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.

FD

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 and a force diagram during this process (while it gains kinetic energy)

$+x$

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 and FD during this process. **System = cart**

FD

$+x$

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.

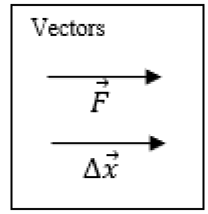
5. **Reason.** Think about the first situation above. What do you think would happen to the amount of energy that flows into the system if your hand exerted the same force for twice the distance? Explain.

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

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. Vector arrows showing the direction of the force from the hand and the displacement of the cart are drawn for you.



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

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

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.

   (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. What energy flow took place?

Vectors

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 a force diagrams for the system of the cart.
   (b) What energy flows are present in this situation?

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

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

FD

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 a force diagram for the system of the wagon.

FD

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

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.

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

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

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? What would the sign (+/-) of the net work be?

   (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**. 1200 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?

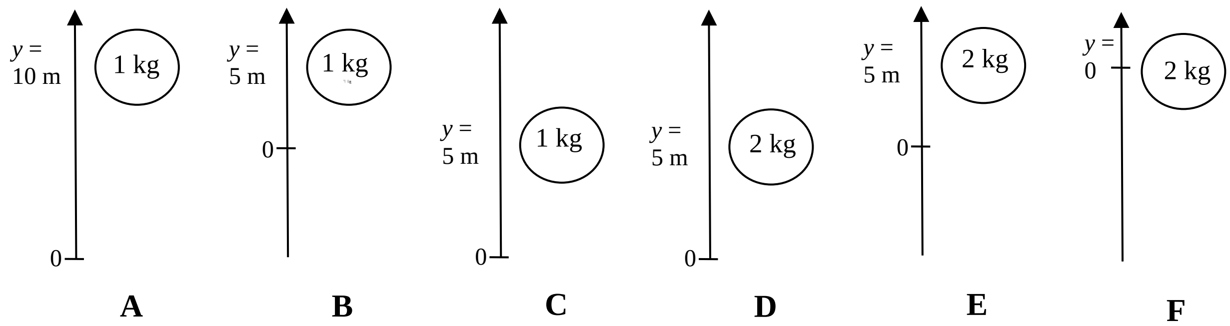
40. A 1.00 kg book falls 0.75 m from a desk to the floor. How much potential energy did the book lose?

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

Homework: Measuring Energy　　　　　Name:

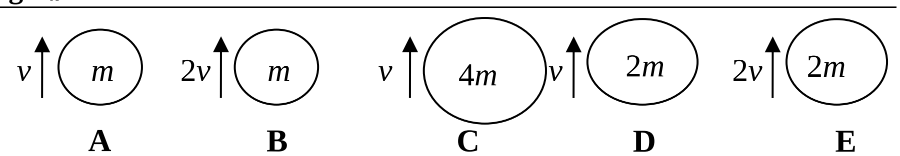
A: Comparing Gravitational Energies Using $E_g = mgy$

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

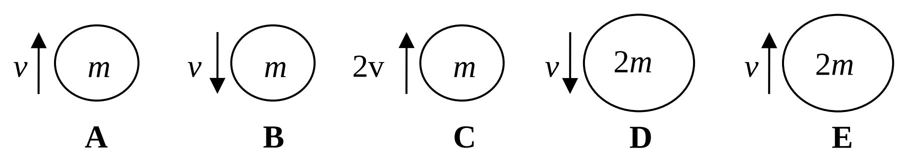


B: Comparing Kinetic Energies Using $E_k = ½mv^2$

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.



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.



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

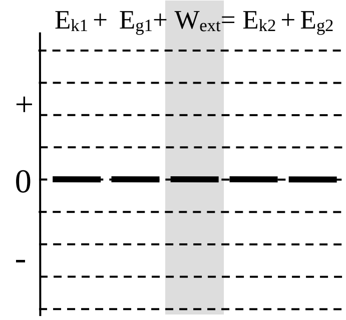
When objects move vertically energy flows in or out of Earth's gravitational field. Let's follow these flows and learn how to model the energy transfers in the system.

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 bar chart for the **earth-ball** system.

Sketch



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.

