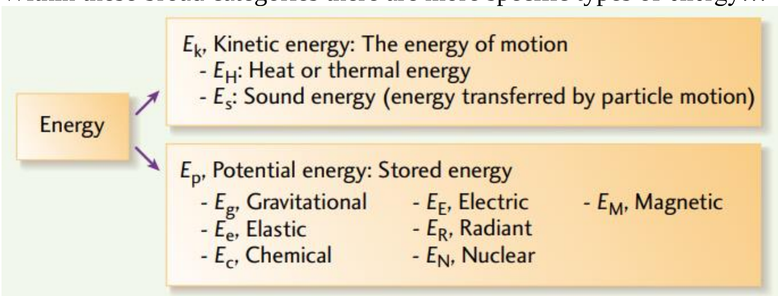
Energy – An introduction

This link (https://bit.ly/343Lgsp) can be useful. We group energy into two broad categories:

potential energy: ____

kinetic energy: ____

Within these broad categories there are more specific types of energy…



Use the following resource to identify one or two examples of each type of energy.

Thermal/heat/sound (K):	Gravitational (P):
Elastic (P):	Chemical (P):
Electric (P):	Magnetic (P):
Radiant (P):	Nuclear (P):

Using various technologies, we are able to transform energy from one form to another. For example, a hydroelectric damn:

Kinetic energy of water → electrical energy

For each of the following processes, identify the energy transformations that are taking place. Note that there can be multiple transformations, or multiple types of energy produced.

a) A match is burning	b) A gas lawnmower cuts the grass
c) A computer	d) A hairdryer
e) A battery powered flashlight	f) A wind turbine
g) A bow and arrow shoots an arrow	h) A nuclear bomb explodes
i) A wrecking ball demolishes a house	j) Solar panels power signs on the highway
k) A gas furnace heats your home	l) Someone jumps on a trampoline

Unfortunately, when we transform energy from one form to another the transformation is not perfect. Some of our input energy gets transformed into other unneeded/undesired/unusable forms of energy, and is essentially wasted.

Energy in Canada – A snapshot

Where do we get our energy from? Where does it go? How efficient is it? The resource found here provides a good visual of how our energy system works: https://www.cesarnet.ca/visualization/sankey-diagrams-canadas-energy-systems

1. ***Start by looking at the energy flow ("All flows") for all of Canada in the year 2013*** Roughly speaking, how does the amount of energy Canada exports compare to how much it uses domestically?

2. ***Now select "Only Domestic flows" for all of Canada in the year 2013*.** What are the main sources of energy in Canada? Write them in order from greatest to least, and estimate (roughly) what percentage each source produces. Take a minute to reflect on your answer. Does anything surprise/bother/encourage you? (no need to write)

3. Look towards the right of the chart: what main categories is the energy being used for? Rank them roughly from greatest to least. Take a minute to reflect. Is this what you expected? Anything surprising? (no need to write)

4. Summarize what you see when you look all the way to the right of the chart. Any reaction? Where is all the energy going?

5. ***Now compare Canada's energy flow in 2013 to 1990 (link if desired: https://bit.ly/3dsrWb0).*** Any major differences? Similarities?

6. ***Now compare Ontario's 2013 energy flow to other major provinces (Quebec, BC, Alberta) (link if desired: https://bit.ly/33ZiFEv).*** Identify some major differences between the provinces.

The charts are interactive – spend some time clicking the various energy flows for additional learning.

Tracking Energy

Energy is a mysterious quantity. If we can find where energy is hidden and how much is there, it becomes a very powerful tool for understanding our universe.

A: The Pullback Car

Your teacher will demonstrate the motion of ***a pullback car***.

1. **Reason.** Two identical carts are moving: one fast and the other slow. Which one has more energy? Describe what you could measure to help decide.

2. **Observe.** The car will be pulled back and let go. Describe the motion of the car.

3. **Interpret.** Complete the chart below listing the types of energy the car has at each moment in time.

Events	1. The hand begins to pull back on the car	2. The hand releases the car	3. The car reaches its top speed	4. The car stops
Type of Energy				
Evidence				

Energy Flow Diagram. An *energy flow diagram* shows the movement of energy between different objects. Only write the names of objects that interact and participate in a flow of energy. Circle the objects that are part of the *system*. Draw arrows between objects to show the flow of energy. Objects outside the system are in the *environment*.

4. **Interpret**. Complete the chart below showing the transfers of energy for each interval.

1-2	2-3	3-4
hand car spring		

5. **Describe**. During interval 1-2, there are three objects that might participate in a flow of energy: the hand, the spring (inside the car) and the car (the rest of the cart). According to the energy flow diagram shown:
   (a) Which objects are system objects? Which are environment objects?

   (b) Which object is gaining energy? Which is losing energy? Draw an arrow showing the transfer of energy.

6. **Describe.** During the interval 3-4 (event 3 the car reaches its top speed and event 4 the car comes to rest):
   (a) Describe the movement of the car.

   (b) What is happening to the amount of kinetic energy? Where did the kinetic energy go? What could we measure to help find the "missing" energy?

Thermal Energy. Energy can be stored in the random vibrations of an object's atoms, which we perceive at *thermal* energy. This often happens when surfaces are rubbing against one another and interact through friction.

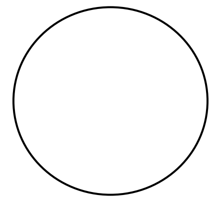
The Idea of the Conservation of Energy. Energy cannot be destroyed and energy can't be created. This powerful idea is called the *conservation of energy*.

B: Going Up the Hill

Your teacher has a cart set up at the bottom end of an inclined track. It has a built-in spring that is initially compressed. There are three events: (1) the cart begins to move (the spring begins to expand), (2) the spring is fully expanded, and (3) the cart reaches its highest point on the track. We will assume that the force of friction on the cart is zero.

1. **Represent and Explain.** Draw an energy flow diagram for interval 1-2. Describe any energy transfers or flows.

1-2

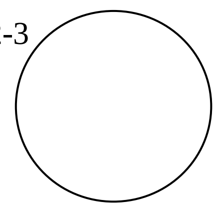


2. **Reason.** During interval 2-3, how is the amount kinetic energy changing? Are any other characteristics of the cart changing?

Gravitational Energy. Gravitational energy is stored energy that exists due to the gravitational interaction with Earth. This energy exists in the Earth-object system. Therefore, we always include Earth as part of the system.

3. **Represent and Explain.** Draw an energy flow diagram for interval 2-3. **System = cart, spring, Earth.** Describe any energy transfers or flows.

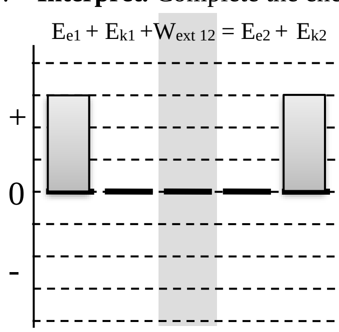
2-3

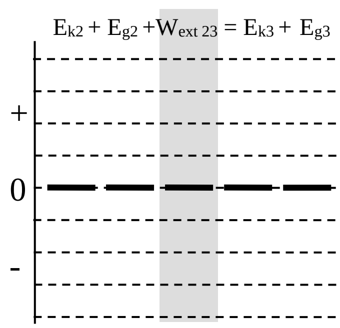


Energy Bar Chart. An *energy bar chart* uses a bar graph to show the relative amount of energy stored in the system objects at two moments in time. The height of the bars is usually not important as long as the bars clearly show the right energy ideas. The middle bar in the chart, W_{ext}, represents the energy flow into or out of the system during the interval of time. Each energy symbol uses a subscript to indicate how the energy is stored.

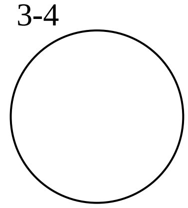
Label	Storage Mechanism	Measureable Characteristic
Kinetic (k)	Movement	speed
Thermal (th)	Vibration of microscopic particles	temperature
Gravitational (g)	The gravitational interaction between Earth and the object (the *field*)	vertical position
Elastic (e)	Stretching or deforming an object	length
Chemical (c)	The chemical bonds between particles	number of bonds/molecules

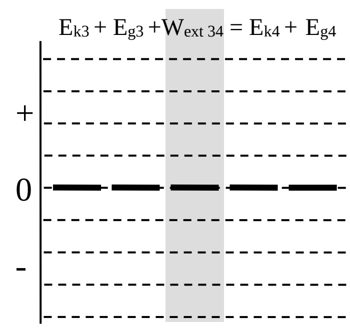
4. **Interpret.** Complete the energy bar charts for each interval. Event 4 is when the cart returns to the bottom of the incline.





3-4





5. There is no gravitational energy in the first chart (1-2). What are we assuming about it?

6. Based on the diagrams, how does the speed of the cart at moment 4 compare to the speed at moment 2.

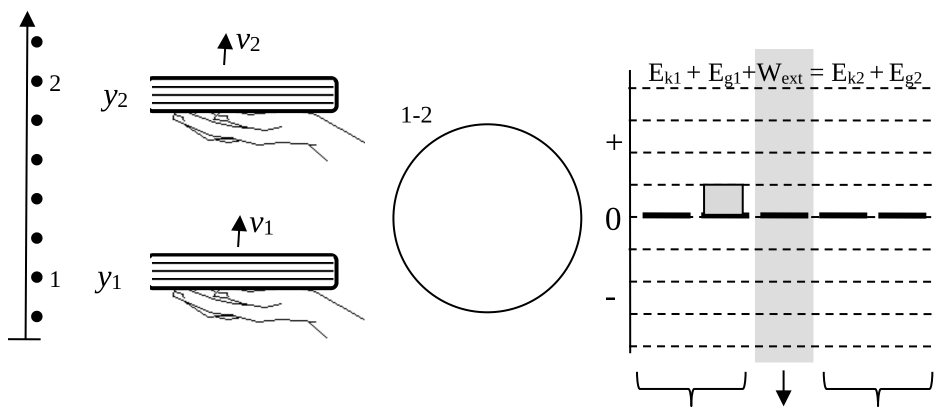
Homework: Tracking Energy Name:

Energy Thinking Process: To track energy, we must answer two important questions:

(1) **Which characteristics of the system are changing?** Start by deciding whether characteristics like the object's *speed* or vertical position is changing. This helps you decide which energies increase, decrease, or stay the same and draw the bar chart. Double check the bar chart math!

(2) **Is energy flowing in or out of the system?** Are there any objects in the environment that are adding energy to or removing energy from the system? Then you are ready to draw the arrows showing the energy flows.

Represent and Explain. You are moving a book with your hand. Three different situations are shown below. For each, complete an energy flow diagram and bar chart. **System = book, Earth**. For each situation, describe the characteristics that are changing and any energy flows. Complete the bar chart double-check; after you count the number of block in each section, the equation at the top should make sense.



