Chapter 8: Energy

Text:
Chapter 8 *(skip sections 8.7 to 8.9)*
Think and Explain: 1-4
Think and Solve: 1-3

Vocabulary:
Work, energy, Joule, Watt, kinetic energy, potential energy, mechanical energy, power, Conservation of Energy

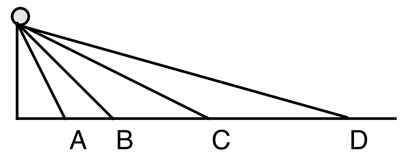
Equations:

$$KE = \frac{1}{2}mv^2 \qquad PE = mgh \qquad W = Fd \qquad P = \frac{W}{t}$$

Key Objectives:
Concepts
- ❑ Relate the direction of force and distance to the work done on an object.
- ❑ Recognize when work is done by a force.
- ❑ Relate the total work done on something to its total energy.
- ❑ Define power and state the units of power.
- ❑ Distinguish between mechanical energy and other forms of energy.
- ❑ Distinguish between potential energy and kinetic energy.
- ❑ Explain the concept of Conservation of Energy.
- ❑ List several types of energy and how it applies to conservation of energy.
- ❑ Describe the energy transformations that take place in daily situations, e.g. driving a car or using a cell phone.

Problem Solving
- ❑ Calculate the work done by a force acting over a distance.
- ❑ Calculate power in watts.
- ❑ Convert between watts and kilowatts.
- ❑ Calculate the kinetic energy, potential energy, and total energy of an object or a system.
- ❑ Apply principle of energy conservation to problem solving involving work, kinetic energy and potential energy.
- ❑ Make and interpret graphs of KE, PE and Total Energy vs time.

Lab 8-1: Rolling Down a Ramp



Purpose: Imagine there is a ball at the top of a hill and there are several ramps getting to the bottom, each with a different steepness. There are two questions you need to experimentally determine:

1. Does the steepness of the ramp affect the time it takes the ball to roll to the bottom, and if so, how?

2. Does the steepness of the ramp affect the final speed of the ball at the bottom of the ramp, and if so, how?

Procedure:
Describe your setup, what you measured and how you measured it.

Make sure height ~10 to 15 cm max. Make sure times are > 1/2 second (so keep distance >1/2 m)

Data:
Make a neat data table for all your trials. Remember units.

Analysis:
Do any math that you need to do here. Explain what you are doing.

Conclusion:
So what did you find? Remember that there are two things you were asked to determine.

Kinetic Energy

Quick Concepts

A. In words, what is kinetic energy?

B. What is the equation (and therefore the definition) of kinetic energy?

C. What are the units used for kinetic energy?

D. Is kinetic energy a vector or a scalar? Why?

E. Can *kinetic energy* ever be negative? Why?

Calculations

1. How much kinetic energy does a 65 kg person running at 2 m/s have?

2. How fast is a 1500 kg car moving if it has a kinetic energy of 200,000 J?

3. What is the mass of something moving at 12 m/s that has a kinetic energy of 1000 J?

4. What is the kinetic energy of a 0.0001 kg bee flying at 5 m/s?

5. A 1200 kg car is driving down the road with a speed of 5 m/s.
   a. What is the kinetic energy of the car?

   b. If the car gains 50,000 J of kinetic energy, how much kinetic energy would it have?

   c. And so how fast would it then be going?

6. A 3 kg box is sliding along the floor. It has an intial speed of 8 m/s.
   a. How much kinetic energy does it have?

   b. If it loses 60 J of kinetic energy, how fast will it be going?

7. If you <u>gain</u> kinetic energy, what has to happen to you?

8. If you <u>lose</u> kinetic energy, what has to happen to you?

Kinetic Energy

9. Both momentum and kinetic energy depend on *mass* and *velocity*.
   a. Is it possible to have a constant kinetic energy, but a changing momentum? Explain.

   b. How about a constant momentum and a changing kinetic energy? Explain.

10. a. Which has more kinetic energy: a mass of 1 kg moving at 2 m/s or a mass of 2 kg moving at 1 m/s?

    b. Which has more momentum: a 1 kg object moving at 2 m/s or a 2 kg object moving at 1 m/s?