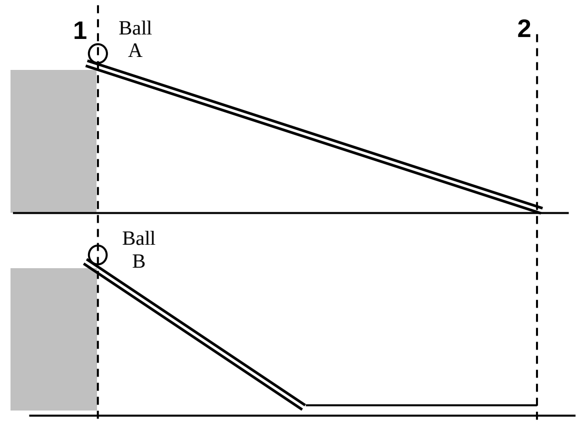
4. **Calculate.** Use your new work-energy equation to find the speed of the ball when it contacts the ground. In other words, rearrange your equation from #3 to isolate v_2. Something neat will happen!

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

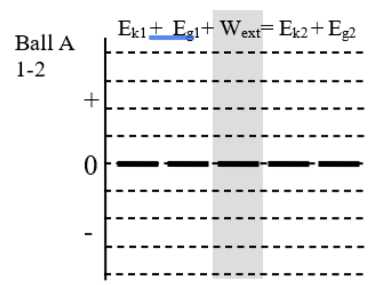
Your teacher has two tracks set up at the front of the class. One track has a steep incline and the other a more gradual incline. Both start at the same height and end at the same height. Friction is very small and can be neglected. There are two important events: (1) Ball A and B are released, (2) Each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



1. **Predict**. Which ball do you think will reach the end of the track first? Explain why you think this.

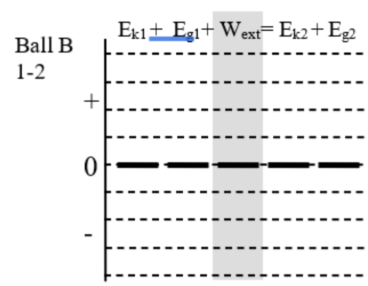
2. **Observe**. Which ball won the race? Explain why this happened.

3. **Predict**. Which ball do you think will be travelling faster when it reaches the end of the track? Explain why you think this.



4. **Observe**. Which ball was travelling faster? We'll try to explain this using energy bar charts.

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



6. **Represent.** Complete an energy bar chart for each ball for the interval 1-2.

7. **Explain.** Use your energy bar charts to explain the result from #4 above.

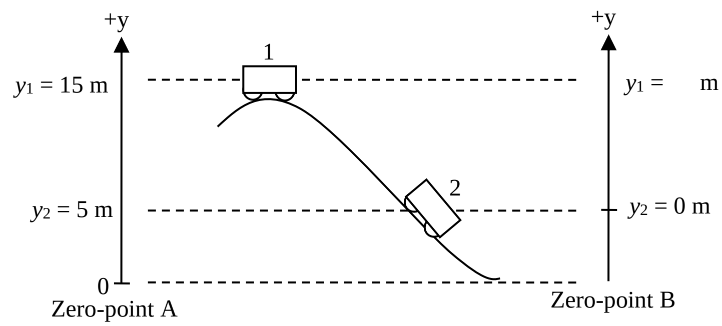
8. **Reason.** Albert says, "I don't understand why ball B wins the race. They both end up traveling roughly the same distance and ball A even accelerates for more time! It should be faster!" Based on your observations and understanding of energy, help Albert understand.

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:

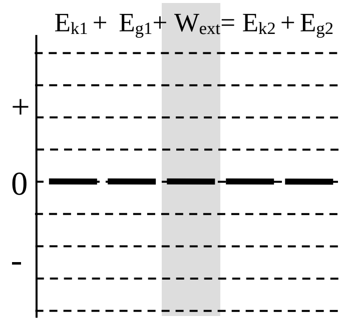
The value for the gravitational energy depends on the choice of the zero-point. If two people choose a different zero-points, will their calculations predict different things? Let's see!