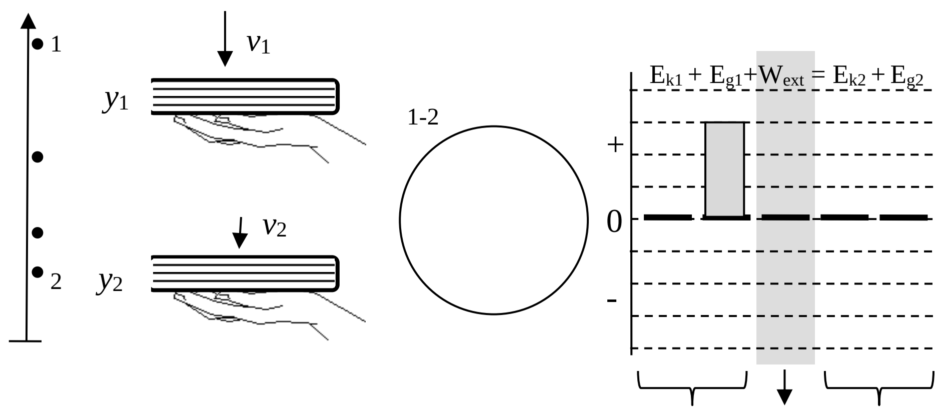
Double check: + =

Describe changes:

- The velocity is constant, so E_k stays the same
- The book is going up, so E_g increases

Energy flow:

- Energy flows in because of the hand



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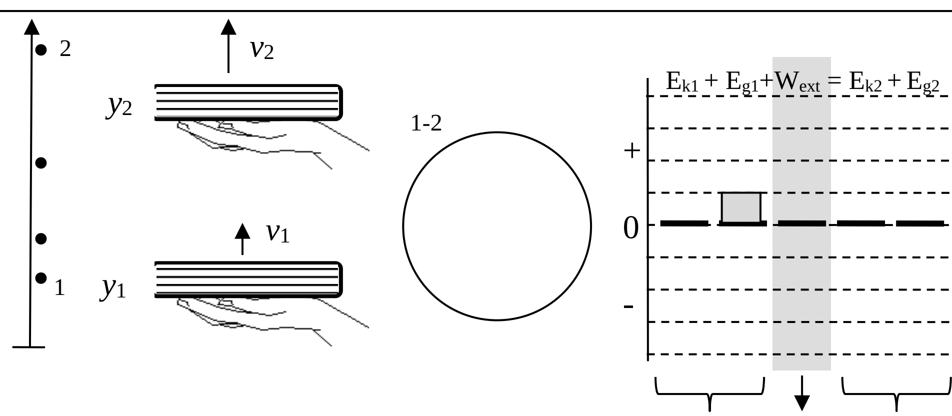
Describe changes:

Energy flows:



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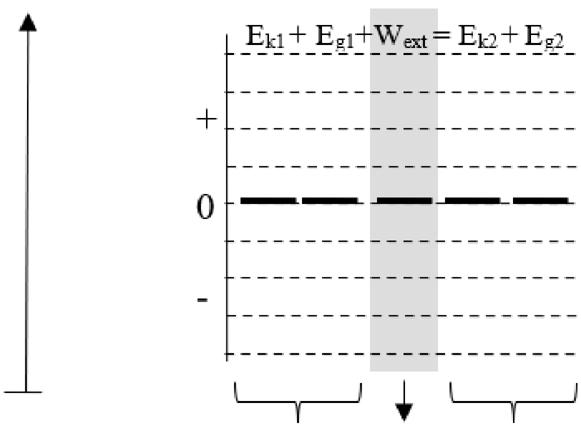
Describe changes:

Energy flows:

Tracking Energy Homework

For each description, complete the energy bar chart and motion diagram, then identify the energy transformations that occur.

a) A car starts from rest at the top of a hill, and the driver accelerates going down the hill



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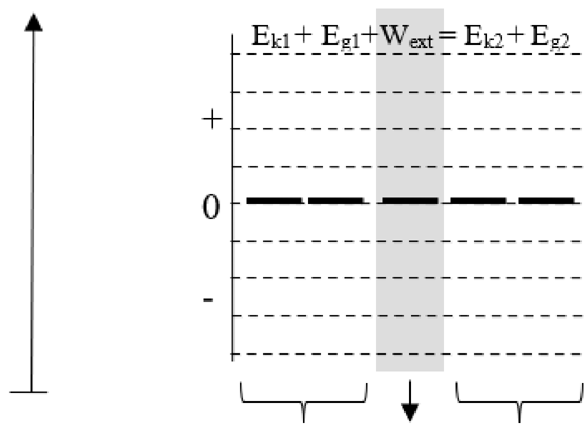
External Energy Transformations…

b) A parachute glides smoothly to the ground at constant velocity.



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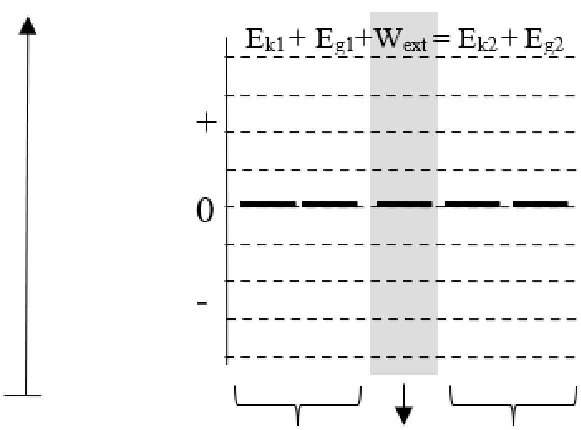
External Energy Transformations…

c) A race car accelerates quickly along a flat race track



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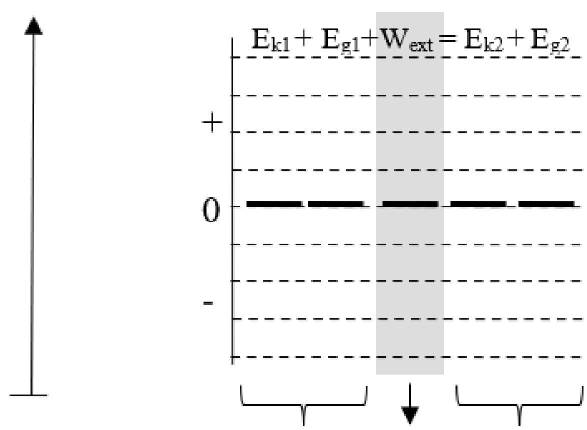
External Energy Transformations…

d) A cannonball is shot upwards and smashes through a castle wall



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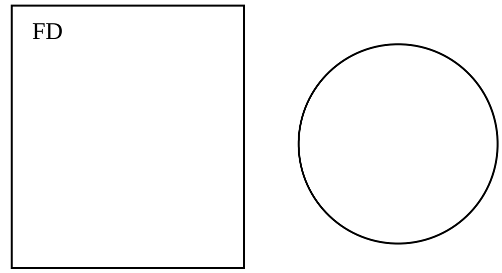
External Energy Transformations…

Doing Work!

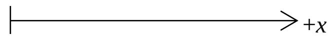
How do we track the transfer energy into or out of a system?

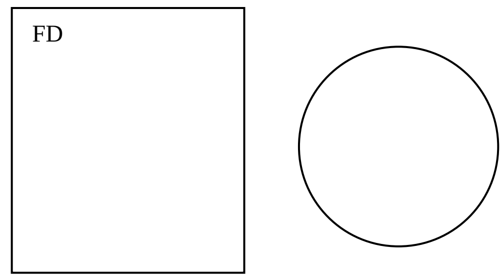
A: The Energetic Cart

We will be using a cart in this investigation, and we will assume the force of friction between the cart and table is zero.

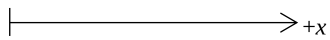


1. **Describe and Represent.** We want some energy to flow from your hand to the cart. Describe how you can do this. Draw a motion diagram, a force diagram, and an energy flow diagram during this process (while it gains kinetic energy). **System = cart**





2. **Describe and Represent.** The cart is initially moving quickly and we want energy to flow from the cart to your hand. Describe how you can do this. Draw an MD, FD, and an energy flow diagram during this process. **System = cart**



3. **Demonstrate**. Use the cart and show these two situations to your teacher. Move on to the next questions while you wait.

Mechanical Work. Energy can be transferred into or out of a system by an external force. We say that the external force does work on the system. If the system loses energy, we say the force does negative work. If the system gains energy, we say the force does positive work. Energy is a scalar quantity; positive or negative work does not indicate a direction, it only indicates a gain or loss of energy for the system.

4. **Explain.** In which case above was the work positive or negative. Explain.

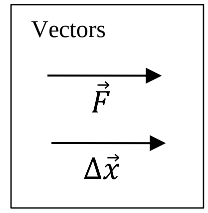
5. **Reason.** Think about the first situation above. What do you think would happen to the amount of energy that flows into the system if your hand exerted the same force for twice the distance? Explain.

6. **Reason.** Think about the second situation above. Suppose the cart was moving at the same speed, but now the force you exerted was twice as large. What would happen to the stopping distance? Explain.

The Definition of Work. The work done by a force on a system (W) depends on three quantities: the size of the force (F), the displacement of the system (Δd) and the angle between the force vector and the displacement vector (θ). These are related by the expression, $W = |F||\Delta d|\cos\theta$. The units of work may be expressed as N·m, but this is equivalent to the unit joules (J) for energy.

B: Working the Angles

1. **Reason and Calculate.** A cart with a mass of 0.70 kg is initially at rest. Then it is pushed horizontally by a hand with a force of 10 N. Friction is negligible.
   (a) Vector arrows showing the direction of the force from the hand and the displacement of the cart are drawn for you. Draw an energy flow diagram for the system of the cart.



   (b) What is the angle between the two vectors? (The angle represents the *difference* in direction of the two vectors)

   (c) After it moves a distance of 0.40 m, how much work (in joules) has been done by the force?

   (d) Interpret the sign of the value for the work that you calculated. How much kinetic energy do you think the cart has now?

2. **Reason and Calculate.** The same cart is rolling along a table and is released. It collides with a block that exerts a 12 N stopping force on the cart. It rolls 0.35 m while stopping.
   (a) Draw vector arrows for the block's force and the displacement of the cart. Draw an energy flow diagram for the system of the cart.

Vectors

   (b) What is the angle between the two vectors? What is the work done by the block's force while bringing the cart to rest?

   (c) Interpret the sign of the value for the work that you calculated. How much kinetic energy do you think the cart originally had?

3. **Reason and Calculate.** Now you push on the cart for 0.50 m while the cart pushes against the block. The block's force is still 12 N and you push horizontally with a force of 15 N.
   (a) Draw energy flow and force diagrams for the system of the cart.

FD

   (b) Calculate the work done by each force acting on the system.

   (c) What is the total work done on the system? How much kinetic energy did the system gain during this process?

Net Work – Kinetic Energy Theorem. The *net work* is the sum of all the work done on the particle. If the net work is positive, the particle *gains* kinetic energy. If the net work is negative, the particle *loses* kinetic energy. This idea is called the *net work - kinetic energy theorem* and is represented by the expression: $W_{net} = E_{k2} - E_{k1} = \Delta E_k$. Note that this is the same as finding the work done on the particle by the net force vector: $W_{net} = |F_{net}||\Delta d| \cos\theta$.

Homework: Doing Work! Name:

You are pulling a wagon. It is a bit tiring, but everything is going well until you try to pull it through a patch of mud. The wagon slows and stops. We will focus on the interval while the wagon is slowing in the mud. We will model the effect of the mud on the wagon like a friction force.

1. **Represent**. Draw an energy flow diagram and a force diagram for the system of the wagon.

2. **Describe.** Which forces cause energy to flow in or out of the system?

FD

3. **Reason.** Use the new expression for work ($W = |F||\Delta d|\cos\theta$) to help complete the chart for each force acting on the car.

4. **Reason.** Overall, is the system gaining or losing energy? Explain how you know.

Force	θ	Sign of work? (+, - or 0)	Flow of energy? (in, out or none)
F_t			
F_f			
F_n			
F_g			

5. **Reason.** Do forces acting perpendicular to the displacement of an object transfer energy in or out of a system? Explain.

6. **Reason.** Did the sign of the work depend on our choice of our positive/negative direction choice? Explain.

7. **Calculate.** The size of your pulling force was 59 N. The friction force from the mud was 75 N. The wagon initially had 8.3 J of kinetic energy. How far did it travel through the mud before stopping?