11. Imagine there are two objects traveling in opposite directions. A mass of 5 kg moving at 4 m/s to the left and a mass of 5 kg moving at 4 m/s to the right.
    a. What is the total kinetic energy of the two objects?

    b. What is the total momentum of the two objects?

12. Imagine you are driving down the road with a certain speed.
    a. If you double your speed, how much does your kinetic energy change? how about momentum?

    b. If you triple your speed, how much does your kinetic energy change? how about momentum?

    c. If you cut your speed in half, what happens to your kinetic energy? how about momentum?

Answers:

1) 130 J	*2) 16.3 m/s*	*3) 13.9 kg*	*4) 0.00125 J*
5. a) 15,000 J	*b) 65,000 J*	*c) 10.4 m/s*	
6. a) 96 J	*b) 4.9 m/s*	*7) speed up*	*8) slow down*
9. a) Yes. Changing direction at constant speed.		*b) No. Constant momentum implies constant speed.*	
10. a) the 1 kg mass (2 J vs. 1 J)		*b) they are the same. both 2 kgm/s*	
11. a) 80 J	*b) 0 kgm/s*		
12. a) 4x K & 2x p	*b) 9x K & 3x p*	*c) 1/4 K & 1/2 p*	

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Potential Energy

Quick Concepts

A. In words, what is potential energy?

B. The potential energy of something depends on three things - what are they?

C. What is the equation (and therefore the definition) of potential energy?

D. What are the units used for potential energy?

E. If an oject is lifted up, does it gain or lose potential energy?

F. If an object loses potential energy, did it get higher or lower?

G. If you carry a heavy box across the room, did the potential energy of the box change?

Calculations

1. How much potential energy does a 5 kg ball have that is 3 meters in the air?

2. A 20 kg child in a tree has 700 J of potential energy. How high is the child?

3. A 70 kg upset mother is standing on the ground underneath a tree. How much potential energy does she have?

4. A father is climbing a ladder that is propped up against a tree. When he is 2.5 meters high he has 2000 J of potential energy. What was his mass?

5. Which has more potential energy: a 50 kg object 3 meters in the air or a 25 kg object 5 meters in the air?

6. An object has 500 J of potential energy. What would be its potential energy if it were twice as high? How about triple the height? And how about if it were 1/4 the height?

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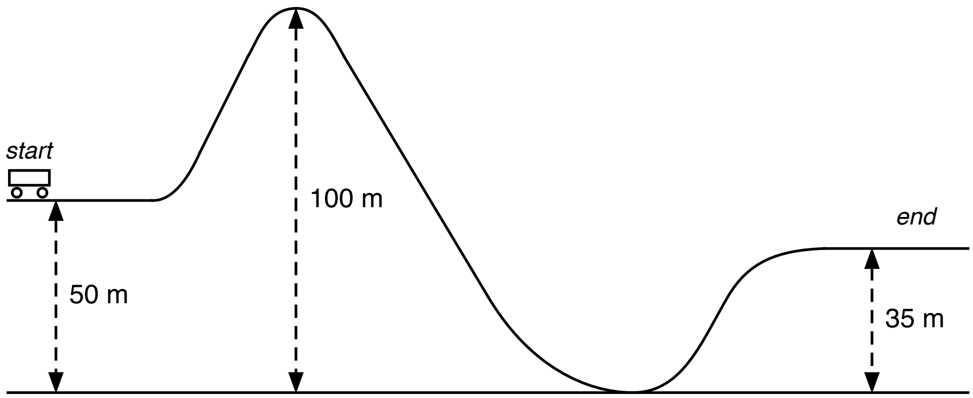
Potential Energy

Questions 7 to 13 refer to the following diagram of a 2000 kg roller coaster.