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**

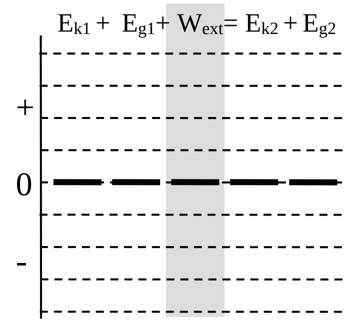


1. Find the value of y_1 using zero-point B.

2. **Represent.**
   (a) Draw an energy bar chart for each zero-point.
   (b) 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				

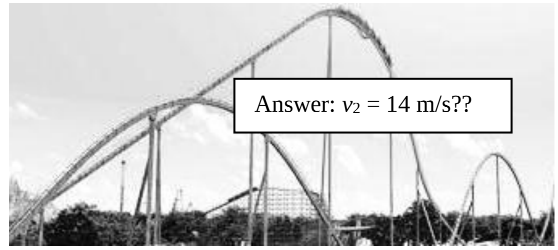
4. **Explain.** Use both the calculations and the bar charts to explain why the choice of zero-point did not affect the results of the calculation.

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

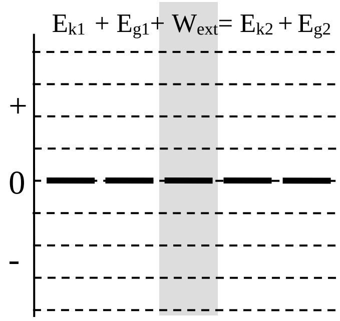
A: The Behemoth

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 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.

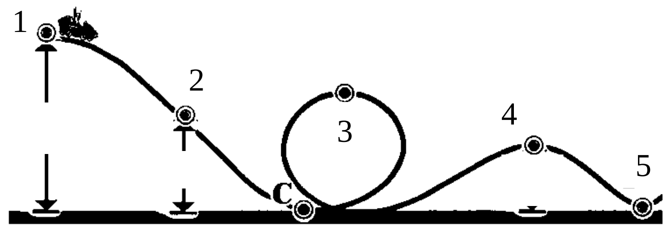
4. **Reason.** In reality, the train reaches the bottom with a speed of 125 km/h. Why is our model not giving the proper result?

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.

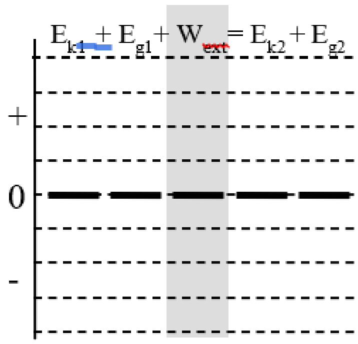
5. **Calculate.** Use the train mass, $m_t = 2.7 \times 10^3$ kg to determine the amount of energy the train lost due to friction in the form of thermal energy. You'll need to compare the amount of kinetic energy the train was supposed to have at the bottom with what it actually had.

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.

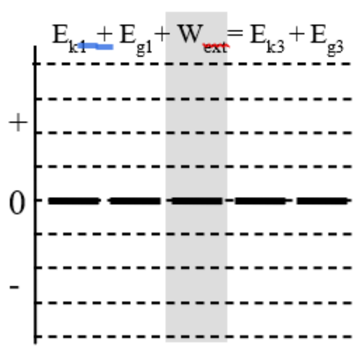


1. **Solve.** Complete the diagram and chart. Determine the rollercoaster's speed at moment 2.



Equation

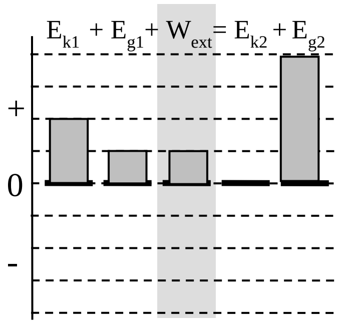
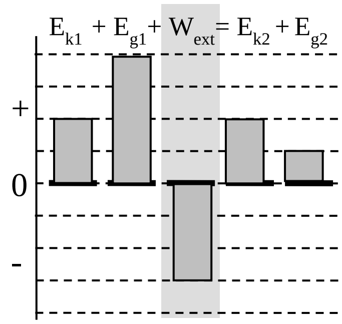
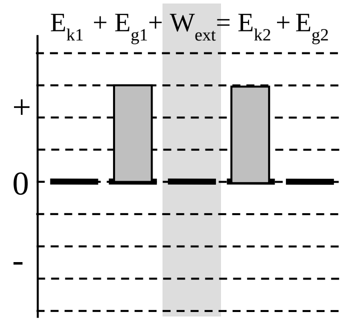
2. **Solve.** When the cart is at the top of the loop-de-loop its speed is 17.0 m/s. How tall is the loop-de-loop? Use the energy bar chart to help.