8. Now you pull the wagon really hard and it starts to speed up.
   (a) **Reason.** Is this situation accurately described by the FD and energy flow diagram above? Explain what changes you would need to make.

   (b) **Reason.** Is the wagon gaining or losing kinetic energy? Use the *kinetic energy-net work theorem* to determine the sign of the net work.

   (c) **Reason.** How does the amount of energy transferred by each force compare in this situation?

Doing Work Homework *(from Irwin Physics 11 p241)*

12. A toddler pushes a chair at a constant speed with a force of 25.0 N for a distance of 2.5 m. How much work is the child doing on the chair?

14. Some physicists with nothing better to do measured the force that teachers were applying to a rope during a staff-student tug of war. The force that was applied by the teachers was 6000 N. How much work did they do on the other team during the two minutes in which they did not move at all?

15. 4050 J of work was done on a pile of snow to move it 3.4 m. What force must have been applied by the snow plow to do this work?

13. A businesswoman is applying a force of 12.0 N [upwards] to carry her briefcase for a horizontal distance of 200.0 m. How much work is she doing on the briefcase?

18. A father is pulling his two girls in their toboggan with a force of 500 N for a distance of 22 m. Calculate the work that would be done by the father in each of the following cases.

a) The snow provides no friction.

b) One of the children drags her hands in the snow, producing a frictional force of 500 N.

c) What visible difference would you see in the motion between a) and b)?

19. How much work is done on a 750 kg load of bricks by a bricklayer if he carried the bricks upward to a height of 8.2 m to repair a chimney?

*Answers: **12**. 62.5J **13**. 0 J **14**. 0J **15**. 12000 N **18a**. 11 000J **18b**. 11000J **19**. 60000 J*

Measuring Energy Homework *(from Irwin Physics 11 p241)*

29. What is the kinetic energy of a 60.0 g tennis ball that is travelling at

a) 10.0 m/s? **b)** 25.0 m/s?

30. What is the mass of an object that is travelling at 10.0 m/s with a kinetic energy of 370 J?

32. A 2000 kg truck is travelling at 80 km/h. What is the kinetic energy of the truck?

33. What speed would the truck in Problem 32 have if its kinetic energy was cut in half by applying the brakes?

34. How much work is done by an Olympic triathlete who accelerates herself on her bicycle (a combined mass of 105 kg) from 5.0 m/s to 10.0 m/s?

35. At what speed must a 250.0 kg motorcycle be travelling to have a kinetic energy of

a) 2.8×10^4 J? **b)** 1.12×10^5 J?

36. How much gravitational potential energy would a 275.0 g book have if it was placed on a shelf

a) 2.60 m high? **b)** 1.80 m high?

c) 0.30 m high?

37. A man decides to climb an office tower using the stairs. If the floors are 3.8 m apart, how much gravitational potential energy would the man have relative to the ground floor if he made it to the

a) fifth floor? **b)** tenth floor?

c) the first basement level?

use m=70.0kg for #37.

38. What percentage of its gravitational potential energy does a squash ball lose if it falls from 3.0 m and returns to a height of 0.76 m after bouncing once?

39. A cliff at the Elora Gorge is 19.6 m above the surface of the Grand River, which is 5.34 m deep. What is a 70.0 kg cliff diver's gravitational potential energy from the top of the cliff with respect to the water's surface and with respect to the bottom of the river?

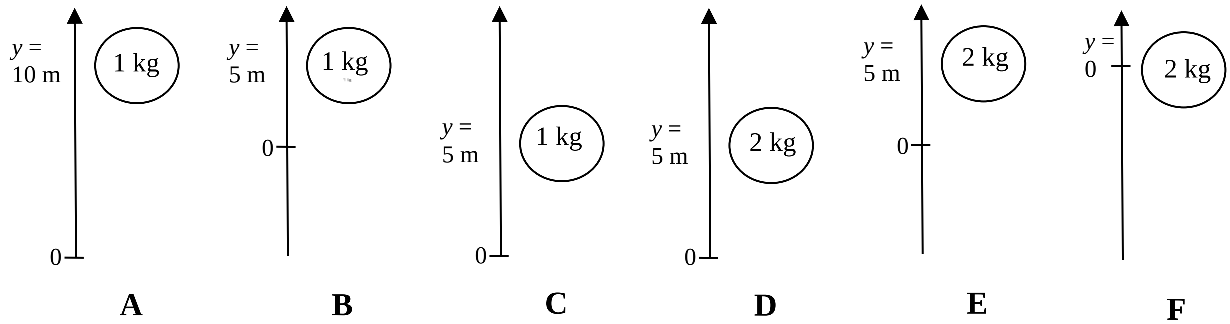
40. A 1.00 kg book falls 0.75 m from a desk to the floor. How much potential energy did the book lose?

*Answers: **29**. 3.00J 18.8J **30**. 7.4kg **32**. 4.9×10^5J **33**. 57 km/h **34**. 3.9×10^3J **35**. 15m/s 30. m/s **36**. 7.15J 0.83J 4.95J **37**. 1.3×10^4J 2.7×10^4J -2.7×10^3J **38**. 75% **39**. 1.37×10^4J 1.75×10^4J **40.** 7.4 J*

<table><tr><td>Homework: Measuring Energy</td><td>Name:</td></tr></table>

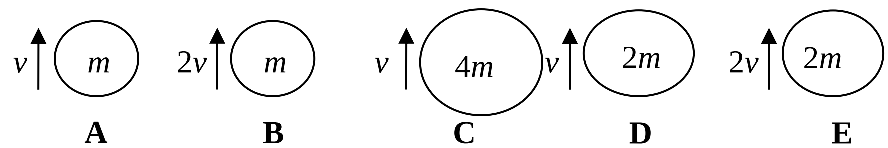
A: Comparing Gravitational Energies Using $E_g = mgy$

1. **Reason.** Six objects and their vertical positions relative to a zero-point are shown. Rank the gravitational energies of each object. Explain your ranking.

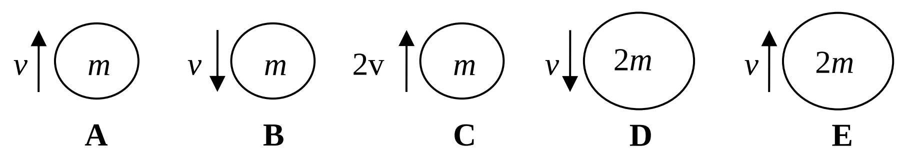


B: Comparing Kinetic Energies Using $E_k = ½mv^2$

1. **Reason.** The velocity and mass of five objects is shown to the right. Suppose v = 1 m/s and m = 1 kg. Rank the amount of kinetic energy each object has. Explain your ranking.



2. **Reason.** The velocity and mass of five objects is shown to the right. Suppose v = 1 m/s and m = 1 kg. Up is positive and down is negative. Rank the amount of kinetic energy each object has. Explain your ranking.



C: Calculating Energies

1. **Reason**. A friend shows you the results of his calculations. (a) Explain what errors he made and (b) correct his work.

m = 250 g
v_1 = 5.0 km/h
y_1 = 3.4 m

$E_{g1} = mgy_1$ = (250 g)(9.8 N/kg)(3.4 m) = 8330 J

$E_{k1} = ½mv_1^2$ = (0.5)(250 g)(5.0 km/h)^2 = 3125 J

2. **Reason.** Two identical test cars are driving down a test track and hit their brakes at the same position. One car is travelling at twice the speed as the other. (a) Compare the kinetic energies of the two cars. (b) Use the idea of work to explain how much farther the faster car travels while braking.

Answer: C#1 E_{g1} = 8.33J and E_{k1} 0.241 J

Changes in Gravitational Energy

When objects move vertically energy flows in or out of Earth's gravitational field. Let's follow these flows and learn how to model the energy transfers in the system.

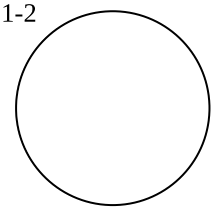
A: The Ball Drop and Kinetic Energy

You will drop a basketball through a displacement of your choice (between 0.5 and 1.2 m) and examine the energy changes.

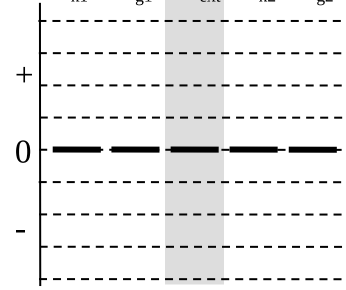
1. **Represent.** Draw a sketch of a ball falling. Event 1 = the ball is released. Event 2 = the ball contacts the ground. Label the two vertical positions y_1 and y_2 (one of these should be the zero-point). Complete the energy-flow diagram and bar chart for the **earth-ball** system.

Sketch

1-2



$E_{k1} + E_{g1} + W_{ext} = E_{k2} + E_{g2}$



Work-Energy Equations. Our bar charts help us to think about energy and to construct an equation that relates the energy of a system at two moments in time. The total energy of a system at one moment plus any work equals the total energy of a system at another moment: $E_{T1} + W_{ext} = E_{T2}$. This is called a *work-energy equation* for the system. The bar chart helps us to decide which energies to include in each total. If a particular energy is zero, we don't bother including it.

2. **Represent.** Construct a work-energy equation for the earth-ball system.

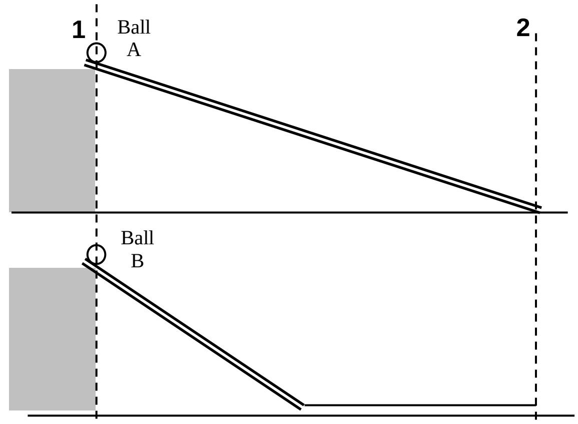
3. **Calculate.** Complete your work-energy equation by replacing each energy symbol with its mathematical expression, including event numbers. For example, E_{g1} is replaced with mgy_1.

4. **Calculate.** Use your new work-energy equation to find the speed of the ball when it contacts the ground. Remember to algebraically isolate for v_2 first! Something neat will happen!

5. **Test.** Use the motion detector to measure the speed of the ball when it contacts the ground.

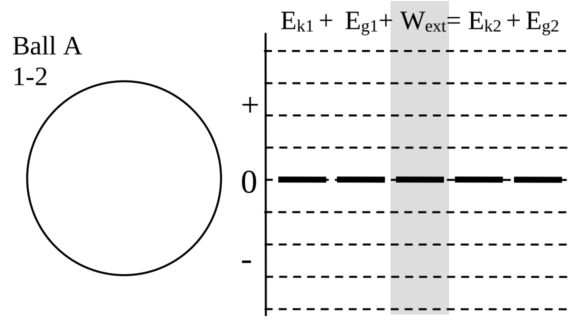
6. **Evaluate.** How does your measured value for the speed compare with your prediction? What might be responsible for a small difference?

