Work

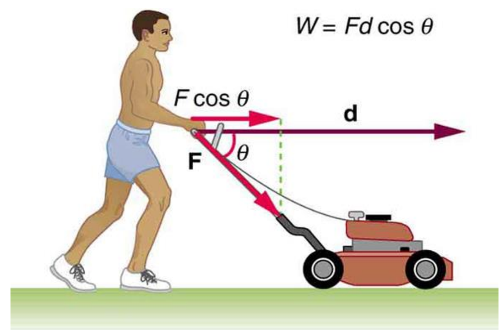
Depends on ____________ and the ____________ the force moves the object

Want the force in the direction of the ____________

$$W = Fd\cos\theta$$

Unit: N m = Joule (J)

____________ (but can be positive and negative)



Marcy pulls a backpack on wheels down the 100-m hall. The 60-N force is applied at an angle of 30° above the horizontal. How much work is done by Marcy?

Mark is carrying books (200 N) down the 100-m hall. How much work is Mark doing on the books?

You carry some books (200 N) while walking down stairs height 2 m and length 3 m. How much work do you do?

A suitcase is hanging straight down from your hand as you ride an escalator. Your hand exerts a force on the suitcase, and this force does work. Which one of the following is correct?

a. The W is negative when you ride up and positive when you ride down
b. The W is positive when you ride up and negative when you ride down
c. The W is positive
d. The W is negative

$W = Fd$

$F = ma$

So work by a ________________________ gives an object some ________________________

Acceleration means the ____________ changes

$$W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_0^2$$

Energy is the ____________ to do ____________

Kinetic Energy — Energy due to ____________

$$KE = \frac{1}{2}mv^2$$

____

Unit: Joule

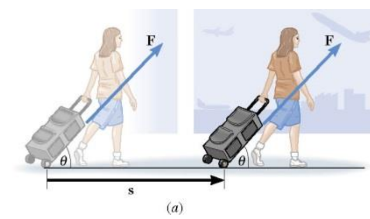
Work-Energy Theorem

$$W = KE_f - KE_0$$

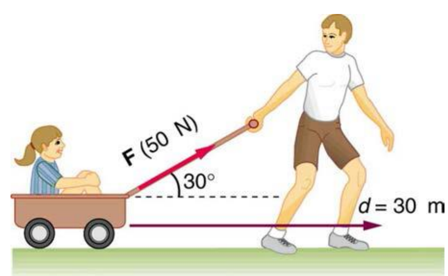
A 0.075-kg arrow is fired horizontally. The bowstring exerts a force on the arrow over a distance of 0.90 m. The arrow leaves the bow at 40 m/s. What average force does the bow apply to arrow?

Physics 03-01 Work and the Work-Energy Theorem	***Name:*** ________________________
Homework	

1. A box is being moved with a velocity v by a force P (parallel to v) along a level horizontal floor. The normal force is F_N, the kinetic frictional force is f_k, and the weight of the box is mg. Decide which forces do positive, zero, or negative work. Provide a reason for each of your answers.
2. A sailboat is moving at a constant velocity. (a) Is work being done by a net external force acting on the boat? Explain. (b) Recognizing that the wind propels the boat forward and the water resists the boat's motion, what does your answer in part (a) imply about the work done by the wind's force compared to the work done by the water's resistive force?
3. A slow-moving car may have more kinetic energy than a fast-moving motorcycle. How is this possible?
4. Work done on a system puts energy into it. Work done by a system removes energy from it. Give an example for each statement.
5. The brakes of a truck cause it to slow down by applying a retarding force of 3.0×10^3 N to the truck over a distance of 850 m. What is the work done by this force on the truck? Is the work positive or negative? Why? (Cutnell 6.1) $\mathbf{-2.6 \times 10^6}$ **J**
6. A person pulls a toboggan for a distance of 35.0 m along the snow with a rope directed 25.0° above the snow. The tension in the rope is 94.0 N. (a) How much is done on the toboggan by the tension force? (b) How much work is done if the same tension is directed parallel to the snow? (Cutnell 6.3) **2980 J, 3290 J**
7. A 75.0-kg man is riding an escalator in a shopping mall. The escalator moves the man at a constant velocity from ground level to the floor above, a vertical height of 4.60 m. What is the work done on the man by (a) the gravitational force and (b) the escalator? (Cutnell 6.4) **-3380 J, 3380 J**
8. Suppose in the picture that 1100 J of work are done by the force F = 30.0 N in moving the suitcase a distance of 50.0 m. At what angle θ is the force oriented with respect to the ground? (Cutnell 6.5) **42.8°**



9. A person pushes a 16.0-kg shopping cart at a constant velocity for a distance of 22.0 m. She pushes in a direction 29.0° below the horizontal. A 48.0-N frictional force opposes the motion of the cart. (a) What is the magnitude of the force that the shopper exerts? (review) Determine the work done by (b) the pushing force, (c) the frictional force, and (d) the gravitational force. (Cutnell 6.7) **54.9 N, 1060 J, -1060 J, 0 J**
10. (a) Calculate the work done on a 1500-kg elevator car by its cable to lift it 40.0 m at constant speed, assuming friction averages 100 N. (b) What is the work done on the lift by the gravitational force in this process? (c) What is the total work done on the lift? (OpenStax 7.3) $\mathbf{5.92 \times 10^5}$ **J,** $\mathbf{-5.88 \times 10^5}$ **J, 0 J**
11. How much work is done by the boy pulling his sister 30.0 m in a wagon as shown in Figure 7.36? Assume no friction acts on the wagon. (OpenStax 7.6) $\mathbf{1.30 \times 10^3}$ **J**
12. Compare the kinetic energy of a 20,000-kg truck moving at 110 km/h with that of an 80.0-kg astronaut in orbit moving at 27,500 km/h. (OpenStax 7.9) $\mathbf{9.34 \times 10^6}$ **J,** $\mathbf{2.33 \times 10^9}$ **J**
13. (a) How fast must a 3000-kg elephant move to have the same kinetic energy as a 65.0-kg sprinter running at 10.0 m/s? (b) Discuss how the larger energies needed for the movement of larger animals would relate to metabolic rates. (OpenStax 7.10) **1.47 m/s**



14. A car's bumper is designed to withstand a 4.0-km/h (1.1-m/s) collision with an immovable object without damage to the body of the car. The bumper cushions the shock by absorbing the force over a distance. Calculate the magnitude of the average force on a bumper that collapses 0.200 m while bringing a 900-kg car to rest from an initial speed of 1.1 m/s. (OpenStax 7.13) $\mathbf{-2.8 \times 10^3}$ **N**
15. Two cars, A and B, are traveling with the same speed of 40.0 m/s, each having started from rest. Car A has a mass of 1200 kg, and car B has a mass of 2000 kg. Compared to the work required to bring car A up to speed, how much additional work is required to bring car B up to speed? (Cutnell 6.17) $\mathbf{6.4 \times 10^5}$ **J**
16. A 5.0×10^4-kg space probe is traveling at a speed of 11000 m/s through deep space. Retrorockets are fired along the line of motion to reduce the probe's speed. The retrorockets generate a force of 4.0×10^5 N over a distance of 2500 km. What is the final speed of the probe? (Cutnell 6.18) **9000 m/s**

Physics 03-02 Potential Energy and Conservative Forces — *Name: ________________*

Potential Energy

Energy due to ______________

Gravitational potential energy

$$PE_g = mgh$$

Since the force of gravity is ______________ and the displacement and force must be in same ______________, we only worry about the ______________ distance

The ______________ the object takes doesn't matter, just the ______________ ______________

Potential Energy is not ______________; it is a ______________

h is measured from ____________________________ point. Just be ______________.