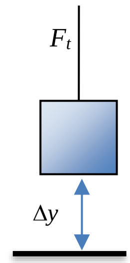


Equation

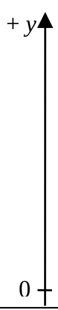
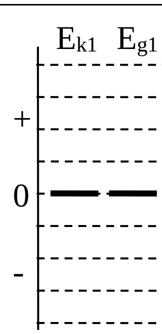
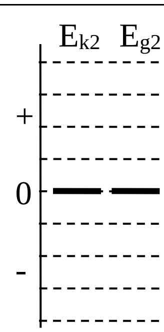
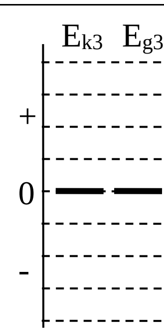
Homework: The Conservation of Energy   Name:

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) State the direction of energy flow, 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?

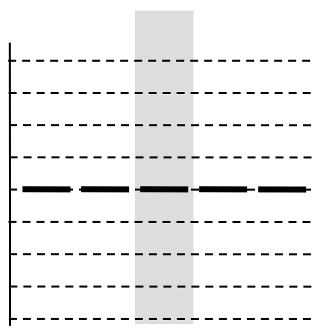
44. The Jetscream amusement park ride at Paramount Canada's Wonderland is shown in Fig. 7.25. It starts off by swinging like a simple pendulum until its amplitude becomes so great that it swings completely around. If the diameter of the circle is 30.0 m, what speed must the ship have at the very bottom 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. State the energy flow, complete the work-energy bar chart and equation for this situation. Be sure to add in the energy labels to the bar chart.

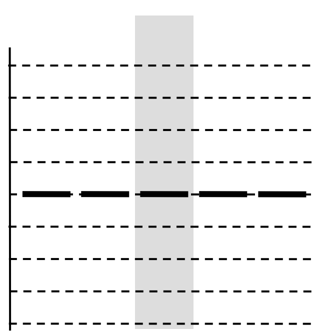
Flow:



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.

Flow:



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).

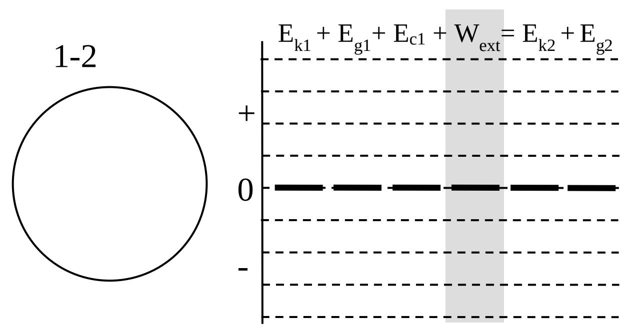
A: The Stair Master

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*?



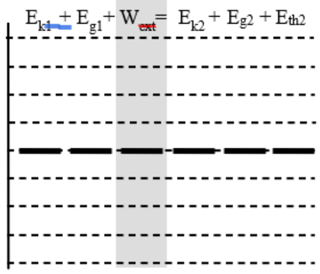
4. **Represent.** Draw a sketch showing events 1 and 2. Be sure to label y_1, y_2, v_1, and v_2 in your sketch. Label any other quantities you will measure to find your power.

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 (we'll call this h = 0 m) and are pulled to the top of the first hill by a motor. At the top, 60.1 m above the platform, 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.
   a) How much energy does the motor provide to the 2700. kg train to achieve this? Use the energy bar chart to help.
   b) How much horsepower does the motor need if it does this work in 67 s?