7. What is the initial potential energy of the coaster?

8. What is the most potential energy the coaster could have? Mark that location on the diagram with an "A."

9. What is the least potential energy the coaster could have? Mark that location on the diagram with an "B."

10. How high is the coaster if it has 1,600,000 J of potential energy? Mark those locations with a "C."

11. At the end of the ride, how much potential energy did the coaster have?

12. How much potential energy did the coaster gain in going to the top of the first hill?

13. How much potential energy did the coaster lose by the end of the ride?

Answers:
1) 150 J 2) 3.5 m 3) 0 J 4) 80 kg 5) 1500 J vs 1250 J, so 50 kg
6) 1000 J, 1500 J, 125 J 7) 1,000,000 J 8) 2,000,000 J (highest point)
9) 0 J (lowest point) 10) 80 m 11) 700,000 J 12) 1,000,000 J 13) 300,000 J

Work

A. What is the definition of work?

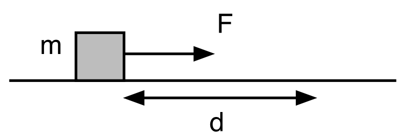
B. How is work related to energy?

C. What are the units for work?

D. Can a force do negative work?

E. If a force is perpendicular to the distance an object moves, how much work would the force do on the object?

Calculations



The diagram above shows a block being pulled across a floor or table by a horizontal force F.

1. If the force was a constant 20 N, how much work was done by the force pulling the object 5 m?

2. If the force was a constant 20 N, how much work was done by the force pulling the object 15 m?

3. How far would a force of 15 N have to pull the object to do 100 J of work?

4. If the distance pulled was 8 meters and the total work done was 90 J, what was the force?

5. If there was a friction force of 5 N, and the object was still pulled to the right 7 meters, how much work did friction do?

6. If friction did –75 J of work, and the object was pulled 8 meters, what was the force of friction?

7. Can friction ever do positive work? Explain.

8. A 35 N force is pulling a box to the right. There is also a frictional force of 15 N acting on the box. The box is pulled a total of 5 meters.
   a. How much work did the 35 N force do?

   b. How much work did friction do?

   c. How much total work was done on the box?

Work

9. A 50 N force is pulling a box to the right a distance of 12 meters. Friction does –200 J of work on the box.
   a. How much work did the 50 N force do?

   b. What was the force of friction?

   c. How much total work was done on the box?

Now Involving Energy!

10. Starting from rest, a 2000 kg car accelerates to 30 m/s.
    a. How much kinetic energy does the car end up with?

    b. How much work was done on the car?

    c. How much work would it take to stop the car?

11. A 4 kg box is lifted 3 meters.
    a. How much potential energy does the box gain?

    b. How much work was done on the box?

12. A 3 kg box has an initial speed of 4 m/s. It slides to a stop in a distance of 1.5 meters.
    a. How much kinetic energy does the box have at the start?

    b. How much work does friction have to do to stop the box?

    c. What was the force of friction while sliding to a stop?

Answers: 1) 100 J 2) 300 J 3) 6.7 m 4) 11.25 N 5) –35 J 6) –9.4 N
7) No! b/c always opposite the motion 8.a) 175 J b) –75 J c) 100 J 9.a) 600 J b) –16.7 N c) 400 J
10. a) 900,000 J b) 900,000 J c) –900,000 J 11. a) 120 J
b) 120 J 12. a) 24 J b) –24 J c) –16 N

Kinetic and Potential Energy Practice

1. A 20 kg rock is lifted 5 m.
   a. What work was done against gravity?

   b. What is its gravitational potential energy?

2. A flower pot weighing 10 N is lifted and given 20 J of gravitational potential energy. How high was it lifted?

3. A 4000 kg roller coaster car is pulled to the top of the first hill, which is 30 m above the starting position.
   a. What is the gravitational potential energy of the car at the top of the hill?

   b. How much work was done on the car to get it to the top of the hill?

   c. What happens to this stored PE as the car travels down the hill?

4. A 10 kg object is moving along at a constant speed of 5 m/s. What is its kinetic energy?

5. If the speed of the object in question 4 doubles, by how much does the KE change?

6. A 5 kg ball is dropped out a window and hits the ground with 500 J of KE. With what speed does the ball hit the ground?

7. If the 5 kg ball hits the ground with 250 J of KE, what is the speed of the ball as it hits the ground?

8. A 0.5 kg lab cart is released on an inclined track. The cart is released from a height of 0.3 m and has a speed of 2.45 m/s at the bottom of the track.
   a. What is the PE of the cart at the top of the track?

   b. What is the KE of the cart at the top of the track?

   c. What is the KE of the car at the bottom of the track?

   d. Why are your answers to *a* and *c* the same?