B: The Ramp Race



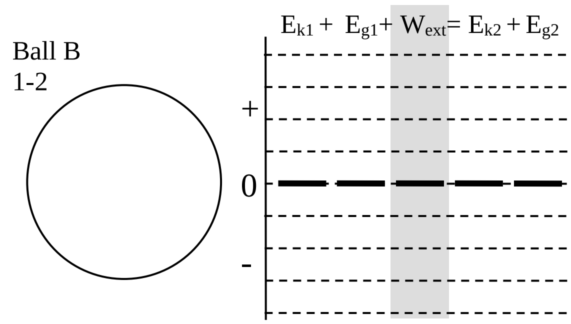
Your teacher has two tracks set up at the front of the class. One track has a steep incline and the other a more gradual incline. Both start at the same height and end at the same height. Friction is very small and can be neglected. There are two important events: (1) Ball A and B are released, (2) Each ball reaches the end of the track.

1. **Reason.** What energy changes take place as the ball travels down the incline?



2. **Represent.** Complete an energy flow diagram and an energy bar chart for each ball for the interval 1-2. **System = Ball, Earth**

3. **Explain.** Describe and explain any similarities between the two sets of diagrams.



4. **Predict.** Use your energy bar chart to predict which ball will have the greater speed at moment 2. Explain.

5. **Observe.** (*as a class)* Record your observations when: (a) the two balls are released at the same time

   and (b) when they reach the end of the track at the same time.

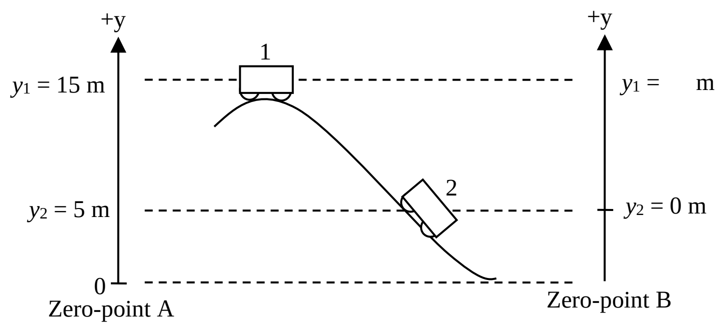
6. **Reason.** Albert says, "I don't understand why ball B wins the race. They both end up traveling roughly the same distance and ball A even accelerates for more time! It should be faster!" Based on your observations and understanding of energy, help Albert understand.

Path Independence. The amount of energy the flows in or out of the gravitational field **does not depend on the path** taken by the object. It only depends on the object's change in vertical position (displacement). The property is called *path independence* – any path between the same vertical positions will give the same results. This happened because gravity does no work on an object during the horizontal parts of the object's motion.

Homework: Changes in Gravitational Energy Name:

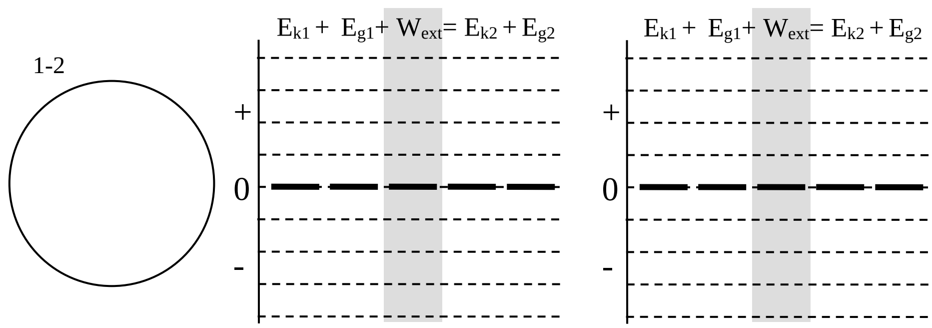
The value for the gravitational energy depends on the choice of the zero-point. If two people choose a different zero-points, will their calculations predict different things? Let's see!

A 100 kg rollercoaster cart rolls down a curving track. It starts from rest at the top. We will examine two moments in time: (1) at the top of the track and (2) part way down. **System = cart, Earth**



1. **Calculate.** Find the value of y_1 using zero-point B.

2. **Represent.**
   (a) Draw an energy bar chart for each zero-point.
   (b) Draw one energy flow diagram.
   (c) Construct a work-energy equation for the system for each zero-point.



Equation:

Equation:

3. **Calculate.** Complete the chart below. Calculate the gravitational energies of the system according to each zero-point. Use these energies to determine how much kinetic energy and speed the cart has a moment 2.

	E_{g1}	E_{g2}	E_{k2}	v_2
Zero-point A				
Zero-point B				

4. **Explain.** Use both the calculations and the bar charts to explain why the choice of zero-point did not affect the results of the calculation.

Changes in Gravitational Energy. Only *changes* in gravitational energy affect predictions using energy techniques. That is why we can set any vertical position as the zero-point. The vertical displacement of the object does not depend on the choice of origin and therefore the *change* in gravitational potential energy does not depend on it either!

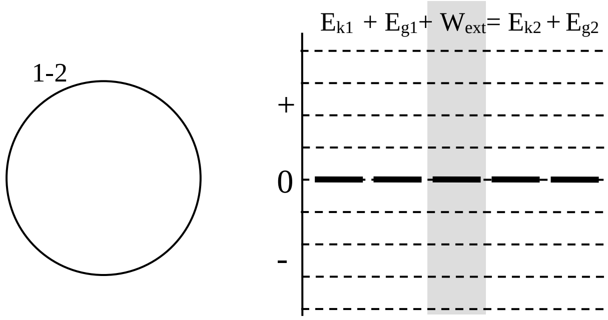
The Conservation of Energy

A: The Behemoth

A recent rollercoaster at Canada's Wonderland is called "The Behemoth" due to its 70.1 m tall starting hill. Assume the train is at rest when it reaches the top of the first hill. We will compare the energy at two moments in time: 1 = at the top of the first hill and 2 = at ground level after the first hill.

1. **Represent.** Choose a zero-point for gravitational energy. Label on the photo the vertical positions y_1 and y_2.

2. **Represent.** Draw an energy bar chart and flow diagram for the earth-train system. Write down a complete work-energy equation that relates the energies of the system at moment 1 with moment 2. Only write down the energy terms that are not zero.



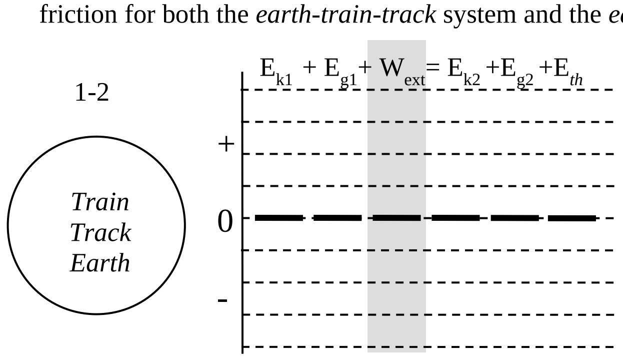
Work-Energy Equation

3. **Calculate.** Use the energy equation to find the speed of the rollercoaster at moment 2 in km/h. (Remember to isolate for the unknown first.)

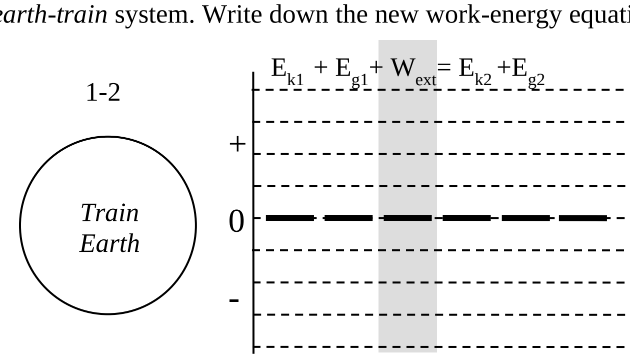
4. **Reason.** The official statistics from the ride's website give the speed after the first drop as 125 km/h. Is our model giving a reliable result? What assumption in our model might need to be changed to get a better prediction?

Thermal Energy. When two objects slide against another, energy is transferred into *thermal energy* (E_{th}) due to a friction interaction. The two sliding objects will warm up, which means the thermal energy is shared between them. You may either treat thermal energy as internal $E_{th} = F_f\ \Delta d$ for the *earth-train-track system* or external $W_{ff}=F_f\ \Delta d$ for the *train-track* system.

5. **Represent.** Draw a new energy storage bar graph and an energy flow diagram that takes into account the effects of friction for both the *earth-train-track* system and the *earth-train* system. Write down the new work-energy equations.



Work-Energy Equation



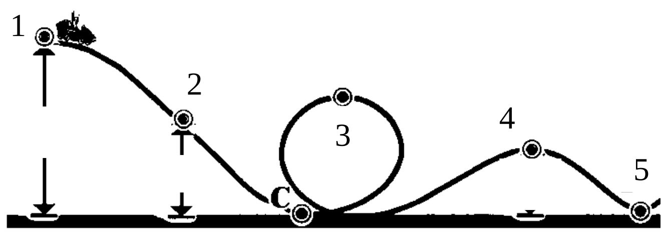
Work-Energy Equation

6. **Calculate.** Use the train mass, $m_t = 2.7 \times 10^3$ kg to determine the amount of thermal energy at moment 2. Hint: which velocity value should you use for E_{k2}?

Answer: v_2 = 14 m/s??

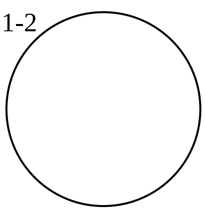
B: The Glebe Flyer

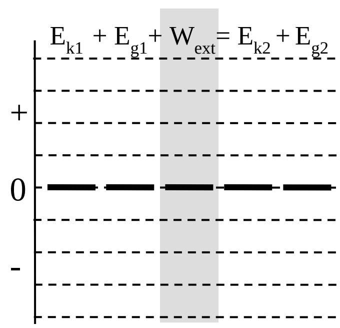
Rumour has it that a rollercoaster is going to be built in our school's courtyard. Plans leaked to the media show a likely design. The train starts from rest at moment 1 located 45 m above the ground. At moment 2 it is located 10 m above the ground. For all our calculations, we will assume that the force of friction is negligible.



1. **Solve.** Label the important vertical positions on the diagram. Complete the diagram and chart. Determine the rollercoaster's speed at moment 2.

1-2

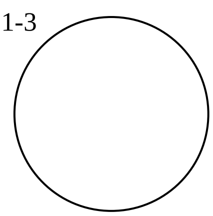


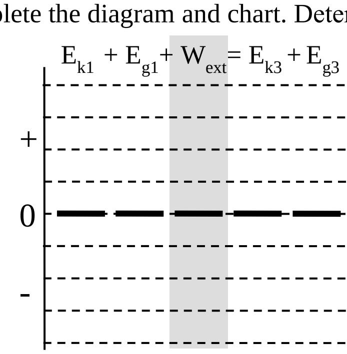


Equation

2. **Solve.** Label the important vertical positions on the diagram. Moment 3 is the top of the loop-de-loop and is located 17 m above the ground. Complete the diagram and chart. Determine the rollercoaster's speed at moment 3.

1-3



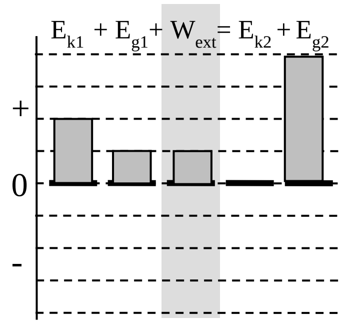


Equation

Path Independence. The full loop-de-loop motion involves some interesting but challenging physics. But by using energy techniques, we did not have to consider those complications at all. When there are no transfers to thermal energy, we don't have to worry about the path an object takes during the interval, no matter how complex. Wow!