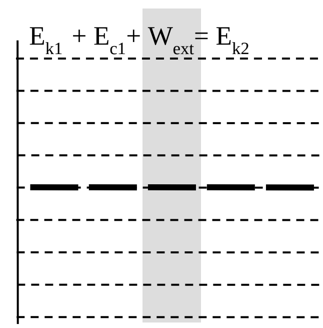


Work-energy equation:

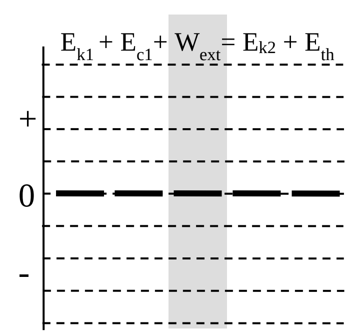
C: He's Got the Power

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. This took him about 6.3 seconds. 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. How much energy does Bolt use to achieve his result?



$$Power = \frac{Work\ done}{time}$$

$$P = \frac{W}{\Delta t}$$

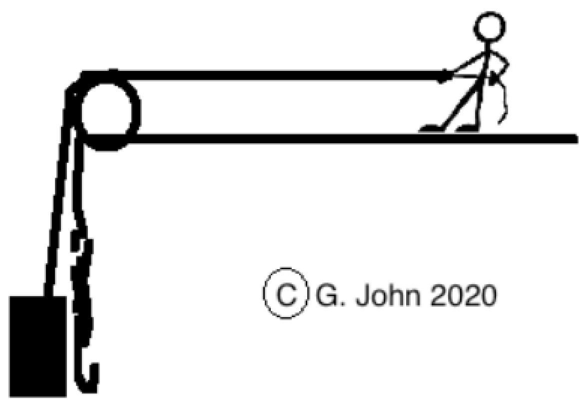
Where:
work done is measured in J
Power is measured in J/s or Watts (W)
Time is measured in s

page 153
1. 2.0×10^2 W
2. 30 s
3. 7.5×10^4 J
4. 5.9×10^2 W
5. 3.7 s
6. 4.1 m

Practice

1. How much power does a crane develop, doing 6.0×10^4 J of work in 5.00 min?
2. How long does it takes a 2.5 kW electric motor to do 7.5×10^4 J of work?
3. How much work can a 500 W electric mixer do in 2.5 min?
4. How much power is developed by a 50 kg girl running up a 3.00 m high flight of stairs in 2.50 s?
5. How long will it take the girl in question 4 to run up a flight of stairs 4.5 m high?
6. A boy who can generate 500 W runs up a flight of stairs in 5.0 s. How high are the stairs if the boy has a mass of 62 kg?

Power and Efficiency Example



A student pulls an object up a cliff with a rope draped over a rock. The object has a mass of 25.0 kg, and the student succeeds in raising it 15.0 m. The student exerts a force of 450.0 N while pulling.

a) How much energy does the rock gain as it is raised?

b) How much work does the student do while they are pulling the rope?

c) What is the efficiency of this system?

d) Where did the extra energy go?

e) A student puts some grease on the rock, increasing the efficiency to 70%. If the student then pulls the rock up the remaining 8.00 m, how much energy did the student save because of the grease?

SPH3U: Energy Problem Set	**Name:**

Energy Transformations, Work and Conservation of Energy

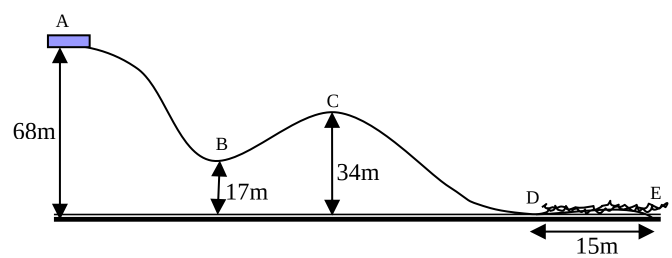
1) A 50.0kg cyclist on a 10.0kg bicycle speeds up from 5.00 m/s to 10.0 m/s in 2.50 seconds. How much work was done by the cyclist? *W=2250J*