9. A 1.5 kg cart is placed on a 0.35m high inclined track.
   a. What is the PE of the cart at the top of the track?

Kinetic and Potential Energy Practice

b. What happens to the PE as the cart rolls down the track?

c. What is the KE of the cart at the bottom of the track?

d. What is the speed of the cart at the bottom of the track?

e. If you replaced the cart with a wooden block, would you expect the PE at the top to equal the KE at the bottom? Explain.

10. After graduation, an enthusiastic A-B graduate tosses her 150 g cap into the air with a speed of 6 m/s.
    a. What is the KE of the cap when it is released?

    b. What happens to the KE as the cap travels up?

    c. How high does the cap go?

11. A happy physics student decides to go sledding. He carries his sled (total mass 60 kg) up the hill and does 3300 J of work against gravity.
    a. How high is the hill?

    b. Assuming the snow is frictionless, how fast will the student and sled be moving at the bottom of the hill?

    c. Taking friction into account, would you expect the speed of the student to be more, less or the same as in part c? Explain in terms of energy.

12. Three physics teachers decided to slide down an icy hill. The first teacher has a mass of 60 kg, the second teacher has a mass of 68 kg and the third teacher has a mass of 80 kg. If the hill is 4 m high, which teacher has the greatest speed at the bottom of the hill?

Answers:
1. a) 1000 J b) 1000 J 2) 2 m 3. a) 1,200,000 J b) 1,200,000 J c) turns into KE (& sound & heat) 4) 125 J 5) quadruples! (500 J) 6) 14.1 m/s 7) 10 m/s
8. a) 1.5 J b) 0 J c) 1.5 J d) conservation of energy 9. a) 5.25 J b) KE c) 5.25 J d) 2.6 m/s e) PE>KE, Friction 10. a) 2.7 J b) PE c) 1.8 m 11. a) 5.5 m b) 10.4 m/s c) less 12) they all will have the same speed at the bottom

Lab 8-2: **Energy of a Tossed Ball**

Purpose: 1. To examine graphs of kinetic and potential energy for a toy ball that is tossed up in the air.
2. To see how the total energy of a ball changes as it goes up and down after tossing it in the air.

Preliminary Questions:

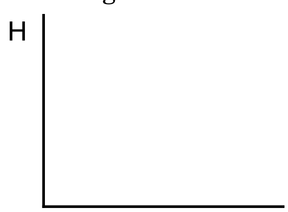
In the following questions, imagine tossing a ball over a motion detector and catching it when it comes back down. Only consider the motion of the ball while it is in the air.

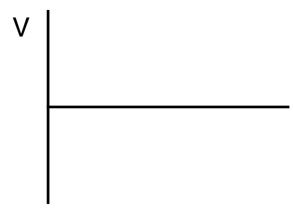
1. What form or forms of energy does the ball have while momentarily at rest at the top of the path?

2. What form or forms of energy does the ball have while in motion near the bottom of the path?

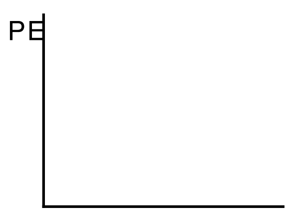
3. What does a height of zero mean to the motion detector?

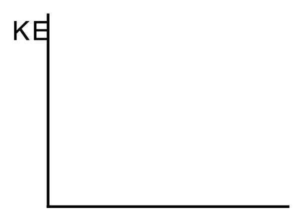
4. Sketch graphs of position vs time and velocity vs. time for the ball while it is in the air. Identify the portions that correspond to the release of the ball, at its maximum height, and when you catch it again.





5. Sketch graphs of potential energy vs. time and kinetic energy vs time for the ball while it is in the air.





6. If there are no frictional forces acting on the ball, how is the change in the ball's potential energy related to the change in kinetic energy?

Procedure:

l. Start Logger Pro by opening up the file that your teacher told you to open up. Look on the board if you didn't pay attention to your teacher.
2. Enter the mass of the ball in the lower right corner of the screen.
3. Place the motion detector on a stool pointing up, and toss the ball up in the air a couple times. With a little luck, one of the tosses will show a "nice" set of graphs. Zoom in on a nice toss (or just ignore the messy ones.)
4. Click on the Examine tool and move the mouse across the distance or velocity graphs of the motion of the ball to answer these questions:
   a. Identify the portion of each graph where the ball had just left your hands and was in free fall. Determine the height and velocity of the ball at this time. Enter your values in the data table.