Spring potential energy

$$PE_s = \frac{1}{2}kx^2$$

Conservative Forces

A force where the ______________ it does is ____________________ of the path

Only thing that matters is ______________ and ______________ point

Energy can be ______________ from one ______________ to ______________.

Law of Conservation of Mechanical Energy

$$PE_f + KE_f = PE_0 + KE_0$$

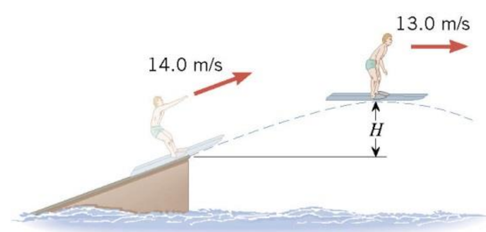
if only ______________________ forces do net work

A toy gun uses a spring to shoot plastic balls (m = 50 g). The spring is compressed by 3.0 cm. Let k=2.22×10^5 N/m. (a) Of course, you have to do some work on the gun to arm it. How much work do you have to do? (b) Suppose you fire the gun horizontally. How fast does the ball leave the gun? (c) Now suppose you fire the gun straight upwards. How high does the ball go?

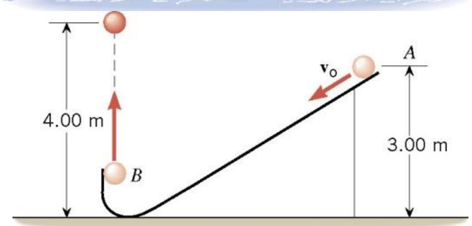
A 1500-kg car is driven off a 50-m cliff during a movie stunt. If it was going 20 m/s as it went off the cliff, how fast is it going as it hits the ground?

Physics 03-02 Potential Energy and Conservative Forces	***Name:*** ___________________
Homework	

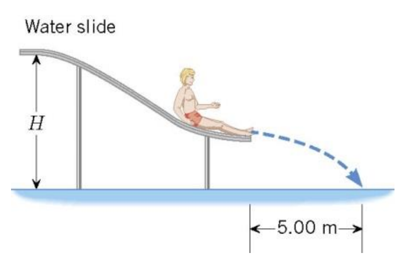
1. Suppose the total mechanical energy of an object is conserved. (a) If the kinetic energy decreases, what must be true about the gravitational potential energy? (b) If the potential energy decreases, what must be true about the kinetic energy? (c) If the kinetic energy does not change, what must be true about the potential energy?
2. A person is riding a Ferris wheel. When the wheel makes one complete turn, is the net work done by the gravitational force positive, negative, or zero? Justify your answer.
3. Does the work you do on a book when you lift it onto a shelf depend on the path taken? On the time taken? On the height of the shelf? On the mass of the book?
4. What is a conservative force?
5. Relative to the ground, what is the gravitational potential energy of a 55.0-kg person who is at the top of the Sears Tower, a height of 443 m above the ground? (Cutnell 6.27) $\mathbf{2.39 \times 10^5}$ **J**
6. A hydroelectric power facility converts the gravitational potential energy of water behind a dam to electric energy. What is the gravitational potential energy relative to the generators of a lake of volume 50.0 km^3 (mass = 5.00×10^{13} kg), given that the lake has an average height of 40.0 m above the generators? (OpenStax 7.16) $\mathbf{1.96 \times 10^{16}}$ **J**
7. A 75.0-kg skier rides a 2830-m-long lift to the top of a mountain. The lift makes an angle of 14.6° with the horizontal. What is the change in the skier's gravitational potential energy? (Cutnell 6.29) $\mathbf{5.24 \times 10^5}$ **J**
8. "Rocket man" has a propulsion unit strapped to his back. He starts from rest on the ground, fires the unit, and is propelled straight upward. At a height of 16 m, his speed is 5.0 m/s. His mass, including the propulsion unit, is about 136 kg. Find the work done by the force generated by the propulsion unit. (Cutnell 6.31) $\mathbf{2.3 \times 10^4}$ **J**
9. Suppose a 350-g kookaburra (a large kingfisher bird) picks up a 75-g snake and raises it 2.5 m from the ground to a branch. (a) How much work did the bird do on the snake? (b) How much work did it do to raise its own center of mass to the branch? (OpenStax 7.18) **1.8 J, 8.6 J**



10. A water-skier lets go of the tow rope upon leaving the end of a jump ramp at a speed of 14.0 m/s. As the drawing indicates, the skier has a speed of 13.0 m/s at the highest point of the jump. Ignoring air resistance, determine the skier's height H above the top of the ramp at the highest point. (Cutnell 6.34) **1.4 m**



11. A particle, starting from point A in the drawing, is shot down the curved runway. Upon leaving the runway at point B, the particle is traveling straight upward and reaches a height of 4.00 m above the floor before falling back down. Ignoring friction and air resistance, find the speed of the particle at point A. (Cutnell 6.38) **4.43 m/s**
12. A 100-g toy car is propelled by a compressed spring that starts it moving. The car follows the curved track. Show that the final speed of the toy car is 0.687 m/s if its initial speed is 2.00 m/s and it coasts up the frictionless slope, gaining 0.180 m in altitude. (OpenStax 7.20) **0.687 m/s**
13. A 5.00×10^5-kg subway train is brought to a stop from a speed of 0.500 m/s in 0.400 m by a large spring bumper at the end of its track. What is the force constant *k* of the spring? (OpenStax 7.22) $\mathbf{7.81 \times 10^5}$ **N/m**
14. A pogo stick has a spring with a force constant of 2.50×10^4 N/m, which can be compressed 12.0 cm. To what maximum height can a child jump on the stick using only the energy in the spring, if the child and stick have a total mass of 40.0 kg? (OpenStax 7.23) **0.459 m**
15. A water slide is constructed so that swimmers, starting from rest at the top of the slide, leave the end of the slide traveling horizontally. As the drawing shows, one person hits the water 5.00 m from the end of the slide in a time of 0.500 s after leaving the slide. Ignoring friction and air resistance, find the height H in the drawing. (Hint: Start by using projectile motion to find the speed when the person hits the water, then use conservation of mechanical energy to find the height.) (Cutnell 6.41) **6.33 m**



Physics 03-03 Nonconservative Forces and Conservation of Energy Name: ___________________

Work done by net external force (nonconservative)

Often both ____________________ and ____________________ forces act on an object at once.

$$E_0 + W_{nc} = E_f$$

Law of Conservation of Energy

The total energy is _______________ in any process. It may __________ form or be __________ from one system to another, but the total __________ the __________.