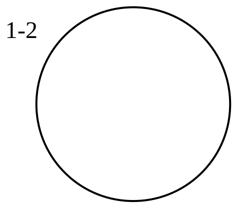
Homework: The Conservation of Energy Name:

1. **Reason.** A block is attached to a rope so you can raise or lower it vertically. An energy bar chart illustrates the energies at two moments in time while it is being raised or lowered.
   (a) Use the bar chart to explain what is happening to the speed and position of the block.
   (b) Draw an energy flow diagram and write a complete work-energy equation for each interval.

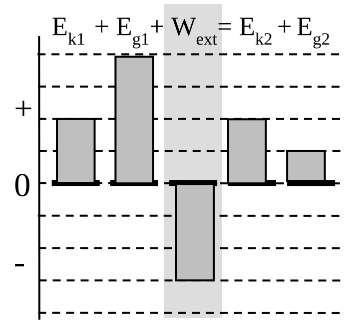


Explain:

Flow:

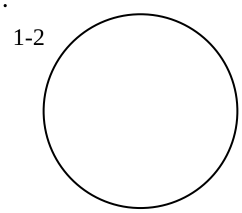


Work-Energy Equation:

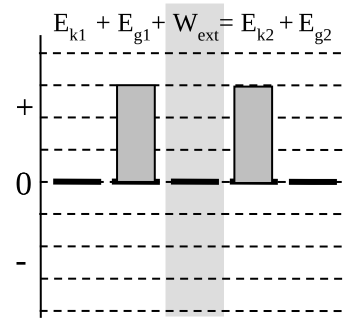


Explain:

Flow:

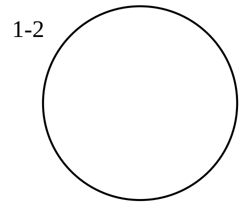


Work-Energy Equation:

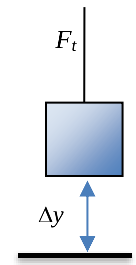


Explain:

Flow:

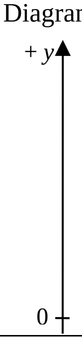


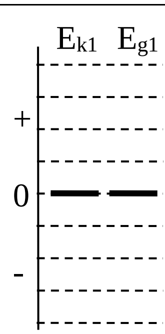
Work-Energy Equation:



2. **Represent and Calculate.** You throw a 200 g ball upwards. It leaves your hand with a speed of 10 m/s. We choose a vertical origin at the vertical position where the ball is released from your hand. We examine three moments in time: (1) it leaves your hand, (2) it is halfway up, and (3) it is at its highest point.
   (a) Draw a motion diagram and label these moments.
   (b) For each moment in time, complete an energy bar chart for the earth-ball system.
   (c) Calculate the energies at each moment and find the total energy of the system. Show your work.

Motion Diagram

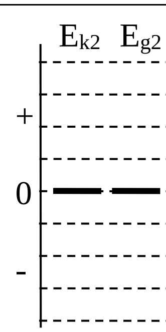




E_{k1} =

E_{g1} =

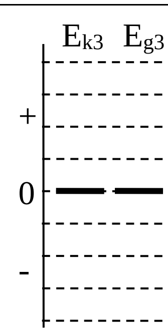
E_{T1} =



E_{k2} =

E_{g2} =

E_{T2} =



E_{k3} =

E_{g3} =

E_{T3} =

   (d) How does the total energy compare at each moment in time? Does this make sense?

Conservation of Energy Homework *(from Irwin Physics 11 p241)*

41. A 5.0 kg rock is dropped from a height of 92.0 m. What is the kinetic energy and the gravitational potential energy when the rock is 40.0 m from the ground?

42. A ball of mass 240 g is moving through the air at 20.0 m/s with a gravitational potential energy of 70 J. With what speed will the ball hit the ground?

43. A basketball rolls off the rim and falls to the floor from a height of 3.05 m. Then it bounces up and loses 15% of its kinetic energy. To what height will it rise this time?

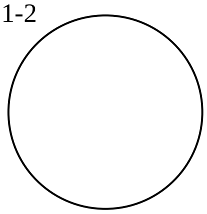
44. The Jetscream amusement park ride at Paramount Canada's Wonderland is shown in Fig. 7.25. It starts off by swinging like a simple pendulum until its amplitude becomes so great that it swings completely around. If the diameter of the circle is 30.0 m, what speed must the ship have at the very bottom to just make it to the highest point and sit there with no residual speed?

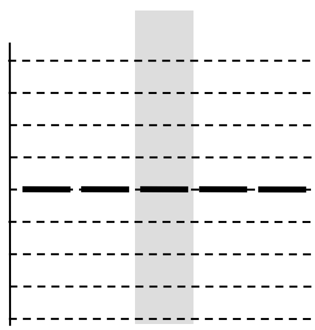
Answers: **41**. E_{k2}=2600J E_{g2}=2000J **42**. 31. m/s **43**. 2.59 m **44**. 24.5 m/s

Representing Conservation of Energy

1. **Represent.** A car is speeding along Carling Avenue. It begins to travel up a hill when the driver spots an accident ahead and slams on the brakes. The car skids and quickly stops part way up the hill. Complete an energy flow diagram, work-energy bar chart and equation for this situation. Be sure to add in the energy labels to the bar chart.

1-2

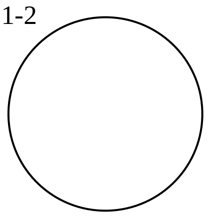


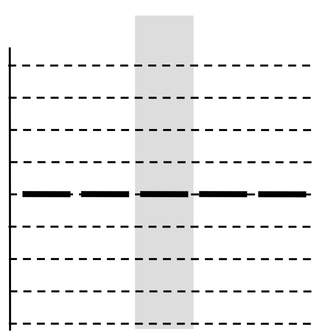


Work-energy equation:

2. **Represent.** A ski resort uses a motor and a rope to pull beginning skiers up a small hill. At event (1) the skier is starts at rest at the bottom of the hill. He grabs the rope, and at event (2) is moving with a constant speed near the top of the hill. Complete an energy flow diagram, work-energy bar chart and equation for this situation.

1-2





Work-energy equation:

Lesson 6: Power

Winning a sprinting race is all about transferring as much energy as possible in the least amount of time. The winner is often the most *powerful* individual.

Power. *Power* is a ratio of the amount of energy transferred (ΔE) to the time taken (Δt): $P = \Delta E / \Delta t$. If that energy transfer is due to work, then $\Delta E = W$. The S.I. unit for power is the *watt* (W) where one watt of power means one joule of energy transferred for each second of time (1 W = 1 J/s).

A: The Stair Master

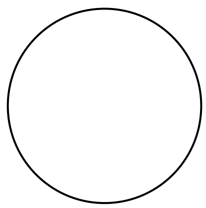
Let's figure out our leg power while travelling up a flight of stairs. We chose two events: (1) at rest at the bottom of the stairs, and (2) at rest at the top of the stairs.

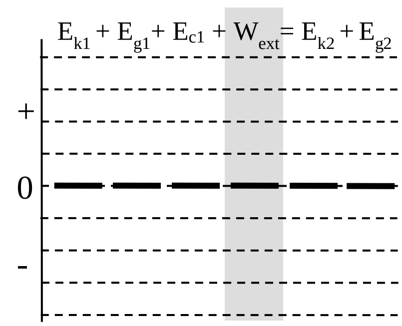
1. **Reason.** Describe the energy changes that take place between events 1 and 2. E_c represents an amount of chemical energy stored in your muscles.

2. **Represent.** Complete an energy flow diagram and bar chart for the interval 1-2. What is the system?

3. **Reason.** To calculate your *power*, you need to identify the change in energy, ΔE, that you will use. There are two important changes in energy in this situation: ΔE_c and ΔE_g. Which of these best represents a change in energy involved with your power *output*?

1-2





4. **Represent.** Draw a sketch showing events 1 and 2. Be sure to label y_1, y_2, v_1, and v_2 in your sketch. Label any other quantities you will measure to find your power.

*** check with your teacher before gathering any equipment ***

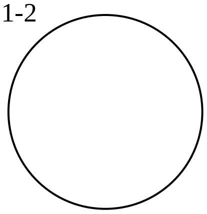
5. **Observe.** Gather the equipment you will need for your measurements. Travel up a flight of stairs at a modest pace (but don't run, we don't want you to fall!) Record your measurements on your diagram.

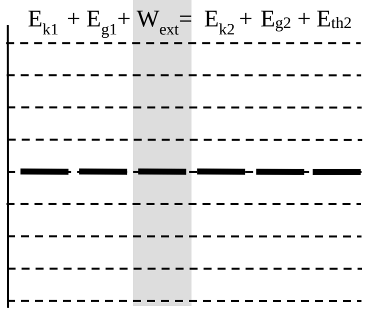
6. **Calculate.** Compute your leg power in watts (W) and horsepower (hp) where 1 hp = 746 W. Show your work. How does this compare to your favourite car? (2020 Honda Civic = 158 hp)

B: Back to the Behemoth!

1. **Solve.** The trains on the Behemoth start at rest from at the loading platform (10 m above the ground) and are lifted to the top of the first hill in 67 s by a chain. At the top, 70.1 m above the ground, the train has a speed of 1.7 m/s. Along the way, the train experiences a frictional force of 3724 N over a 99 m distance along the track. The train (including passengers) has a mass of 2700 kg. How powerful should the motor be to accomplish this task? Complete the energy diagram and bar chart below**. System = earth, train, wheels.**

1-2



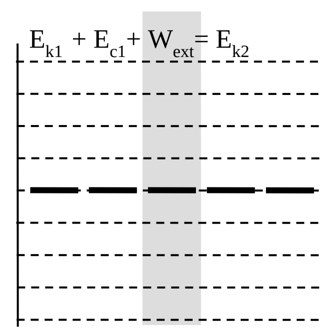


Work-energy equation:

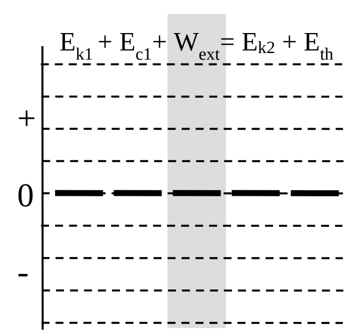
C: He's Got the Power

1. **A Powerful Run.** Usain Bolt is able to reach a top speed of 44.72 km/h by the 65-m mark of a 100-m race. It took him about 6.3 seconds to reach that top speed. He has a mass of 96 kg. He accomplishes this by transferring energy stored in chemicals in his legs into kinetic energy. We will explore his ability to change chemical energy to kinetic energy using two models.

   (a) **Model #1: 100% Efficient.** Let's begin by assuming that all Bolt's chemical energy is transferred to kinetic energy. Draw an energy bar chart showing the transfer of energy. What is his power while he is accelerating to his top speed?