Lab 8-2: **Energy of a Tossed Ball**

b. Identify the point on each graph where the ball was at the top of its path. Determine the time, height, and velocity of the ball at this point. Enter your values in the data table.
c. Find a time where the ball was moving downward, but a short time before it was caught. Measure and record the height and velocity of the ball at that time.
d. For each of the three points in the data table, calculate the Potential Energy (PE), Kinetic Energy (KE), and Total Energy (TE). Use the position of the Motion Detector as the zero of your gravitational potential energy. Show your calculations below, and record the answers in the data table.

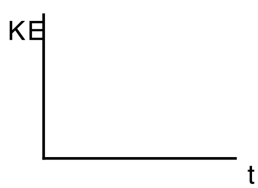
Data:

Position	Height (m)	Velocity (m/s)	PE (J)	KE (J)	TE (J)
After release					
On the way up					
Top of path					
Before catch					

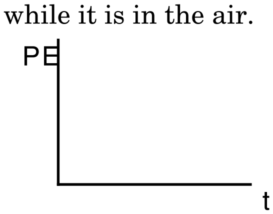
Conclusions:

1. How well do the calculations above show conservation of energy? Explain.

2. Click on the top graph's vertical axis label and change the display to Kinetic Energy, *KE*. Inspect your kinetic energy vs. time graph for the toss of the ball. Sketch the shape of the graph while the ball was in the air and explain what happens to the kinetic energy of the ball while it is in the air.



3. Click on the bottom graph's vertical axis and change the display to the Potential Energy, *PE*. Inspect your potential energy vs. time graph for the toss of the ball. Sketch the shape of the graph while the ball was in the air and explain what happens to the kinetic energy of the ball while it is in the air.

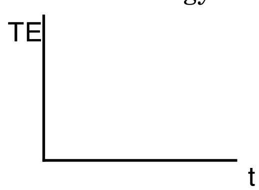


Lab 8-2: **Energy of a Tossed Ball**

4. Compare your energy graphs predictions (from the Preliminary Questions) to the real data for the ball toss.

5. Click on the vertical axis of the KE graph and choose "More" then check Potential energy and click ok. You should now have both the KE and PE graphs on the same graph (rescale if needed). Notice that when KE=0 PE is at a maximum. Why is PE not equal to zero when KE is at a maximum?

6. Logger Pro will also calculate Total Energy, the sum of KE and PE. Click on the top graph's vertical axis label, choose "More" and add the Total Energy to the graph. Sketch the shape of the graph of Total Energy vs time and explain what happens to it while the ball was in the air.



7. What do you conclude from this graph about the total energy of the ball as it moved up and down in free fall? Was energy conserved?

8. Would the shapes of the graphs you made change if you had entered the wrong mass for the ball? Explain.

Follow-Up Questions:

1. A ball is tossed up in the air with 50 J of kinetic energy. Its initial height is 0 meters.
   a. What is its potential energy? How about its total energy?

   b. As it goes up in the air, what happens to its kinetic energy?

   c. As it goes up in the air, what happens to its total mechanical energy?

   d. At its maximum height, what is its kinetic energy? potential energy? total energy?

   e. At some point, the balls kinetic energy is 30 J. What is its potential energy? total energy?

   f. At some point, the balls potential energy is 40 J. What is its kinetic energy? total energy?

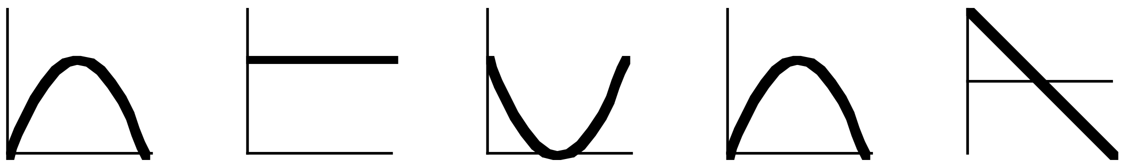
   g. Where is it when:
      i) its potential energy equals its kinetic energy?