Efficiency

Useful energy ______________ is always less than energy ______________.

$$Efficiency\ (Eff) = \frac{useful\ energy\ or\ work\ output}{total\ energy\ input} = \frac{W_{out}}{E_{in}}$$

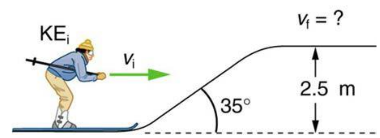
A rocket starts on the ground at rest. Its final speed is 500 m/s and height is 5000 m. If the mass of the rocket stays approximately 200 kg, find the work done by the rocket engine.

A 1500-kg car's brakes failed and it coasts down a hill from rest. The hill is 10 m high and the car has a speed of 12 m/s at the bottom of the hill. How much work did friction do on the car?

Captain Proton's rocket pack provides 800,000 J of work to propel him from resting on his ship which is near the earth to 50 m above it. Captain Proton's mass is 90 kg. What is his final velocity?

Physics 03-03 Nonconservative Forces and Conservation of Energy	***Name: ___________________***
Homework	

1. Do devices with efficiencies of less than one violate the law of conservation of energy? Explain. List four different forms or types of energy. Give one example of a conversion from each of these forms to another form.
2. A basketball player makes a jump shot. The 0.600-kg ball is released at a height of 2.00 m above the floor with a speed of 7.20 m/s. The ball goes through the net 3.10 m above the floor at a speed of 4.20 m/s. What is the work done on the ball by air resistance, a nonconservative force? (Cutnell 6.46) **-3.8 J**
3. A projectile of mass 0.750 kg is shot straight up with an initial speed of 18.0 m/s. (a) How high would it go if there were no air friction? (b) If the projectile rises to a maximum height of only 11.8 m, determine the magnitude of the average force due to air resistance. (Cutnell 6.48) **16.5 m, 2.9 N**
4. The (nonconservative) force pulling a 1500-kg car up a mountain road does 4.70×10^6 J of work on the car. The car starts from rest at sea level and has a speed of 27.0 m/s at an altitude of 200 m above sea level. Obtain the work done on the car by the combined forces of friction and air resistance, both of which are nonconservative forces. (Cutnell 6.49) $\mathbf{-1.21 \times 10^6}$ **J**
5. A 60.0-kg skier with an initial speed of 12.0 m/s coasts up a 2.50-m high rise as shown in the figure. Find her final speed at the top, given that the coefficient of friction between her skis and the snow is 0.0800. (Hint: Find the distance traveled up the incline assuming a straight-line path as shown in the figure.) (OpenStax 7.24) **9.46 m/s**



6. (a) How high a hill can a car coast up (engine disengaged) if work done by friction is negligible and its initial speed is 110 km/h? (b) If, in actuality, a 750-kg car with an initial speed of 110 km/h is observed to coast up a hill to a height 22.0 m above its starting point, how much thermal energy was generated by friction? (c) What is the average force of friction if the hill has a slope 2.5° above the horizontal? (OpenStax 7.25) **47.6 m,** $\mathbf{1.89 \times 10^5}$ **J, 375 N**
7. Using energy considerations and assuming negligible air resistance, show that a rock thrown from a bridge 20.0 m above water with an initial speed of 15.0 m/s strikes the water with a speed of 24.8 m/s independent of the direction thrown. (OpenStax 7.27) **24.8 m/s**
8. If the energy in fusion bombs were used to supply the energy needs of the world, how many of the 9-megaton variety would be needed for a year's supply of energy (using data from Table 7.1)? This is not as farfetched as it may sound—there are thousands of nuclear bombs, and their energy can be trapped in underground explosions and converted to electricity, as natural geothermal energy is. (Annual world energy use = 4×10^{20} J; Large fusion bomb (9 megaton) = 3.8×10^{16} J) (OpenStax 7.28) $\mathbf{1 \times 10^4}$ **bombs**
9. Use of hydrogen fusion to supply energy is a dream that may be realized in the next century. Fusion would be a relatively clean and almost limitless supply of energy. To illustrate this, calculate how many years the present energy needs of the world could be supplied by one millionth of the oceans' hydrogen fusion energy. (Fusion of all the hydrogen in Earth's oceans = 10^{34} J; Annual world energy use = 4×10^{20} J) (OpenStax 7.29) $\mathbf{2.5 \times 10^7}$ **years**

Physics 03-04 Power **Name:** ________________________

Rate that ______________ is ______________

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

Unit: joule/s = watt (W)

Power is the ______________ that ______________ is ______________

A 1000 kg car accelerates from 0 to 100 km/h in 3.2 s on a level road. Find the average power of the car.

Electrical Energy

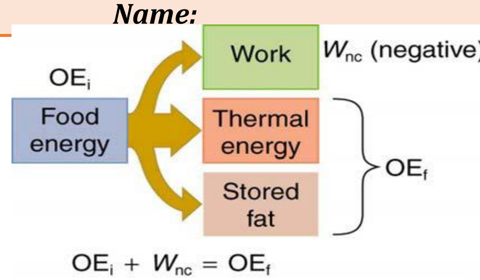
Often measured in ______________ because $Pt = W$

If it costs $0.10 per kWh, how much will it cost to run a 1000 W microwave for 2 minutes?