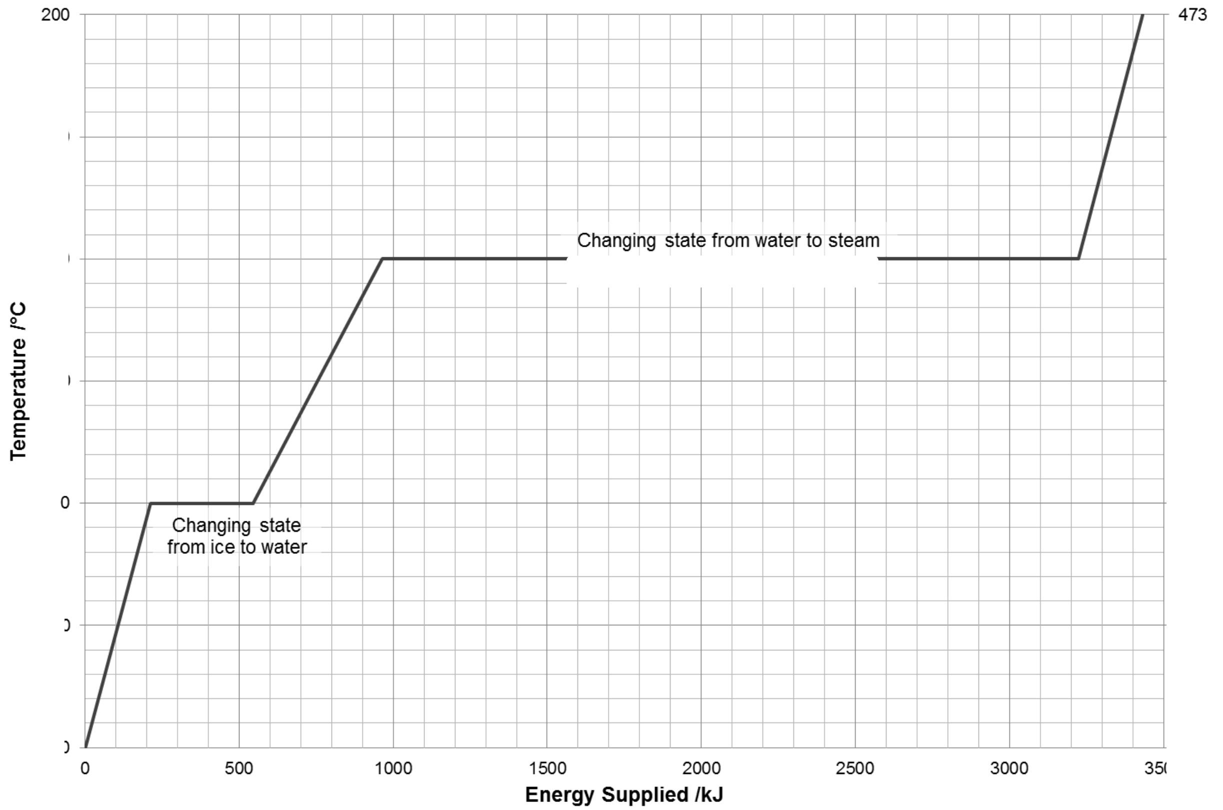
   (b) **Model #2: Thermal Losses.** Unfortunately, the human body is not perfectly efficient like our chart above suggests. Quite a bit of chemical energy becomes thermal energy. Let's assume that his muscles are 50% efficient at transferring chemical energy to kinetic energy. Draw the bar chart for this revised situation. What is his power output now?



2. **Energy Consumption**. Which consumes more energy, a 1.2 kW hair dryer used for 10 minutes or a 10 W nightlight left on for 24 h? (Hint: what unit should be used for time?)

SPH3U: Thermal Energy & Specific Heat Capacity

1) Use the diagram of *temperature of a 1kg block of ice* to answer the questions below



From http://wordpress.mrreid.org/2012/09/27/specific-heat-latent-heat-and-scalds/

The plateau at 0°C is when solid water (ice) is changing into liquid water (water).

a) What does the higher plateau represent? ____

b) At what temperature does the second plateau occur? ____________________________________ . Use this information to add a temperature scale (°C).

c) Correctly place the following terms on the diagram: ***solid, liquid, gas***.

d) Use the graph to find the amount of energy required (*ignore change of states*) to raise the temperature of

i) 1 kg of water from 0°C to 100°C?

iii) 1 kg of ice from -100°C to 0°C?

ii) 1 kg of water only 1°C?

iv) 1 kg of steam from 100°C to 200°C?

***Specific heat capacity**, c, is the energy required per unit mass to raise the temperature.*

$c_{water} = 4.2 \dfrac{J}{g\ °C}$ $c_{ice} = 2.1 \dfrac{J}{g\ °C}$ $c_{vapour} = 2.0 \dfrac{J}{g\ °C}$

The specific heat capacity c is used in the equation:

$E_H = mc\Delta T$ where E_H = heat energy
m = mass
c = specific heat capacity
ΔT = change in temperature

e) Compare your answers from question (d) to the specific heat capacities of water, ice and vapour.

2) Use the graph and/or the equation to find the change in temperature of a **2.0 kg** sample of water that absorbs 200 kJ of energy.

3) Use the graph to find the energy required to change the state
a) 1 kg of ice to water @ 0°C
b) 1 kg of water into steam @ 100°C

*The **latent heat** of a substance is the energy needed to change the state of a substance. **Latent heat of fusion** is the energy required to change solid water (ice) into liquid water: L_{fusion}= 330 kJ/kg*
*The **latent heat of vaporization** is the energy required to change water into water vapour: $L_{vaporization}$= 2300 kJ/kg*

Use the graph or the equations to answer the following questions

4) How much energy is needed to vaporize 3kg of liquid water at 100°C into 3kg of water vapour at 100°C?

5) How much energy is needed to increase the temperature of 1kg of liquid water from 10°C to 75°C?

6) A glass of water absorbs 50 kJ of energy and its temperature increases by 12°C, what mass of water was used?

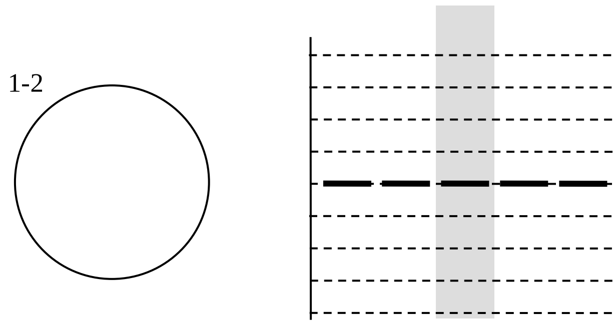
7) How much energy is required to melt a 75 kg snowman (from -10ºC ice to 0ºC water)?

8) How much energy is needed to change 500g of ice at –20ºC into steam at 120ºC?

*Answers: **7**. 2625 kJ **8**. 1566 kJ*

Energy Transfer – including power

1. Represent. The engine of a car transfers the energy stored in gasoline into thermal energy and kinetic energy of the vehicle. In a typical car, only 20% of the energy stored in the gasoline becomes kinetic energy. At moment 1, the car has 1 L of gasoline in its tank. At moment 2, that amount of gasoline has been consumed.



Work-energy equation:

2. **Solve.** Complete question #2 above. A 57 kg skier is pulled up the hill at a speed of 1.1 m/s. The top of the hill is 13.7 m above the bottom. A trip up the hill takes 23 seconds. What is the power output of the motor while pulling this skier?

Heat Energy Homework *(from Irwin Physics 11 p276)*

24. How much heat energy is gained per kilogram of water when it is heated from 10.0°C to 90.0°C?

26. What was the initial temperature of a 1.50 kg piece of copper that gains 2.47×10^4 J of energy when it is heated to a final temperature of 150°C?

28. What temperature change would occur in each of the following circumstances?

a) 250 g of mercury gains 1.93 kJ of heat energy

b) 5.0 kg of water gains 100 kJ of heat energy

29. A 25.0g piece of iron, originally at 500C has its temperature fall to 100C when it is placed in a cold water bath. How much energy was lost by the piece of iron during the cooling process?

31. Native Canadians used to boil water from maple tree sap by heating rocks and placing them into vats of sap sitting in hollowed-out tree logs. For this problem, assume that the syrup and the rocks have the heat capacities of water and sand, respectively. What mass of stone, heated to 1000°C, would be needed to increase 20.0 kg of sap from 60.0°C to 85.0°C?

32. A duck wants to take a bath and fills the tub with 50.0 L of water at a temperature of 38.0°C. After taking a phone call from his friend Bob, a lemming, the bath water had cooled by 10.0°C. How much more hot water at 80.0°C must the duck add to return the bath to the desired temperature?

33. A 200 W heater is used to heat 0.10 kg of a liquid from 20.0°C to 80.0°C, which takes one minute.

a) What is the heat given off by the heater to the liquid?

b) What is the heat capacity of the liquid?

34. a) What is the latent heat of fusion of a 1.5 kg substance that requires 3.75×10^4 J to melt it?

b) When the substance is cooled to its freezing point, how much heat energy is given off by 1.0 kg of the substance when it freezes into a solid?

36. How much heat must be removed by a freezer in order to change twenty 60 g sections of water at 0°C to ice at 0°C?

37. Brandy is made by distilling ethyl alcohol, which is done by boiling the alcohol until it turns into a gas. How much heat is required to completely distil 0.750 kg of ethyl alcohol?

38. A 0.200 kg block of ice at −15°C is placed into a pan on a stove, heated to a liquid, and then to vapour with a final temperature of 115°C. Calculate the total amount of heat required for this process.

24. 336 kJ/kg **26**. 108C **28**. 55.1C 4.76C **29**. 4.6 kJ **31**. 2.87 kg **32**. 11.9L **33**. 2.0 kJ/kg **34.** 25kJ/kg 25kJ **36**. 396 kJ **37**. 645 kJ **38**. 622 kJ

SPH3U: Energy Problem Set **Name:**

Energy Transformations, Work and Conservation of Energy

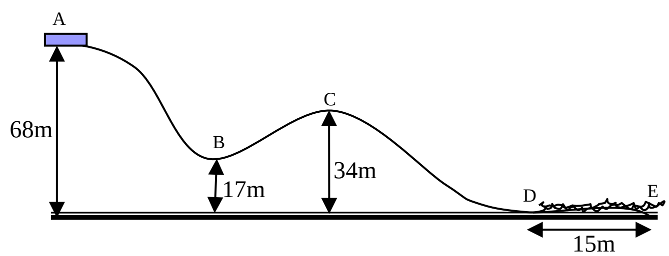
1) A 50.0kg cyclist on a 10.0kg bicycle speeds up from 5.00 m/s to 10.0 m/s in 2.50 seconds. How much work was done by the cyclist? *W=2250J*

2) A person throws a rock from an 85.0 m cliff overlooking the ocean, with an initial velocity of 18.0 m/s [up]. Find the max height of the ball and the velocity of the ball right before it hit the water below the cliff.
h_{max}=101.2m v_3=45.0m/s [down]

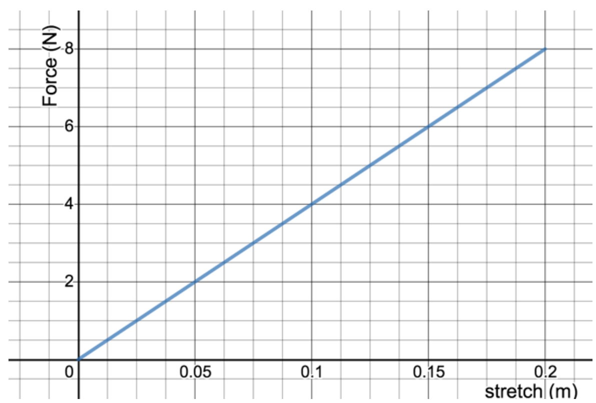
3) A person lifts up a 1.00 kg block from the ground to a height of 2.00 m before releasing it. The block continues travelling another 8.00 m before coming to rest and returning back to the ground. Using the work-energy theorem, calculate the energy of the block and the velocity of the block at each of the events: (1) on the ground (2) at a height of 2.0m (3) at max height (4) halfway down (5) block right before it hits the ground.
$E_{g1}=E_{k1}=0$ v_2=12.7 m/s E_{g2}=20.0J E_{k2}=80.0J E_{g3}=100. J E_{k2}=0J $E_{g4}=E_{k4}$=50.0J v_4=10.m/s
E_{g5}=0K E_{k5}=100. J v_5=14.1 m/s [down]

4) A person is pulling a 15.0 kg box across the floor with a force of 65.0 N [32.0º above the horizontal] for a total displacement of 5.00m (The applied force is equivalent to 55.1N [horizontally] and 34.4 N [vertically]). The coefficient of friction between the box and the ground is μ_k=0.250. Find
   a) the normal force — F_N=116 N
   b) the acceleration of the box — a=1.75 m/s^2
   c) the work done by each of the forces — W_{Fa}=276J W_{Ff}= -145J W_{Fnet}=131J
      $W_{Fn}=W_{Fg}$=0J
   d) the final velocity of the box — v_2=4.18 m/s

5) A 100.0 kg cart starts at point A at 2.00 m/s (68.0m off the ground) on a smooth rollercoaster.
   a) Find the speed of the rollercoaster at point B, 17.0m off the ground.
   b) Find the breaking force required to stop the cart in 15.0m if the brakes are applied at point D
   c) Find the coefficient of kinetic friction
   v_B=32.0 m/s *$F_{breaking}$=4547 N* μ=4.55



6) An elastic band is stretched 20.0 cm in order to launch a 14.0g rubber stopper vertically upward.
   a) How much energy is stored in the elastic band?
   b) How high will the rubber stopper rise above the launch height



Power and Efficiency

7) Several friends use a simple rope and pulley to raise a tree house from the ground into a tree. The mass of the tree house is 150 kg. By pulling together, the friends manage to exert an average force of 1.6 x 10^3 N as they raise the tree house a distance of 3.2 m above the ground.
   a) Find the work done in the raising the tree house. *($5.1x10^3J$)*
   b) How much "useful work" is done? *($4.7x10^3J$)*
   c) What is the efficiency of the rope and pulley is raising the tree house? *(92%)*
   d) Suggest why the efficiency of this simple machine is not 100%.