Lab 8-2: **Energy of a Tossed Ball**

ii) its total energy equals its kinetic energy?

iii) its total energy equals its potential energy?

2. The following graphs all came from this lab. Label them correctly (include units.)



3. Some other students did the same lab with a 0.25 kg ball. They recorded the initial height and velocity of the ball as shown in the table. Fill in the rest of the table. Here are some hints:
What is the kinetic energy of the ball at its maximum height?
What number stays constant even though the ball is going up and down and changing speeds?

(mass = 0.25 kg)	Height (m)	Velocity (m/s)	PE (J)	KE (J)	TE (J)
Initial Data	0.75	3.70			
Top of Path					
Random Position		-2.3			

4. Explain how the following statement applies to this lab: "Energy can not be created or destroyed, but it can change forms."

Conservation of Energy (no friction)

1. A highdiver (m = 75 kg) is standing atop a 60 meter tall tower and then jumps to a pool below.
   a. How much potential energy does the diver have at the top of the tower?

   b. How much potential energy does the diver have when they hit the water?

   c. How much kinetic energy does the diver have at the top of the tower?

   d. How much kinetic energy does the diver have when they hit the water?

   e. How much total energy did the diver have as they fell?

   f. When the diver was halfway down, how much potential and kinetic energy did the diver have?

   g. How fast was the diver going just as they hit the water?

2. Charlene has a mass of 70 kg and is jumping on a trampoline. The trampoline gives her an initial velocity of 12 m/s straight up.
   a. How much kinetic energy does she have as she leaves the trampoline?

   b. How much kinetic energy does she have at her highest point?

   c. How much potential energy does she have as she leaves the trampoline?

   d. How much potential energy does she have at her highest point?

   e. How high up does she go?

   f. When she is one meter above the trampoline, what is her total energy?

3. You toss your 7 kg backpack straight up in the air, giving it a kinetic energy of 120 J.
   a. How fast did you throw it?

   b. How high does it go?

4. A 72 kg skier is at the top a frictionless hill with a vertical drop of 95 meters.
   a. How much potential energy does the skier have at the top of the hill?

   b. How fast is the skier going at the bottom of the hill?

Conservation of Energy (no friction)

5. A 1500 kg car is stopped on a hill when the brakes fail (i.e. no friction) and it rolls down the hill. The car rolls until it has speed of 3 m/s.
   a. How much kinetic energy does the car have a the bottom?

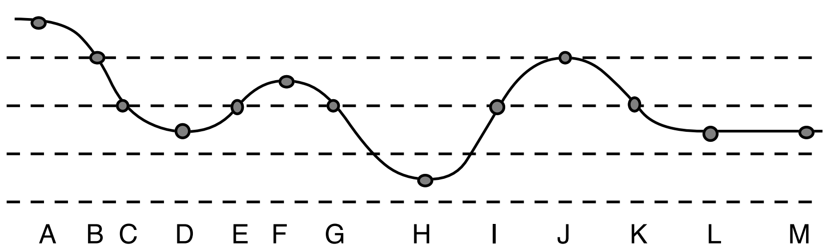
   b. What was the vertical drop of the car on the hill?

6. A frustrated painter throws his brush (m = 0.04 kg) straight up in the air with an initial velocity of 23 m/s. How high does the brush go?

7. A 32 kg child is having fun at the playground on a Super Slide. It is 4.5 meters high and absolutely frictionless. How fast is the child going at the bottom of the slide?

8. A 1300 kg roller coaster car is 45 meters high in the air. It rolls down a frictionless hill, and "falls" a vertical distance of 25 meters to the bottom of the first hill. How fast is the roller coaster car traveling at the bottom of the first hill?

9. The drawing below represents a frictionless hill, with lines of equal height shown. A ball is given an initial kinetic energy at point A, and then the position of the ball is shown at several positions later.



   For each of the questions below, rank the position from greatest to least
   a. Where is the ball going the fastest?

   b. Where does the ball have the most potential energy?

   c. Where does the ball have the most total energy?