Physics 03-04 Power	*Name: ________________________*
Homework	

1. Is it correct to conclude that one engine is doing twice the work of another just because it is generating twice the power? Explain.
2. Explain, in terms of the definition of power, why energy consumption is sometimes listed in kilowatt-hours rather than joules.
3. A spark of static electricity, such as that you might receive from a doorknob on a cold dry day, may carry a few hundred watts of power. Explain why you are not injured by such a spark.
4. A person is making homemade ice ream. She exerts a force of magnitude 22 N on the free end of the crank handle, and this end moves in a circular path of radius 0.28 m. The force is always applied parallel to the motion of the handle. If the handle is turned once every 1.3 s, what is the average power being expended? (Cutnell 6.56) **30 W**
5. One kilowatt · hour (kWh) is the amount of work or energy generated when one kilowatt of power is supplied for a time of one hour. A kilowatt · hour is the unit of energy used by power companies when figuring your electric bill. Determine the number joules of energy in one kilowatt · hour. (Cutnell 6.57) $\mathbf{3.6 \times 10^6}$ **J**
6. A 300-kg piano is being lifted at a steady speed from ground level straight up to an apartment 10.0 m above the ground. The crane that is doing the lifting produces a steady power of 400 W. How much time does it take to lift the piano? (Cutnell 6.58) **73.5 s**
7. In 2.0 minutes, a ski lift raises four skiers at constant speed to a height of 140 m. The average mass of each skier is 65 kg. What is the average power provided by the tension in the cable pulling the lift? (Cutnell 6.59) **3000 W**
8. A person in good physical condition can put out 100 W of useful power for several hours at a stretch, perhaps by pedaling a mechanism that drives an electric generator. Neglecting any problems of generator efficiency and practical considerations such as resting time: (a) How many people would it take to run a 4.00-kW electric clothes dryer? (b) How many people would it take to replace a large electric power plant that generates 800 MW? (OpenStax 7.32) **40, 8 million**
9. What is the cost of operating a 3.00-W electric clock for a year if the cost of electricity is $0.0900 per kWh? (OpenStax 7.33) **$2.37**
10. A large household air conditioner may consume 15.0 kW of power. What is the cost of operating this air conditioner 3.00 h per day for 30.0 d if the cost of electricity is $0.110 per kWh? (OpenStax 7.34) **$149**
11. (a) What is the average power consumption in watts of an appliance that uses 5.00 kWh of energy per day? (b) How many joules of energy does this appliance consume in a year? (OpenStax 7.35) **208 W,** $\mathbf{6.57 \times 10^9}$ **J**
12. A 500-kg dragster accelerates from rest to a final speed of 110 m/s in 400 m (about a quarter of a mile) and encounters an average frictional force of 1200 N. What is its average power output in watts and horsepower if this takes 7.30 s (1 hp = 746 W)? (OpenStax 7.37) $\mathbf{4.80 \times 10^5}$ **W, 643 hp**
13. (a) How long will it take an 850-kg car with a useful power output of 40.0 hp (1 hp = 746 W) to reach a speed of 15.0 m/s, neglecting friction? (b) How long will this acceleration take if the car also climbs a 3.00-m-high hill in the process? (OpenStax 7.38) **3.20 s, 4.04 s**
14. (a) What is the available energy content, in joules, of a battery that operates a 2.00-W electric clock for 18 months? (b) How long can a battery that can supply 8.00×10^4 J run a pocket calculator that consumes energy at the rate of 1.00×10^{-3} W? (OpenStax 7.40) $\mathbf{9.46 \times 10^7}$ **J, 2.54 yr**

Physics 03-05 Energy in Humans and the World *Name:* _



Energy in Humans

Human bodies (all living bodies) convert _______________

Rate of ______________________________ use is _______________ rate

- Basal _______________ rate (BMR)
- Total energy _______________ at rest
- Highest: _______________ and _______________

Table 7.4 Basal Metabolic Rates (BMR)

Organ	Power consumed at rest (W)	Oxygen consumption (mL/min)	Percent of BMR
Liver & spleen	23	67	27
Brain	16	47	19
Skeletal muscle	15	45	18
Kidney	9	26	10
Heart	6	17	7
Other	16	48	19
Totals	85 W	250 mL/min	100%

Table 7.5 Energy and Oxygen Consumption Rates[4] (Power)

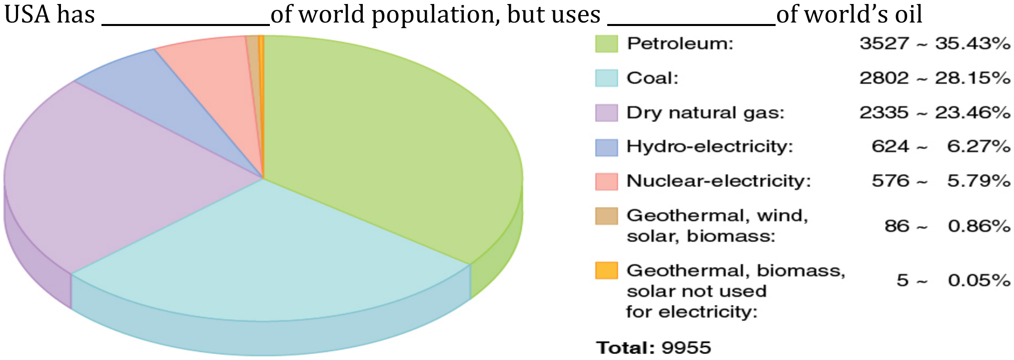
Activity	Energy consumption in watts	Oxygen consumption in liters O_2/min
Sleeping	83	0.24
Sitting at rest	120	0.34
Standing relaxed	125	0.36
Sitting in class	210	0.60
Walking (5 km/h)	280	0.80
Cycling (13–18 km/h)	400	1.14
Shivering	425	1.21
Playing tennis	440	1.26
Swimming breaststroke	475	1.36
Ice skating (14.5 km/h)	545	1.56
Climbing stairs (116/min)	685	1.96
Cycling (21 km/h)	700	2.00
Running cross-country	740	2.12
Playing basketball	800	2.28
Cycling, professional racer	1855	5.30
Sprinting	2415	6.90

World Energy Use

Energy is required to do _______________

World wide, the most common source of energy is _______________

USA has _______________of world population, but uses _______________of world's oil



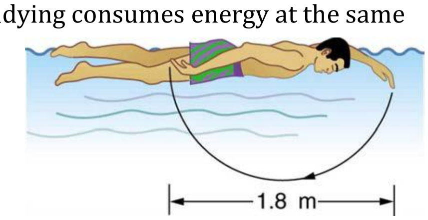
World energy consumption continues to _______________ quickly

Physics 03-05 Energy in Humans and the World **Name: ____________________________**

- Growing economies in ________________ and ________________
- ________________________________ are very polluting
- Many countries trying to develop ________________ energy like ________________ and ________________
- Generally, ________________ energy use per capita = better ________________ of living