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]*

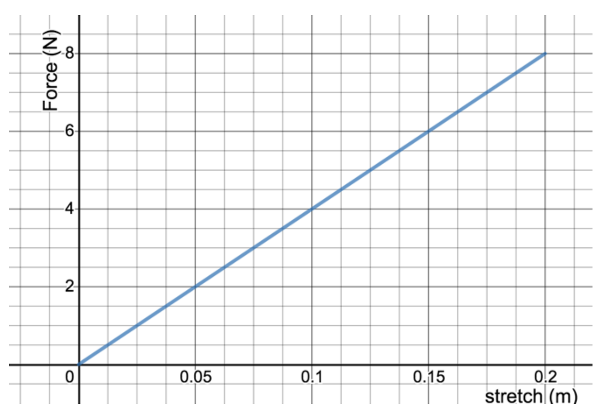
3) A person lifts up a 1.00 kg block from the ground to a height of 2.00 m before releasing it. The block continues travelling another 8.00 m before coming to rest and returning back to the ground. Using the work-energy theorem, calculate the energy of the block and the velocity of the block at each 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 $\mu_k=0.250$. 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 1.6×10^3 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? *($5.4x10^3 W$)*

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 2.52×10^4 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

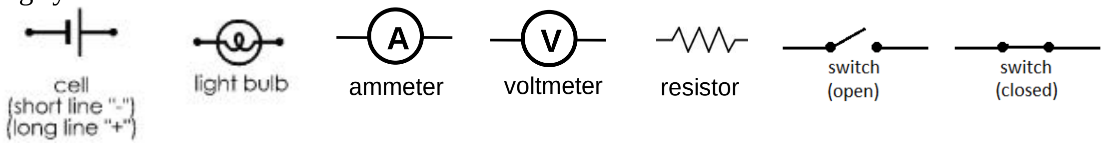
Table 8.5
Latent Heats of Fusion and Vapourization

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

SPH3U - Simple Circuits

Use the following website to build circuits: https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc

A circuit diagram is a simplified drawing of an electric circuit. Circuit diagrams use straight lines for wires and the following symbols



Represent. Draw a circuit diagram for a simple circuit using a cell, resistor/light bulb, wires and a switch.

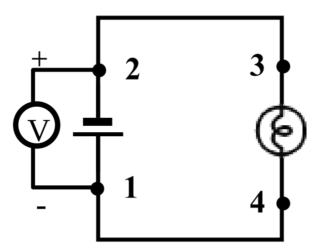
The flow of electricity is called the *electron current*, or just simply, the *current*. It is the movement of electrons through the circuit. An *ammeter* measures the current in *amperes* (A). To measure the current travelling through one point in a circuit, simply "insert" the ammeter into that location in the circuit.

Represent. Draw a circuit diagram showing how to connect an ammeter. Then measure the current at different points in your circuit.

A *voltmeter* measures the change in energy of a unit of charge as it moves between two points in a circuit. To use a voltmeter, you must connect the meter's two leads to two different points in a circuit. A voltmeter connects across two points, without disconnecting the original circuit (connected in *parallel*).

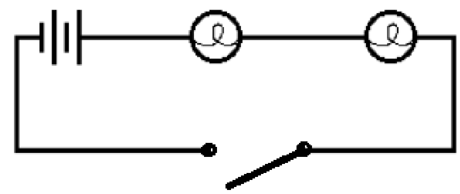
Test. Construct a simple circuit. Connect the voltmeter across different parts of the circuit with the pair of leads connected at the points numbered in the chart below. Complete the chart.

Voltmeter leads connected at points	Part of circuit charge moves through	Observed meter reading
1 and 2		
2 and 3		
3 and 4		
4 and 1		



Explain. According to your measurements, what is happening to the amount of energy carried by the electrons moving in this circuit between each pair of points?

Series Circuits



Construct the circuit shown in the diagram, and make sure "Show Current" is checked showing electrons.

1. Close the switch. Observe and Explain.

2. Open the switch. Observe and explain.

3. Close the switch, then break one of the connections between a wire and a lightbulb. Observe and explain.

4. Reattach the wire to the lightbulb so that both lights work. Now use an ammeter to measure the current at a variety of locations along your circuit. Summarize your findings.

5. Use a voltmeter to measure the voltage between a variety of points of your circuit. Summarize your findings.

6. Take a moment to observe the brightness of the bulbs (shown by the yellow lines) and the speed of energy flow. Now add a third lightbulb to your circuit, also in series ("in a row"), and again observe the brightness of the bulbs and speed of energy flow. Explain.

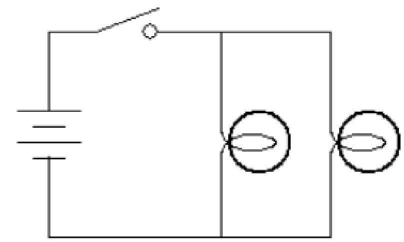
7. Suppose you re-did steps 4 and 5 above. What would you expect to find? Explain briefly, then confirm.

