeping the total mass of the carts the same. Be sure the carts still move freely over the track.

To keep the initial kinetic energy approximately the same for different masses of cart A, how should you change the initial velocity of the moving cart? Try it out.

Select the cart masses you will use for $m_A = m_B$, $m_A > m_B$, and $m_A < m_B$ for the same total mass. Determine an initial velocity for each case that will give you approximately the same initial kinetic energy for cart A. Use a stopwatch and meter stick to practice giving cart A these initial velocities.

Set up the camera and tripod to give you the best video of the collision immediately before and after the carts collide. What will you use for a calibration object in your videos? What quantities in your prediction equations do you need to measure with the video analysis software? Is it possible to obtain information before and after the collision with one video analysis, or will you need to analyze each video more than once? Write down your measurement plan.

MEASUREMENT

Follow your measurement plan from the Exploration section. Record a video of one collision situation. Use a stopwatch and the distance traveled by the cart before impact with the bumper to estimate the initial velocity of the cart.

Open one your video in VideoTOOL and follow the instructions to acquire data. As a lab group, decide how you will acquire data and analyze the collision. (Will you acquire data for the cart A's motion before the impact and repeat the process for cart A and B after the collision, or will you acquire data for the entire motion of the carts in a single analysis?) Change the masses of the carts and repeat this process for the remaining two collision situations.

Measure and record the masses of the two carts for each situation. Analyze your data as you go along (before making the next video), so you can determine if your initial choice of masses and speeds is sufficient. Collect enough data to convince yourself and others of your conclusions about the efficiency of the collision.

Save all of your data and analysis. You can use it again for Laboratory VI.

ANALYSIS

From your videos, determine the velocities of the carts before and after the collision. Use your equations from the Warm-up and Prediction questions to calculate the initial and final kinetic energy, efficiency, and energy dissipated for each case.

Record the measured and calculated values in an organized data table in your lab journal.

CONCLUSION

Given the same initial energy, in which case(s) ($m_A = m_B$, $m_A > m_B$, or $m_A < m_B$) was the energy efficiency the largest? The smallest? Was it ever the same? Could the collisions you measured be considered essentially elastic collisions? Why or why not? (The energy efficiency for an elastic collision is 1.)

Was a significant portion of the energy dissipated? Was it the same for each collision situation? How does it compare to the case where the carts stick together after the collision? Into what other forms of energy do you think the cart's initial kinetic energy is most likely to transform?

Was your boss right? Is the damage done to vehicles when a car hits a stationary truck and they bounce apart less than when a truck hits a stationary car (given the same initial kinetic energies)? State your results that support this conclusion.

PROBLEM #5:
POWER AND THE HUMAN BODY

You have a summer job in a laboratory investigating the factors that determine the maximum rate of energy output (power) from a human body. You realize that your body cannot convert all of its energy into mechanical energy - some of it goes into your body's responses such as sweating, increased heart action, and body temperature change. Most of these body responses seem to be linked to increased heart rate. You decide to determine if the usable mechanical power produced by humans is a function of a person's heart rate. The easiest change in energy of a system to measure is the change in gravitational potential energy. You will also determine the maximum human power output under this situation.

EQUIPMENT

You are the piece of equipment for this problem. You will be free to use the physics building and its surrounding area along with whatever is in the lab already. But, you must have your TA's approval before you begin! A stopwatch and a wide range of masses will be provided.

PREDICTIONS

Write down a relationship between power, energy, and time. Make an educated guess of the maximum useable power your body can produce.

Make a qualitative guess at the relationship between heart rate (pulse) and power output, and sketch a graph of your heart rate versus the usable mechanical power you are producing.

WARM-UP

Read: Serway & Vuille Chapter 5, Sections 5.2, 5.3, and 5.6.

1. Draw a picture that shows a situation in which you can easily measure the energy you transfer to do a specific task. Define the system transferring the energy and the system that the energy is transferred to. Write down the energy of each system before the transfer. Write down the energy of each system after the transfer.

2. Write down the energy conservation equation for this interaction process. Identify which terms in your equation represent the useful energy.

3. Identify the time interval in which you complete the energy transfer process.

4. Write an expression for the useful power transferred by your body, in terms of energy and time. How is heart rate related to power transferred by your body? Is there a reasonable limit to how high your heart rate can be?

EXPLORATION

Develop a simple way to determine your own useful power output. You must determine a way to measure your useful energy output over a period of time. Consider the ways that you know how to measure a change in energy - the easiest to measure is a change in potential energy. Determine whether you will use your arms or legs to transfer the energy.

Always stay in control while you are measuring your power output. Do not hurt yourself! **If you have special health concerns,** please consult your teaching assistant and/or have another member of your group try the method that you devised to determine the power output of a human.

Make a few test runs using the method that you have devised. What will affect your ability to measure your usable power output accurately? Consult your teaching assistant if you are having difficulties measuring your power output.

Try producing the largest range of useful power output possible. Find the smallest power output that gives a measurable effect and the largest power output that is comfortable for you. Qualitatively, what happens to your pulse rate? What are some other physical responses your body has? Will you need to rest in between each trial in order to get an accurate measure of your pulse rate for each independent trial?

What is the difference between peak power and average power? What should you use in your analysis? If you use average power, over what time interval will you take the average?