8) A farmer is contemplating using a small waterfall on his property for hydroelectric power generation. He collects data, and finds that 3000 kg of water fall 15.0 m every minute. Assuming the highest possible efficiency that he is able to achieve in transforming the water's gravitational potential energy to electric energy is 74%, what continuous power in Watts could he generate? *($5.4x10^3W$)*

9) A container factory uses 370 W motor to operate a conveyor belt that lifts containers from one floor to another. To raise 250 kg a vertical distance of 3.6 m, the motor runs for 45 s.
   a) Determine the useful energy output. *(8.8kJ)*
   b) How much energy does the motor use? *(17kJ)*
   c) What is the efficiency of the motorized conveyor system? *(53%)*

10) A 1.5 kW water pump is used to empty a swimming pool. It drains a 100 000 L swimming pool by lifting the water from the bottom to a drain hose on the pool deck 3.06 m above the bottom. If the pump was running for 3.5 hours, find the efficiency of the pump. Note that the intended output of the pump is to lift water and 1 L of water has a mass of 1 kg. (*from oerb*) *(15.9%)*

46. A karate blow can transfer 35.0 J of total energy to kinetic energy. If this transfer is only 25% efficient, what maximum velocity can the 70.0 kg target ever reach?

47. Several students in an auto shop class need to lift an engine out of a car using a rope and pulley system. The mass of the engine is 170.0 kg. By pulling as a team, the students can exert a force of about 1.72×10^3 N to lift the engine to the necessary height of 2.20 m.
a) How much "useful work" was done by the students?
b) How much work was done in total to lift the engine?
c) What was the overall efficiency of the students in lifting the engine?

Thermal Energy

$c_{aluminum}=9.1x10^2 \frac{J}{kg°C}$ $c_{ethyl\ alcohol}=2.4x10^2 \frac{J}{kg°C}$ $c_{copper}=3.9x10^2 \frac{J}{kg°C}$ $c_{sand}=8.0x10^2 \frac{J}{kg°C}$
$c_{mercury}=1.4x10^2 \frac{J}{kg°C}$ $c_{iron}=4.6x10^2 \frac{J}{kg°C}$

11) A 21 kg aluminum block absorbs $1.5x10^5$ J of energy. Calculate the change in temperature. (7.8°C)

12) After 2.0 kg of mercury gained 2.52 x 10^4 J of heat energy, its final temperature was 130 °C. What was its initial temperature?

13) Calculate the energy required to melt a 4.0 kg block of ice initially at -20.0°C. (The final temperature of the water is 0°C) E_H=1488 kJ

Table 8.4
Specific Heat Capacities

Material	Specific heat capacity (J/kg°C)
Liquid nitrogen	1.1×10^2
Gold	1.3×10^2
Lead	1.3×10^2
Mercury	1.4×10^2
Steam	2.0×10^2
Silver	2.3×10^2
Ethyl alcohol	2.4×10^2
Glycerine	2.4×10^2
Methyl alcohol	2.5×10^2
Brass	3.8×10^2
Copper	3.9×10^2
Iron	4.6×10^2
Crown glass	6.7×10^2
Pyrex®	7.8×10^2
Granite	8.0×10^2
Sand	8.0×10^2
Aluminium	9.1×10^2
Air	1.0×10^3
Wood	1.8×10^3
Ice	2.1×10^3
Concrete	2.9×10^3
Water	4.2×10^3

Table 8.5
Latent Heats of Fusion and Vapourization

Substance	L_f (J/kg)	Melting/freezing point (°C)	L_v (J/kg)	Boiling/condensation point (°C)
Aluminum	9.0×10^4	659	1.1×10^7	1509
Ethyl alcohol	1.1×10^5	−130	8.6×10^5	78
Methyl alcohol	6.8×10^4	−97.8	1.1×10^6	64.7
Iron	2.5×10^5	1530	6.3×10^6	1820
Lead	2.3×10^4	327	8.7×10^5	1780
Nitrogen	2.5×10^4	−209.9	2.0×10^5	−196.8
Oxygen	1.4×10^4	−218.9	2.1×10^5	−183
Silver	1.1×10^5	960	2.3×10^6	1950
Water	3.3×10^5	0	2.3×10^6	100

Energy Research & Artifact Project

Artifact: an object made by humans with cultural, social or historical significance

In this independent project you need to create some kind of artifact connected to an energy-related topic or issue of your choice. You will be given a great deal of freedom to choose the type of artifact you create, and you will have one full day to work on it. Some examples include:

A poster	A video	A song/rap	An essay/written analysis	A story
A diorama	A piece of art	A poem	An interpretive dance	A pamphlet/brochure
A dramatic production		Public service announcement	Feel free to suggest other options…	

Your artifact can be either informative or persuasive.

Trying to educate people about the issue. Can include both sides of the argument (pros/cons).

Trying to convince people about the merit of an idea (or lack thereof). Can be one-sided/biased.

Some other comments & considerations…

- Yes, you are expected to do some research into your topic
- Artifacts that are primarily visual in nature (ex. a painting) should be accompanied by a brief written explanation describing what the artifact is intending to demonstrate/communicate.
- You will be given one full day at home this week to complete your project
- Artifact can be submitted this week (Oct 23) or when we return for our final week (Nov 2)
- Although you can use any resources you wish, your artifact must contact value added by you. For example, simply making a slideshow of pictures from the internet would not be ok…but assembling those pictures in a creative/artistic/impactful way would be ok
- This is intended to be complete in a day, not over the full upcoming week. **I will keep my expectations reasonable!!**

I will be marking this project according to the following criteria:

Evidence/quality of research & learning	***Effectiveness to inform/persuade***	***Overall impression***

Have fun

Be creative

Learn

Some possible topic ideas: (more ideas to come)

Pipelines – are they really that bad?	First Nations – are they benefitting enough from the energy industry?	Energy in developing countries – how does it work?
Hydroelectricity - what impact do dams have on people & environment?	Buying local – is it really energy efficient?	Air conditioners – comfortable yes, but what's the impact?
Geothermal energy – why isn't there more of it?	Solar panels – can they be improved? Energy cost to build?	Emails – what's the energy/environmental cost?
Why are renewable energy sources still way behind non-renewable	Incandescent vs. fluorescent vs. LED lights – what's it all about?	Wind turbines – ugly eyesore or energy source of the future?
Biomass, tidal energy – what's it all about?	Energy storage – is it a good idea?	Living "off the grid" – how does it work from an energy point of view?
Household heating & cooling -	Vegetarianism – the energy efficient way to live?	COVID – what's been its impact on the energy sector?
Oil & gas – shutting it down would put many out of work	Energy use in other countries – what can we learn from them?	Canada's energy attitudes – regional differences/conflict

SPH3U: Composite System Problems (2020)	Name:

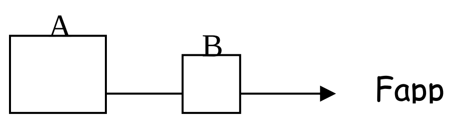
A composite system involves 2 objects moving together: the instantaneous velocity and acceleration of each object is always the same. Each of these problems can be solved using either forces or energy:

To solve using forces, draw one interaction diagram (ID), a force diagram for each object (FDs) and then write Newton's 2nd Law (N2L) equations for each object.

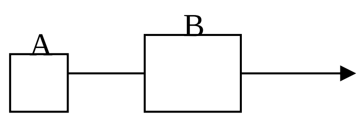
Using energy, draw an energy flow diagram, an energy bar chart and a work-energy equation for each object.

1) Two steel blocks rest on a frictionless, horizontal surface. Block B (m_B= 6.0 kg) is attached by a light string to block A (m_A=12.0kg). Calculate the acceleration of block A and the applied force if the masses travel 3.0 m [right] and the tension in the string between A and B is 24.0N.

a=2.00 m/s^2 F_{app}=36N

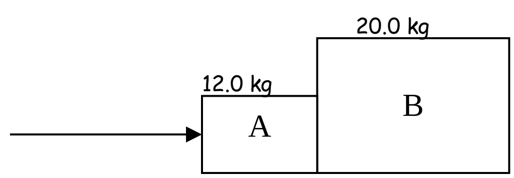


2) A 5.0 kg block A is attached to a 10.0 kg block B on a rough surface where the coefficient of kinetic friction is 0.200. If block A accelerates at 1.80 m/s^2 for 3.00 m [right], calculate the tension in the string between A and B and the applied force. *F_T=19.0N Fa=57.0N*



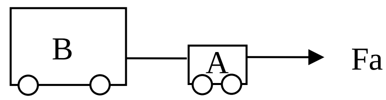
3) Two crates of mass 12.0 kg and 20.0 kg, respectively, are pushed by an applied force across a smooth floor as shown. The creates accelerate at 1.75m/s^2 [right] for 3.00 m [right]. Calculate the force the 20.0 kg box pushes on the 12.0 kg box and the force applied to the crates.

$F_{N\,A\text{-}B}$=35.0N F_a=56.0 N



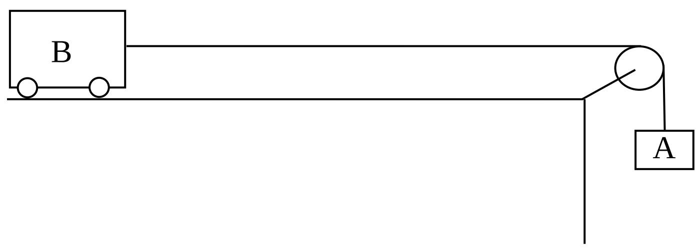
4) An applied force pulls two stationary objects (m_A=10.0 kg and m_B=30.0 kg) connected by a light string on a smooth surface for 0.400s, travelling 3.00m. Find the final velocity of mass B, the acceleration of mass B, the magnitude of the tension in the string and the magnitude of the applied force.

v_2=15.0 m/s a=37.5m/s^2 F_T=1125N F_a=1.50x10^3N

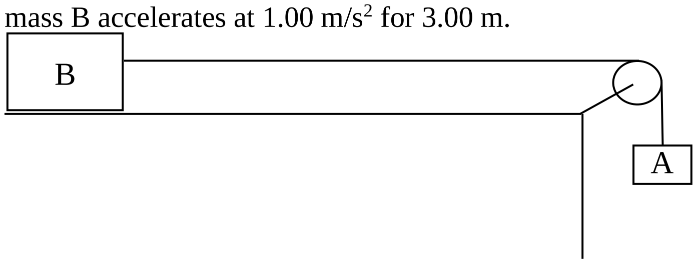


5) Two masses (m_B=30.0 kg & m_A=?) are connected over a massless and frictionless pulley system as shown. Find the acceleration of mass B and the mass A if the tension in the rope is (a) 75N (b) 150 N. Assume the system is frictionless and the displacement = 3.00 m.