Homework

1. Explain why it is easier to climb a mountain on a zigzag path rather than one straight up the side. Is your increase in gravitational potential energy the same in both cases? Is your energy consumption the same in both?
2. Discuss the relative effectiveness of dieting and exercise in losing weight, noting that most athletic activities consume food energy at a rate of 400 to 500 W, while a single cup of yogurt can contain 1360 kJ (325 kcal). Specifically, is it likely that exercise alone will be sufficient to lose weight? You may wish to consider that regular exercise may increase the metabolic rate, whereas protracted dieting may reduce it.
3. What is the difference between energy conservation and the law of conservation of energy? Give some examples of each.
4. (a) What is the power output in watts and horsepower of a 70.0-kg sprinter who accelerates from rest to 10.0 m/s in 3.00 s? (b) Considering the amount of power generated, do you think a well-trained athlete could do this repetitively for long periods of time? (OpenStax 7.45) $\mathbf{1.17 \times 10^3}$ **W, 1.56 hp, Very high power**
5. Calculate the power output in watts and horsepower of a shot-putter who takes 1.20 s to accelerate the 7.27-kg shot from rest to 14.0 m/s, while raising it 0.800 m. (Do not include the power produced to accelerate his body.) (OpenStax 7.46) **641 W, 0.860 hp**
6. (a) What is the efficiency of an out-of-condition professor who does 2.10×10^5 J of useful work while metabolizing 500 kcal of food energy? (b) How many food calories would a well-conditioned athlete metabolize in doing the same work with an efficiency of 20%? (OpenStax 7.47) **0.100, 251 kcal**
7. Energy that is not utilized for work or heat transfer is converted to the chemical energy of body fat containing about 39 kJ/g. How many grams of fat will you gain if you eat 10,000 kJ (about 2500 kcal) one day and do nothing but sit relaxed for 16.0 h and sleep for the other 8.00 h? Use data from Table 7.5 for the energy consumption rates of these activities. (OpenStax 7.48) **17.9 g**
8. Using data from Table 7.5, calculate the daily energy needs of a person who sleeps for 7.00 h, walks for 2.00 h, attends classes for 4.00 h, cycles for 2.00 h, sits relaxed for 3.00 h, and studies for 6.00 h. (Studying consumes energy at the same rate as sitting in class.) (OpenStax 7.49) **3800 kcal**
9. The swimmer shown in Figure 7.44 exerts an average horizontal backward force of 80.0 N with his arm during each 1.80 m long stroke. (a) What is his work output in each stroke? (b) Calculate the power output of his arms if he does 120 strokes per minute. (OpenStax 7.56) **144 J, 288 W**



10. Review: A toy gun uses a spring with a force constant of 300 N/m to propel a 10.0-g steel ball. If the spring is compressed 7.00 cm and friction is negligible: (a) How much force is needed to compress the spring? (b) To what maximum height can the ball be shot? (c) At what angles above the horizontal may a child aim to hit a target 3.00 m away at the same height as the gun? (d) What is the gun's maximum range on level ground? (OpenStax 7.63) **-21.0 N, 7.50 m, 5.77°, 84.23°, 15.0 m**
11. Review: (a) What force must be supplied by an elevator cable to produce an acceleration of 0.800 m/s^2 against a 200-N frictional force, if the mass of the loaded elevator is 1500 kg? (b) How much work is done by the cable in lifting the elevator 20.0 m? (c) What is the final speed of the elevator if it starts from rest? (d) How much work went into thermal energy? (OpenStax 7.64) $\mathbf{1.61 \times 10^4}$ **N,** $\mathbf{3.22 \times 10^5}$ **J, 5.66 m/s, 4.00 kJ**

Physics 03-06 Impulse and Momentum Name: ________________________

Impulse

$$J = F\Delta t$$

Unit: Ns

Is a ________________

Both ________________ and ________________ play role in how responds to ________________

Linear Momentum

$$p = mv$$

Unit: kg m/s

Is a ________________

Is important when talking about ________________

Impulse-Momentum Theorem

$$F\Delta t = mv_f - mv_0$$

________________ = change in ________________

Find change in momentum

- Use ______________________________ and ____________of contact to find average ____________ of contact

A baseball (m = 0.14 kg) with initial velocity of -40 m/s (90 mph) is hit. It leaves the bat with a velocity of 60 m/s after 0.001 s. What is the impulse and average net force applied to the ball by the bat?

A raindrop (m = .001 kg) hits a roof of a car at -15 m/s. After it hits, it spatters so the effective final velocity is 0. The time of impact is .01 s. What is the average force?

What if it is ice so that it bounces off at 10 m/s?

Homework

1. Two identical automobiles have the same speed, one traveling east and one traveling west. Do these cars have the same momentum? Explain.
2. Two objects have the same momentum. Do the velocities of these objects necessarily have (a) the same directions and (b) the same magnitudes? Give your reasoning in each case.
3. (a) Can a single object have kinetic energy but no momentum? (b) Can a system of two or more objects have a total kinetic energy that is not zero but a total momentum that is zero? Account for your answers.

4. You have a choice. You may get hit head-on either by an adult moving slowly on a bicycle or by a child that is moving twice as fast on a bicycle. The mass of the child and bicycle is one-half that of the adult and bicycle. Considering only the issues of mass and velocity, which collision do you prefer? Or doesn't it matter? Account for your answer.
5. When you're driving a golf ball, a good "follow-through" helps to increase the distance of the drive. A good follow-through means that the club head is kept in contact with the ball as long as possible. Using the impulse-momentum theorem, explain why this technique allows you to hit the ball farther.
6. Explain in terms of impulse how padding reduces forces in a collision. State this in terms of a real example, such as the advantages of a carpeted vs. tile floor for a day care center.
7. (a) Calculate the momentum of a 2000-kg elephant charging a hunter at a speed of 7.50 m/s. (b) Compare the elephant's momentum with the momentum of a 0.0400-kg tranquilizer dart fired at a speed of 600 m/s. (c) What is the momentum of the 90.0-kg hunter running at 7.40 m/s after missing the elephant? (OpenStax 8.1) $\mathbf{1.50 \times 10^4}$ **kg m/s, 24.0 kg m/s,** $\mathbf{6.66 \times 10^2}$ **kg m/s**
8. (a) What is the mass of a large ship that has a momentum of 1.60×10^9 kg · m/s, when the ship is moving at a speed of 48.0 km/h? (b) Compare the ship's momentum to the momentum of a 1100-kg artillery shell fired at a speed of 1200 m/s. (OpenStax 8.2) $\mathbf{1.20 \times 10^8}$ **kg,** $\mathbf{1.32 \times 10^6}$ **kg m/s**
9. A bullet is accelerated down the barrel of a gun by hot gases produced in the combustion of gun powder. What is the average force exerted on a 0.0300-kg bullet to accelerate it to a speed of 600 m/s in a time of 2.00 ms (milliseconds)? (OpenStax 8.7) $\mathbf{9.00 \times 10^3}$ **N**
10. A car moving at 10 m/s crashes into a tree and stops in 0.26 s. Calculate the force the seat belt exerts on a passenger in the car to bring him to a halt. The mass of the passenger is 70 kg. (OpenStax 8.8) **2690 N**
11. Suppose a child drives a bumper car head on into the side rail, which exerts a force of 4000 N on the car for 0.200 s. (a) What impulse is imparted by this force? (b) Find the final velocity of the bumper car if its initial velocity was 2.80 m/s and the car plus driver have a mass of 200 kg. You may neglect friction between the car and floor. (OpenStax 8.11) **−800 kg m/s, −1.20 m/s**
12. One hazard of space travel is debris left by previous missions. There are several thousand objects orbiting Earth that are large enough to be detected by radar, but there are far greater numbers of very small objects, such as flakes of paint. Calculate the force exerted by a 0.100-mg chip of paint that strikes a spacecraft window at a relative speed of 4.00×10^3 m/s, given the collision lasts 6.00×10^{-8} s. (OpenStax 8.12) $\mathbf{6.67 \times 10^3}$ **N**
13. A 75.0-kg person is riding in a car moving at 20.0 m/s when the car runs into a bridge abutment. (a) Calculate the average force on the person if he is stopped by a padded dashboard that compresses an average of 1.00 cm. (b) Calculate the average force on the person if he is stopped by an air bag that compresses an average of 15.0 cm. (OpenStax 8.13) $\mathbf{-1.50 \times 10^6}$ **N,** $\mathbf{-1.00 \times 10^5}$ **N**
14. A volleyball is spiked so that its incoming velocity of +4.0 m/s is changed to an outgoing velocity of −21 m/s. The mass of the volleyball is 0.35 kg. What impulse does the player apply to the ball? (Cutnell 7.1) **−8.7 kg m/s**
15. A baseball (m = 149 g) approaches a bat horizontally at a speed of 40.2 m/s (90 mph) and is hit straight back at a speed of 45.6 m/s (102 mph). If the ball is in contact with the bat for a time of 1.10 ms, what is the average force exerted on the ball by the bat? Neglect the weight of the ball, since it is so much less than the force of the bat. Choose the direction of the incoming ball as the positive direction. (Cutnell 7.4) **−11600 N**