8. Add a second battery in the same direction as the first. Observe and explain.

9. Change the direction of your second battery. Observe and explain.

Parallel Circuits

Construct the circuit shown in the diagram, and make sure "Show Current" is checked showing electrons.



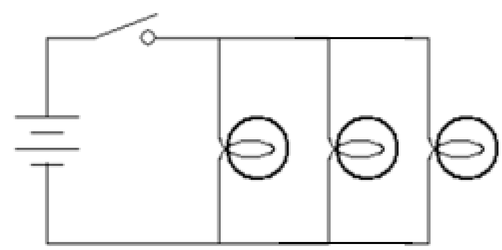
1. Close the switch so that both lights are on. Use an ammeter to measure the current at various places in your circuit. Summarize your findings.

2. Use a voltmeter to measure the voltage across a variety of locations in your circuit. Summarize your findings.

3. Take a moment to observe the brightness of the bulbs. Now break one of the connections between a wire and a lightbulb. Observe and explain.

4. Reconnect the lightbulb.

5. Now you will now add a third lightbulb to your circuit, also in parallel (see picture). What do you expect to happen to the current, voltage, brightness, etc. in your circuit? Test your hypothesis.



6. As you add bulbs in parallel, why does their brightness stay constant?

7. As you add bulbs in parallel, how does this affect the battery?

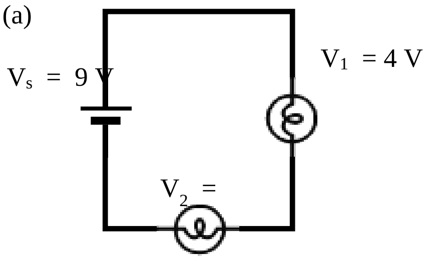
Circuit Analysis

Kirchoff's Voltage Law – The sum of the voltages in a closed loop of a system must equal zero

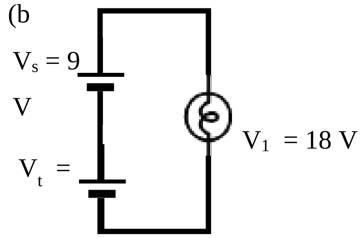
Kirchoff's Current Law –current flowing into a node equals the current flowing out of that node

Calculate. For each loop in the circuits below, use Kirchhoff's voltage law to determine any missing voltage values.

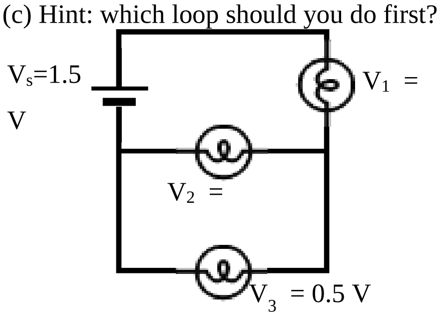
(a)



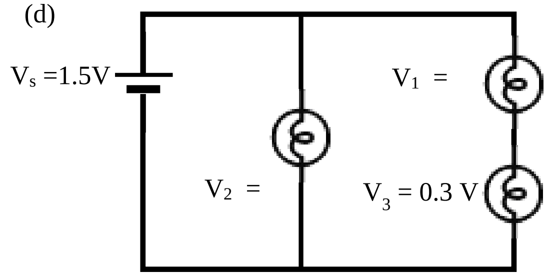
(b



(c) Hint: which loop should you do first?

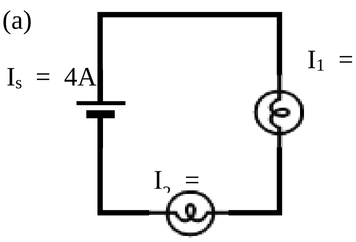


(d)

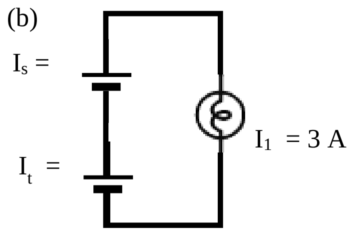


Calculate. Use Kirchhoff's current law to determine any missing current values.