Answers: 1. a) 45,000 J b) 0 J c) 0 J d) 45,000 J e) 45,000 J f) 22,500 & 22,500 J
g) 34.6 m/s 2. a) 5040 J b) 0 J c) 0 J d) 5040 J e) 7.2 m f) 5040 J3. a) 5.86 m/s
b) 1.71 m 4. a) 68,400 J b) 43.6 m/s c) 68,400 J 5. a) 6750 J b) 0.45 m c) 6750 J
d) 27,000 N 6) 26.5 m 7) 9.49 m/s 8) 22.4 m/s 9. a) H b) A c) all the same!

Lab 8-4: Power

Purpose: To determine your horsepower as you do work against gravity running up stairs.

Procedure:
1. Calculate your mass in kg from your weight in pounds. Show your work in the table, and record your answer in the table below. Use the conversion factor 1 lb = 0.454 kg.
2. In the stairwell, measure the height from the first floor to the second floor, and record this in the answer column of row 2.
3. Time how long it takes you to go from the first floor to the second floor and record this in the answer column of row 3.
4. Complete each row of the data table below – showing your work in the middle column and the answer in the answer column.

Data & Calculations:

**** Do the data and calculations individually ****

		Show Work Here	*Answer*
1.	Your mass (kg)		
2.	Height change in climbing (m)	---	4.13 m
3.	Time to climb stairs (s)	---	
4.	Potential Energy gained (J)		
5.	Power you generated (W)		
6.	Horsepower (750 W = l hp)		

Questions:
1. What was your horsepower? How long do you think you could do that amount of horsepower (a couple minutes, a few hours, all day, etc.)
2. What was the biggest horsepower generated in the class?
3. What is meant by the term “work?”
4. What is meant by the term “power?”
5. Do the calculations depend on you hitting every step or could you do two steps at once?
6. You seemingly gave yourself potential energy. Where did this energy come from?

NAME: ___________________

Power

A. What is meant by the term "work?"

B. What is power?

C. What are the units of power?

Calculations

1. What is the power of a person that can do 5000 J of work in 4 seconds?

2. A force does 500 J of work in 1 minute. What is the power of the force?

3. How much energy is used by a 75 W light bulb in 2 minutes?

4. How much energy does a 4500 W generator produce if it is running for 6 hours?

5. How long would it take a 40 W engine to do 5000 J of work?

6. How long would take something producing 250 W to do 1,000 J of work? How about 10,000 J?

7. How much power does it take to lift 20 kg to a height of 15 meters in only 5 seconds?

8. How long would it take a 5,000 W crane to lift 150 kg to a height of 30 meters?

9. Every year, there is a race at the Empire State Building, from the ground floor to the 86th floor observation deck. The participants climb 1576 stairs for a total height of 320 meters.
   a. The record for this event is a time of 9 minutes and 33 seconds. If that person had a mass of 70 kg, what was the power needed?

   b. Using <u>your</u> power output from the Power Lab, how long would it take you to complete this task? Do you think that is a realistic estimate of how long it take you to do this?

10. Which is more powerful: doing 1000 J of work in 50 seconds or doing 500 J of work in 25 seconds?

Answers: 1) 1250 W 2) 8.3 W 3) 9000 J 4) 97,200,000 J 5) 125 s 6) 4 s; 40 s 7) 600 W 8) 9 s 9. a) 391 W b) ---- 10) same, both 20 W

Conservation of Energy Concepts

A. What is the Law of Conservation of Energy? (There are two main ideas.)

B. What is meant by "type" or "form" of energy?

Ideas

1. Identify the following types of energy.
   a. The energy an object has because it is moving.

   b. The energy something has because of its height above the ground.

   c. The energy something has because of its temperature.

   d. The energy in a stretched rubber band.

   e. The energy when two opposing magnets are held close together.

   f. The energy in some gasoline.

   g. The energy from the outlets in your house.

   h. The energy in a battery. (There are two decent answers for this one.)

2. Identify the type(s) of energy present in each situation
   a. A dancer is held up in the air.

   b. A hot cup of tea.

   c. A ball is moving up in the air.

   d. A lit candle.

   e. A roller coaster is speeding up going down a hill.

   f. A rock is being held in a stretched elastic band (a sling shot.)

3. For each of the following situations, give the energy transformations that are taking place.
   a. You walk to school.

   b. You drive to school in a non-hybrid car.

   c. You use your phone all day.

   d. Dynamite explodes and breaks apart a building.