Physics 03-07 Conservation of Momentum — *Name: ________________________*

System

All the ________________ involved in the ________________
Usually only ________________ objects

________________ Forces – Forces that the objects exert on each other
________________ Forces – Forces exerted by things outside of the system

Law of Conservation of Momentum

In an ________________ system the total momentum remains ________________

$$p_0 = p_f$$

Reasoning Strategy

1. Decide on the ________________
2. Identify ________________ and ________________ ________________
3. Is the system ________________? If no, then ________________ use conservation of momentum
4. Set the total ________________ momentum of the isolated system ________________ to the total ______________ momentum

Two billiard balls are colliding on a table. In order to apply the law of conservation of momentum, what should the system be? One ball or both billiard balls?

A hockey puck of mass 0.17 kg and velocity 5 m/s is caught by a .5 kg mitten laying on the ice. What is the combined velocity after the puck is in the mitten? (ignore friction)

A 5 kg baseball pitching machine is placed on some frictionless ice. It shoots a 0.15 kg baseball horizontally at 35 m/s. How fast is the pitching machine moving after it shoots the ball?

Physics 03-07 Conservation of Momentum	***Name: __________________________***
Homework	

1. In movies, Superman hovers in midair, grabs a villain by the neck, and throws him forward. Superman, however, remains stationary. Using the conservation of linear momentum, explain what is wrong with this scene.
2. A satellite explodes in outer space, far from any other body, sending thousands of pieces in all directions. How does the linear momentum of the satellite before the explosion compare with the total linear momentum of all the pieces after the explosion? Explain.
3. You are a passenger on a jetliner that is flying at a constant velocity. You get up from your seat and walk toward the front of the plane. Because of this action, your forward momentum increases. What, if anything, happens to the forward momentum of the plane? Give your reasoning.
4. An ice boat is coasting along a frozen lake. Friction between the ice and the boat is negligible, and so is air resistance. Nothing is propelling the boat. From a bridge someone jumps straight down and lands in the boat, which continues to coast straight ahead. (a) Does the horizontal momentum of the boat change? (b) Does the speed of the boat increase, decrease, or remain the same? Explain.
5. A 55-kg swimmer is standing on a stationary 210-kg floating raft. The swimmer then runs off the raft horizontally with a velocity of +4.6 m/s relative to the shore. Find the recoil velocity that the raft would have if there were no friction and resistance due to the water. (Cutnell 7.16) **-1.2 m/s**
6. Two friends, Al and Jo, have a combined mass of 168 kg. At an ice skating rink they stand close together on skates, at rest and facing each other, with a compressed spring between them. The spring is kept from pushing them apart because they are holding each other. When they release their arms, Al moves off in one direction at a speed of 0.90 m/s, while Jo moves off in the opposite direction at a speed of 1.2 m/s. Assuming that friction is negligible, find Al's mass. (Cutnell 7.18) **96 kg**
7. In a science fiction novel two enemies, Bonzo and Ender, are fighting in outer space. From stationary positions they push against each other. Bonzo flies off with a velocity of +1.5 m/s, while Ender recoils with a velocity of -2.5 m/s. (a) Without doing any calculations, decide which person has the greater mass. Give your reasoning. (b) Determine the ratio of the masses (m_{Bonzo}/m_{Ender}) of these two people. (Cutnell 7.17) **1.7**
8. Train cars are coupled together by being bumped into one another. Suppose two loaded train cars are moving toward one another, the first having a mass of 150,000 kg and a velocity of 0.300 m/s, and the second having a mass of 110,000 kg and a velocity of −0.120 m/s. (The minus indicates direction of motion.) What is their final velocity? (OpenStax 8.23) **0.122 m/s**
9. Suppose a clay model of a koala bear has a mass of 0.200 kg and slides on ice at a speed of 0.750 m/s. It runs into another clay model, which is initially motionless and has a mass of 0.350 kg. Both being soft clay, they naturally stick together. What is their final velocity? (OpenStax 8.24) **0.272 m/s**
10. Consider the following question: *A car moving at 10 m/s crashes into a tree and stops in 0.26 s. Calculate the force the seatbelt exerts on a passenger in the car to bring him to a halt. The mass of the passenger is 70 kg.* Would the answer to this question be different if the car with the 70-kg passenger had collided with a car that has a mass equal to and is traveling in the opposite direction and at the same speed? Explain your answer. (OpenStax 8.25) **2690 N**
11. What is the velocity of a 900-kg car initially moving at 30.0 m/s, just after it hits a 150-kg deer initially running at 12.0 m/s in the same direction? Assume the deer remains on the car. (OpenStax 8.26) **27.4 m/s**
12. A 1.80-kg falcon catches a 0.650-kg dove from behind in midair. What is their velocity after impact if the falcon's velocity is initially 28.0 m/s and the dove's velocity is 7.00 m/s in the same direction? (OpenStax 8.27) **22.4 m/s**

Physics 03-08 Elastic and Inelastic Collisions **_Name: ____

________________– ________________ energy often ________________

________________– ________________ energy usually not ________________

- Converted into ________________
- Converted into ________________ or ________________