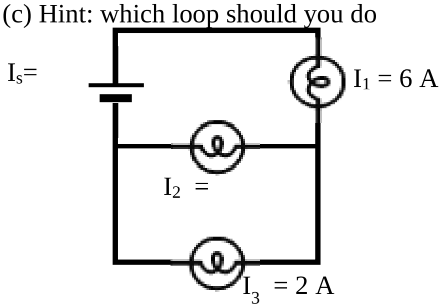
(a)



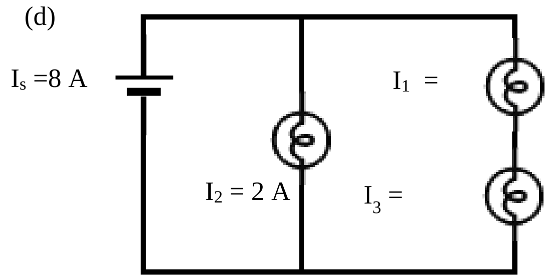
(b)



(c) Hint: which loop should you do



(d)

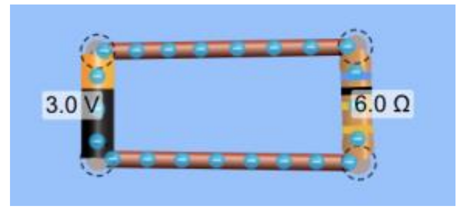


SPH 3U – Electricity – Circuit simulation

Answer the questions below using the circuit simulation. No need to do any calculations!
https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc

1) **Verify Ohm's law**: Use a voltmeter and an ammeter to find the current and voltage across a 6 ohm resistor in a simple circuit. Enter your results in the table below. Using your results, find an equation for voltage, current and resistance?

Voltage (V)	Current (I)	Resistance (Ohms)
3		6
6		6
12		6
18		6
24		6



2) Use a voltmeter and an ammeter to find the current and voltage across the resistors for the following circuits:
   a) A simple circuit: a 12 V battery connected to one 6 ohm resistor

   b) A series circuit: a 12V battery connected to one 9 ohm and one 3 ohm resistor

   c) A parallel circuit: a 12V battery connected to 6 ohm and 3 ohm resistors in parallel

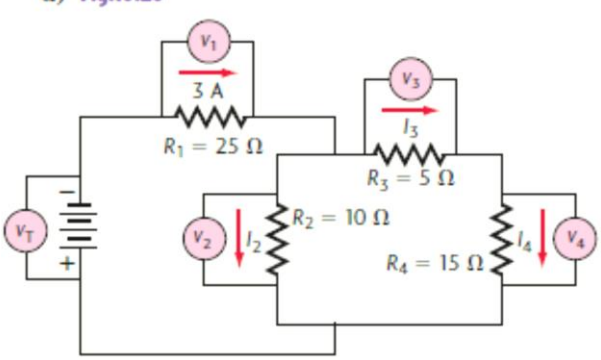
   d) A complex circuit: a battery with resistors in series and parallel

   Draw your 4 circuits on the next page using the following symbols, find and label the voltage and the current across each resistor. Make conclusions based on your observations.

Battery	Resistor	wire	Voltmeter	Ammeter

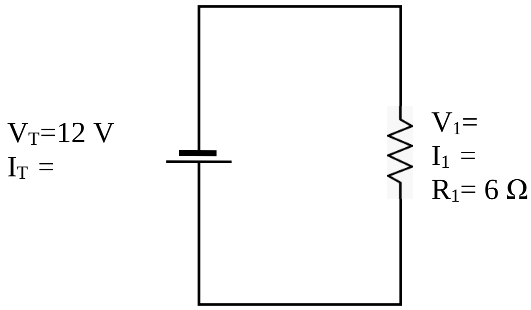
3) Build the following circuit and determine all the unknown voltages, resistances and currents.

d) Fig.16.26



Name	V (V)	I (A)	R (Ω)
R_1			
R_2			
R_3			
R_4			
Total, R_0			

3a) A simple circuit: a 12 V battery connected to one 6 ohm resistor.



3b) A series circuit: a 12V battery connected to one 9 Ω and one 3 Ω resistor

3c) A parallel circuit: a 12V battery connected to a 6 ohm and a 3 ohm resistors in parallel

3d) A complex circuit: a battery with resistors in series and parallel