(a) a = 2.5 m/s^2 m_A = 10. kg (b) a = 5 m/s^2 m_A = 30. kg

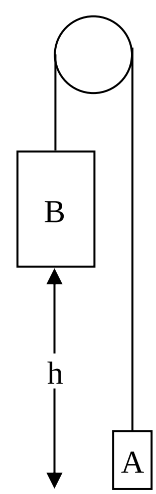


6) Two masses (m_B=30.0kg & m_A=10.0 kg) are connected over a massless and frictionless pulley system as shown. Find the tension in the rope, the final velocity of mass B and the force of friction acting on mass B if mass B accelerates at 1.00 m/s^2 for 3.00 m. FT=90.N v2=2.45 m/s2 Ff=60.0N



7) Two masses (m_B=30.0 kg & m_A=?) are connected over a massless and frictionless pulley system as shown on the right. Find the mass A required so that mass B falls 3.00 m in 5.00 seconds.

m_B=28.59 kg



Lesson 3: Measuring Energy

Recorder: ____________________
Manager: ____________________
Speaker: ____________________
0 1 2 3 4 5

The idea of work provides us with a handy way to measure the amount of energy transferred during some process involving forces. Now we need to use work to find out how much energy transfers into kinetic or gravitational energy.

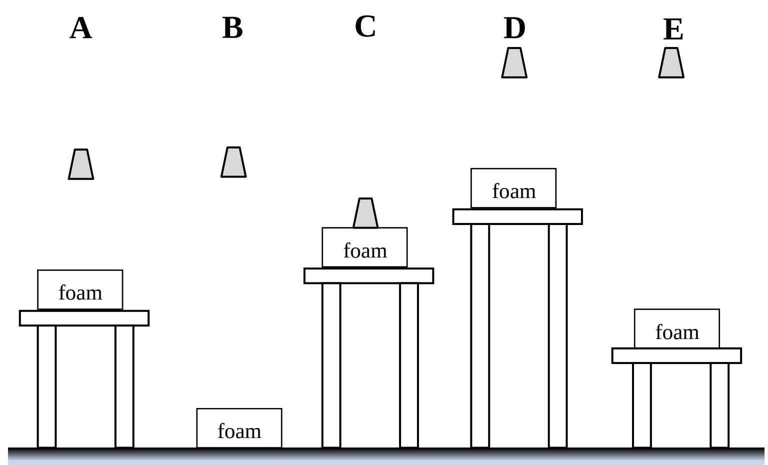
A: Making a Dent in Things

Imagine you lift a heavy weight and place a foam block underneath. You let go of the weight and it falls on top of the block. A dent is left in the piece of foam.

1. **Explain.** How does energy flow while you lift the heavy weight?

2. **Reason.** What could you change about this situation to change the size of the dent in the same foam block?

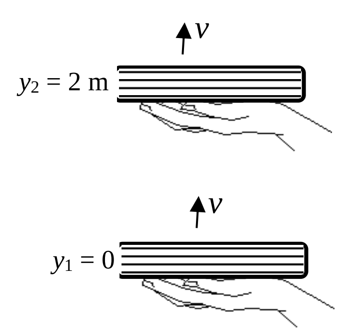
3. **Reason.** A foam block is placed on different tables with different heights above the floor. The weight is released from different positions above the floor. Rank the size of the dent created in each foam block. Explain your ranking.



Gravitational Energy. When we lift an object, energy is flows due to the gravitational interaction between the object and Earth. The energy is stored in the earth's *gravitational field*, not in the object itself – we notice no difference in any characteristics of the object. When we include the earth in our system, we always include its gravitational field.

B: Work and Gravitational Energy

Let's go back to an earlier example. Emmy holds a book of mass m in her hand and raises the book vertically at **constant** speed.



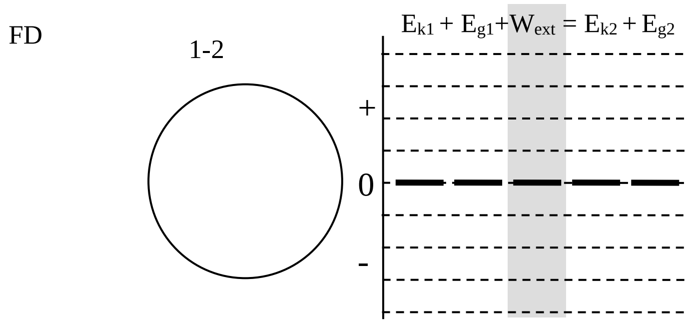
1. **Describe.** During the process of lifting the book, describe the transfers of energy that occur.

2. **Reason.** Suppose we changed y_1 and y_2 by moving each of them one metre upwards. Would this change affect the amount of energy that flows or is transferred in this situation? Explain.

Zero-point for Gravitational Energy. Only the change in an object's vertical position affects the amount of energy flowing in or out of Earth's gravitational field, since we assume the gravitational force is constant. This gives us a freedom to choose a *zero point* for gravitational energy: at a chosen vertical position, we **set** the amount of energy stored in the gravitational field equal to zero. Choosing a zero-point is a critical step in modeling energy problems with vertical movement.

3. **Represent and Describe.** Complete a force diagram for the book. Draw an energy flow diagram and bar chart for the book-earth system. The diagram on the previous page shows your *zero point* for the gravitational energy. Get in the habit of labelling your vertical positions "y_1", "y_2", like in that diagram.

4. **Explain and Calculate.** The bar chart leads us to an equation: $W_{ext} = E_{g2}$. Complete this equation by replacing W_{ext} with an expression for the work using the symbols m, g and y_2.



Gravitational Energy. The *gravitational energy* (E_g) of an object of mass (m) located at a vertical position (y) from the zero-point is given by the expression, $E_g = mgy$. The *zero-point* for gravitational energy is the origin for vertical position measurements where y = 0. As a result, an object has E_g units of gravitational energy *relative* to the zero-point. Or, E_g is the amount of energy we would need to add to (or remove from) the system to move the object from the zero-point to the vertical position y. This equation is constructed based on the choices that g is a positive value and upwards is the positive direction.

Units for Energy. The equations for work and gravitational energy give units of N·m. We choose to create a new unit for energy called the *joule*, where 1 N·m = 1 J. In fundamental units, 1 J = 1 kg·m^2/s^2. Important tip: in order to get an answer in units of *joules*, you must use units of kg, m, and s in your energy calculations!

C: Work and Kinetic Energy

Another example that we looked at earlier was our cart which was at rest and then speed up as we pushed on it with our hand.

1. **Explain.** We are going to create an expression for the kinetic energy of our cart after we push on it. For each step you see in this process, explain the ideas used to get from one step to the next.

Steps	Description
1) $E_{k2} = E_{k1} + W_{net}$	*The final kinetic energy is equal to the initial kinetic energy plus any energy added to the system.*
2) $E_{k2} = W_{net}$	
3) $E_{k2} = \|F_{net}\|\|\Delta d\| \cos\theta$	
4) $E_{k2} = \|ma\|\|\Delta d\|$	
5) $E_{k2} = \|ma\|\|(v_2^2 - v_1^2)/2a\|$	
6) $E_{k2} = \|ma\|\|v_2^2/2a\|$	
7) $E_{k2} = \|m\|\|v_2^2/2\|$	
8) $E_{k2} = ½mv_2^2$	

Kinetic Energy. The energy carried by a moving object is labeled *kinetic energy*. The amount of kinetic energy can be found from the expression $E_k = ½mv^2$. Where v is the instantaneous velocity of the object at the moment in time you are interested in. The value of the kinetic energy **does not** depend on the object's direction of motion – energy is a scalar quantity. Remember, to get a result in joules, always use units of kg and m/s in this equation.

Lesson 7: Energy Challenge

Recorder: ____________________
Manager: ____________________
Speaker: ____________________
0 1 2 3 4 5

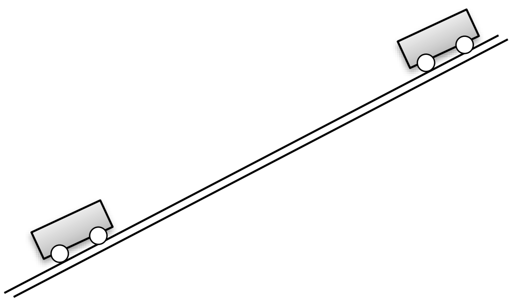
An inclined dynamics track is set up at the front of the room. A cart on the track has a friction pad attached underneath. You get to choose where along the track to release the cart. Your challenge is to predict the speed of the cart after it is released, when it reaches the 2.0 m mark near the bottom of the track.

1. **Represent.** Complete part A of the solution process below. Use symbols for any quantities that you will need to know to solve this problem. Label the important vertical positions. Don't rush up and measure anything yet.

2. **Measure.** Your group should finish all of part A except for the given quantities. Now, measure any quantities you think will be important for solving this problem. Record your measurements (with uncertainties!) as the givens for this problem. Your teacher will give you a value for the force of friction.

A: Pictorial Representation

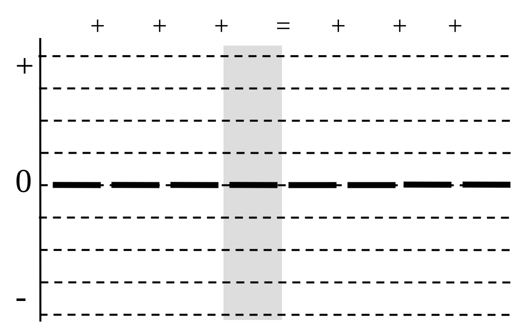
~~Sketch showing events~~, describe events, coordinate system, label givens & unknowns with symbols, conversions



3. **Reason.** You need to choose the system objects for this problem. Which objects are involved in transfers of energy? Which should we include in our choice of system?

B: Physics Representation

Energy bar chart, flow diagram, event numbers



4. **Describe.** In the word representation, describe the movement of the cart. Describe any energy changes and the state characteristics associated with them.

C: Word Representation

Describe changing characteristics and energies, assumptions, estimated result (no calculations)

Answers: #1(a) 1180 W, (b) 2350 W, #2 nightlight!

D: Mathematical Representation

Describe purpose of math, complete equations, algebraically isolate, substitutions with units, final statement of prediction

Energy Calculation Techniques. There are two ways to approach the math work in energy problems like these:

(1) **Compute each energy value.** This approach involves a separate calculation for each energy symbol involved in a problem. This can be helpful in lengthy problems. The downside is this approach adds a lot of steps, work, and time. It creates more opportunities to make simple arithmetical mistakes.

(2) **Construct one equation and isolate.** This approach involves completing one work-energy equation and isolating the unknown quantity using symbols. This is the preferable technique, but there are occasions when the equation might become quite complicated and messy, making the first approach easier. In this problem, isolate v_2^2 and then substitute values.

E: Evaluation

Answer has reasonable size, direction and units? Explain why.

5. **Test and Evaluate.** Once you have completed your full solution (including part E), use the equipment at the front to test your result. Record your results here. Does your model of this problem successfully predict the results? Explain.