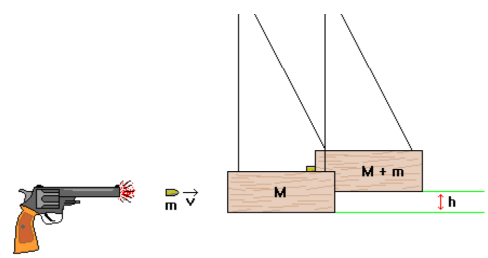
Elastic – ________________ energy ________________

Inelastic – ________________ energy ________________

Completely inelastic – the objects ________________ together

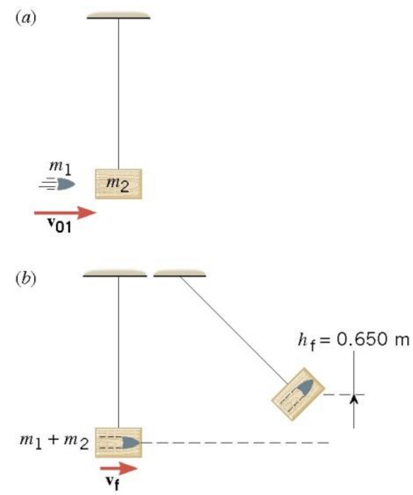
You are playing marbles. Your 0.10 kg shooter traveling at 1 m/s hits a stationary 0.05 kg cat's eye marble. If it is an elastic collision what are the velocities after the collision?

A ballistic pendulum can be used to determine the muzzle velocity of a gun. A .01 kg bullet is fired into a 3 kg block of wood. The block is attached with a thin .5m wire and swings to an angle of 40°. How fast was the bullet traveling when it left the gun?

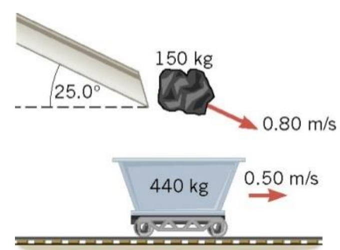


Physics 03-08 Elastic and Inelastic Collisions	*Name: _______________________*
Homework	

1. In an elastic collision, is the kinetic energy of *each* object the same before and after the collision? Explain.
2. What is an elastic collision?
3. What is an inelastic collision? What is a perfectly inelastic collision?
4. Mixed-pair ice skaters performing in a show are standing motionless at arms length just before starting a routine. They reach out, clasp hands, and pull themselves together by only using their arms. Assuming there is no friction between the blades of their skates and the ice, what is their velocity after their bodies meet?
5. In a football game, a receiver is standing still, having just caught a pass. Before he can move, a tackler, running at a velocity of +4.5 m/s, grabs him. The tackler holds onto the receiver, and the two move off together with a velocity of +2.6 m/s. The mass of the tackler is 115 kg. Assuming that momentum is conserved, find the mass of the receiver. (Cutnell 7.25) **84 kg**



6. A 2.50-g bullet, traveling at a speed of 425 m/s, strikes the wooden block of a ballistic pendulum, such as that in the picture. The block has a mass of 215 g. (a) Find the speed of the bullet/block combination immediately after the collision. (b) How high does the combination rise above its initial position? (Cutnell 7.28) **4.89 m/s, 1.22 m**
7. A 1055-kg van, stopped at a traffic light, is hit directly in the rear by a 715-kg car traveling with a velocity of +2.25 m/s. Assume that the transmission of the van is in neutral, the brakes are not being applied, and the collision is elastic. What is the final velocity of (a) the car and (b) the van? (Cutnell 7.26) **-0.432 m/s, 1.82 m/s**
8. A cue ball (mass = 0.165 kg) is at rest on a frictionless pool table. The ball is hit dead center by a pool stick, which applies an impulse of +1.50 Ns to the ball. The ball then slides along the table and makes an elastic head-on collision with a second ball of equal mass that is initially at rest. Find the velocity of the second ball just after it is struck. (Cutnell 7.29) **9.09 m/s**
9. A 5.00-kg ball, moving to the right at a velocity of +2.00 m/s on a frictionless table, collides head-on with a stationary 7.50-kg ball. Find the final velocities of the balls if the collision is (a) elastic and (b) completely inelastic. (Cutnell 7.31) **-0.4 m/s, 1.6 m/s; 0.8 m/s**
10. A mine car, whose mass is 440 kg, rolls at a speed of 0.50 m/s on a horizontal track, as the drawing shows. A 150-kg chunk of coal has a speed of 0.80 m/s when it leaves the chute. Determine the velocity of the car/coal system after the coal has come to rest in the car. (Cutnell 7.34) **0.56 m/s**

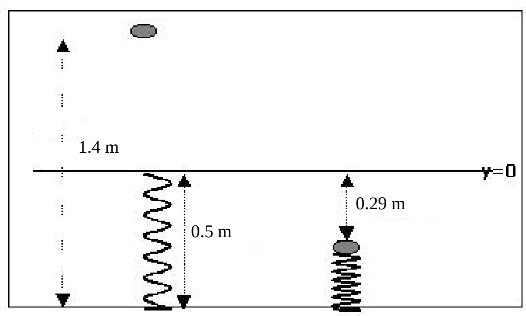


11. A 30,000-kg freight car is coasting at 0.850 m/s with negligible friction under a hopper that dumps 110,000 kg of scrap metal into it. (a) What is the final velocity of the loaded freight car? (b) How much kinetic energy is lost? (OpenStax 8.36) **0.182 m/s, $\mathbf{8.52 \times 10^3}$ J**
12. During an ice show, a 60.0-kg skater leaps into the air and is caught by an initially stationary 75.0-kg skater. (a) What is their final velocity assuming negligible friction and that the 60.0-kg skater's original horizontal velocity is 4.00 m/s? (b) How much kinetic energy is lost? (OpenStax 8.32) **1.78 m/s, -267 J**
13. An automobile has a mass of 2100 kg and a velocity of +17 m/s. It makes a rear-end collision with a stationary car whose mass is 1900 kg. The cars lock bumpers and skid off together with the wheels locked. (a) What is the velocity of the two cars just after the collision? (b) Find the impulse (magnitude and direction) that acts on the skidding cars from just after the collision until they come to a halt. (c) Review: If the coefficient of kinetic friction between the wheels of the cars and the pavement is $\mu_k = 0.68$, determine how far the cars skid before coming to rest. (Cutnell 7.33) **8.9 m/s, $\mathbf{-3.6 \times 10^4}$ Ns, 5.9 m**