MEASUREMENT

As a group, decide who will produce the power for your measurements. Settle on a consistent method and make the necessary measurements to determine the power output. Produce a range of powers and measure your pulse rate for each case.

ANALYSIS

Create a graph of heart rate (pulse) versus power output. How does it compare to your prediction?

CONCLUSION

What are some of your body's responses to power production? Does the response depend on how much power is being produced? What happens to your heart rate (pulse) as you produce more power?

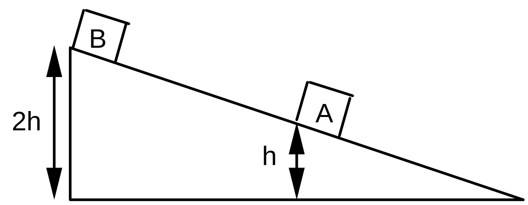
What was your largest power output? How long do you think that you could sustain your largest power output? What power output could you sustain for a long time?

☑ CHECK YOUR UNDERSTANDING

1. A 1-kg ball dropped from a height of 2 meters rebounds only 1.5 meters after hitting the floor. The amount of energy dissipated during the collision with the floor is

   (a) 5 joules.
   (b) 10 joules.
   (c) 15 joules.
   (d) 20 joules.
   (e) More than 20 joules.

2. Two boxes start from rest and slide down a *frictionless* ramp that makes an angle of 30^o to the horizontal. Block A starts at height h; while Block B starts at a height of 2h.



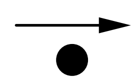
   a. Suppose the two boxes have the same mass. At the bottom of the ramp,

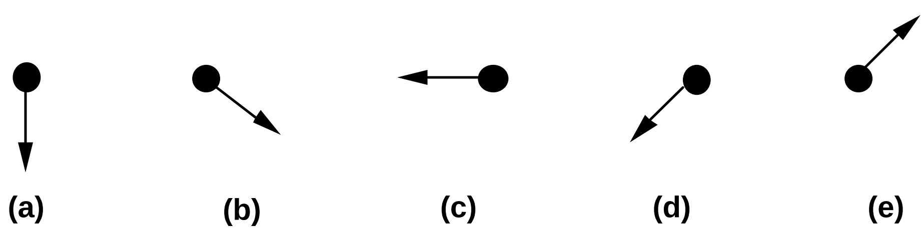
   (a) Box A is moving twice as fast as box B.
   (b) Box B is moving twice as fast as box A.
   (c) Box A is moving faster than box B, but not twice as fast.
   (d) Box B is moving faster than box A, but not twice as fast.
   (e) Box A has the same speed as box B.

   b. Suppose box B has a larger mass than box A. At the bottom of the ramp,

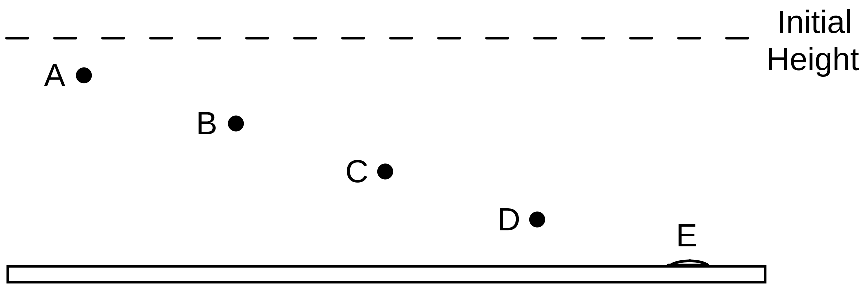
   (a) Box A is moving twice as fast as box B.
   (b) Box B is moving twice as fast as box A.
   (c) Box A is moving faster than box B, but not twice as fast.
   (d) Box B is moving faster than box A, but not twice as fast.
   (e) Box A has the same speed as box B.

3. A hockey puck is moving at a constant velocity to the right, as shown in the diagram. Which of the following forces will do *positive* work on the puck (i.e., cause an *input* of energy)?





4. Five balls made of different substances are dropped from the same height onto a board. Four of the balls bounce up to the maximum height shown on the diagram below. Ball E sticks to the board.



a. For which ball was the most energy dissipated in the collision?

(a) Ball A
(b) Ball B
(c) Ball C
(d) Ball D
(e) Ball E

b. Which ball has the largest energy efficiency?

(a) Ball A
(b) Ball B
(c) Ball C
(d) Ball D
(e) Ball E

5. Two carts initially at rest on flat tracks are pushed by the same constant force. Cart 1 has twice the mass of cart 2. They are pushed through the same distance.
a. Which cart has the largest kinetic energy at the end and why?
b. Which cart takes the most time to travel the distance?

TA Name:______________________________

PHYSICS 1101 LABORATORY REPORT

Laboratory V

Name and ID#: ______________________________

Date performed: ______________ Day/Time section meets: ______________________________

Lab Partners' Names: ______________________________

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Problem # and Title: ______________________________

Lab Instructor's Initials: __________

Grading Checklist	Points
LABORATORY JOURNAL:	
PREDICTIONS (individual predictions and warm-up completed in journal before each lab session)	
LAB PROCEDURE (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; logical progression from problem statement through conclusions; pictures provided where necessary; 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.