Physics

Unit 3: Work, Energy, and Momentum

1. *Meanings and concepts of terms like work, kinetic energy, gravitational potential energy, Conservation of mechanical energy, work-energy theorem, conservative force, nonconservative, elastic and inelastic collisions, impulse, momentum, isolated system, conserved*
2. *Know how force and time are related to collisions and impulse.*
3. *When is linear momentum and kinetic energy is conserved.*
4. *Mike is cutting the grass using a human-powered lawn mower. He pushes the mower with a force of 100 N directed at an angle of 20° below the horizontal direction. Calculate the work that Mike does on the mower in pushing it 5 m across the yard.*
5. *The kinetic energy of a car is 7000 J as it travels along a horizontal road. How much work is required to stop the car in 20 s?*
6. *A 15-kg block is lifted vertically 10 meters from the surface of the earth. To one significant figure, what is the change in the gravitational potential energy of the block?*
7. *An engineer is asked to design a playground slide such that the speed a child reaches at the bottom does not exceed 4.0 m/s. Determine the maximum height that the slide can be.*
8. *A ball of mass 5-kg is dropped from a height of 1.4 m (from the ground) onto a massless spring (the spring has an equilibrium length of 0.5 m). The ball compresses the spring by an amount of 0.29 m by the time it comes to a stop. Calculate the spring constant of the spring.*



9. *A warehouse worker uses a forklift to lift a crate of pickles on a platform to a height 5 m above the floor. The combined mass of the platform and the crate is 100 kg. If the power expended by the forklift is 2000 W, how long does it take to lift the crate?*
10. *Jennifer is walking at 0.5 m/s. If Jennifer weighs 980 N, what is the magnitude of her momentum?*
11. *A 10.0-kg steel ball is dropped straight down onto a hard horizontal floor and bounces straight up. Its speed just before and just after impact with the floor is 100 m/s. Determine the magnitude of the impulse delivered to the floor by the steel ball.*
12. *A 5000-kg cannon at rest contains a 100-kg cannon ball. When fired, the cannon ball leaves the cannon with a speed of 20 m/s. What is the recoil speed of the cannon?*
13. *A 2000-kg car traveling east at 50 m/s collides with a 500-kg car traveling west at 30 m/s. The cars stick together after the collision. What is their common velocity after the collision?*
14. *A driver slams on the brakes of a 900-kg car going at 40 m/s so that the wheels lock. The road is sloping upwards. If the car stops 20 m higher than it started, what is the work that friction did to stop the car?*

4. $F = 100\ N\ @20°, s = 5\ m$
$W = Fs \cos\theta = (100\ N)(5\ m) \cos 20° =$
$\mathbf{470\ J}$

5. $KE_0 = 7000\ J, t = 20\ s$
$W = KE_f - KE_0 = 0 - 7000\ J =$
$\mathbf{-7000\ J}$

6. $m = 15\ kg, h = 10\ m$
$PE = mgh = (15\ kg)\left(9.8\frac{m}{s^2}\right)(10\ m) =$
$\mathbf{1470\ J}$

7. $v_f = 4\frac{m}{s}$
$PE_f + KE_f = PE_0 + KE_0$
$\cancel{m}gh_f + \frac{1}{2}\cancel{m}v_f^2 = \cancel{m}gh_0 + \frac{1}{2}\cancel{m}v_0^2$
$\left(9.8\frac{m}{s^2}\right)(0\ m) + \frac{1}{2}\left(4\frac{m}{s}\right)^2 = \left(9.8\frac{m}{s^2}\right)h_0 +$
$\frac{1}{2}\left(0\frac{m}{s}\right)^2$
$8\frac{m^2}{s^2} = 9.8\frac{m}{s^2}\ h_0$
$h_0 = \mathbf{0.816\ m}$

8. $m = 5\ kg, h_0 = 1.4\ m, h_f = 0.5\ m -$
$0.29\ m = 0.21\ m, x = 0.29\ m$
$KE_0 + PE_0 = KE_f + PE_f$
$0 + mgh_0 = 0 + mgh_f + \frac{1}{2}kx^2$
$(5\ kg)\left(9.8\frac{m}{s^2}\right)(1.4\ m) =$
$(5\ kg)\left(9.8\frac{m}{s^2}\right)(0.21\ m) + \frac{1}{2}k(0.29\ m)^2$
$68.6\ J = 10.29\ J + (0.04205\ m^2)k$
$58.31\ J = (0.04205\ m^2)k$
$k = \mathbf{1387\ \frac{N}{m}}$

9. $h = 5\ m, m = 100\ kg, P = 2000\ W$
$P = \frac{W}{t} = \frac{Fs}{t} = \frac{mas}{t}$
$2000\ W = \frac{(100\ kg)\left(9.8\frac{m}{s^2}\right)(5\ m)}{t}$
$t = \mathbf{2.45\ s}$

10. $W = mg \rightarrow 980\ N = m\left(9.8\frac{m}{s^2}\right) \rightarrow m =$
$100\ kg$
$p = mv$
$p = (100\ kg)\left(0.5\frac{m}{s}\right) = \mathbf{50\ kg\frac{m}{s}}$

11. $m = 10\ kg, v_0 = -100\frac{m}{s}, v_f = 100\frac{m}{s}$
$J = F \cdot t = mv_f - mv_0$
$J =$
$(10\ kg)\left(100\frac{m}{s}\right) - (10\ kg)\left(-100\frac{m}{s}\right) =$
$\mathbf{2000\ Ns}$

12. $m_c = 5000\ kg, v_{0c} = 0, v_{fc} = ?$
$m_b = 100\ kg, v_{0b} = 0, v_{fb} = 20\frac{m}{s}$
$m_c v_{0c} + m_b v_{0b} = m_c v_{fc} + m_b v_{fb}$
$(5000\ kg)(0) + (100\ kg)(0) =$
$(5000\ kg)v_{fc} + (100\ kg)\left(20\frac{m}{s}\right)$
$0 = (5000\ kg)v_{fc} + 2000\ kg\frac{m}{s}$
$-2000\ kg\frac{m}{s} = (5000\ kg)v_{fc}$
$v_{fc} = \mathbf{-0.40\frac{m}{s}}$

13. $m_1 = 2000\ kg, v_{01} = 50\frac{m}{s}, v_{f1} = ?$
$m_2 = 500\ kg, v_{02} = -30\frac{m}{s}, v_{f2} = ?$
$m_1 v_{01} + m_2 v_{02} = m_1 v_{f1} + m_2 v_{f2}$
$(2000\ kg)\left(50\frac{m}{s}\right) + (500\ kg)\left(-30\frac{m}{s}\right) =$
$(2000\ kg)v_f + (500\ kg)v_f$
$85000\ kg\frac{m}{s} = 2500\ kg\ v_f$
$v_f = \mathbf{34\ m/s}$

14. $E_0 + W_{nc} = E_f$
$\frac{1}{2}mv_0^2 + W_{nc} = mgh_f$
$\frac{1}{2}(900\ kg)\left(40\frac{m}{s}\right)^2 + W_{nc}$
$= (900\ kg)\left(9.8\frac{m}{s^2}\right)(20\ m)$
$720000\ J + W_{nc} = 176400\ J$
$W_{nc} = -5.44 \times 10^5\ J$