

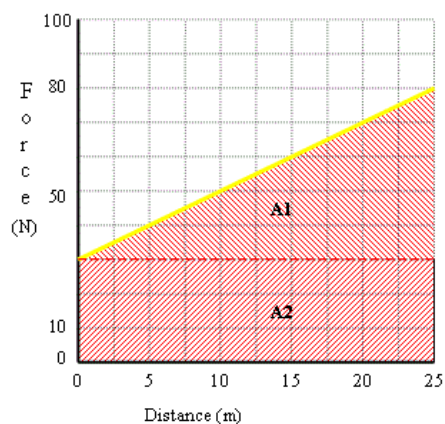
Unit 3 ~ Learning Guide Name: _____

Instructions:

Using a pencil, complete the following notes as you work through the related lessons. Show ALL work as is explained in the lessons. You are required to have this package completed BEFORE you write your unit test. Do your best and ask questions if you don't understand anything!

Work & Energy:

1. How much work does a golfer do lifting a 46 g golf ball out of the hole and up to his pocket (0.95 m above the ground)?
2. A rock of mass 4.7 kg is lowered from height 3.0 m to 2.1 m. How much work is done on the rock?
3. A 55 kg jogger accelerates from 4.0 m/s to 8.0 m/s. How much work is done, and how many times greater is their final E_k compared to their initial E_k ?
4. As a shovel pushes snow, more force is required to push the shovel (snow builds up in front of it). A graph of this is shown below. What work is done when moving the snow, and what force was required to move the shovel when there was no snow on it?



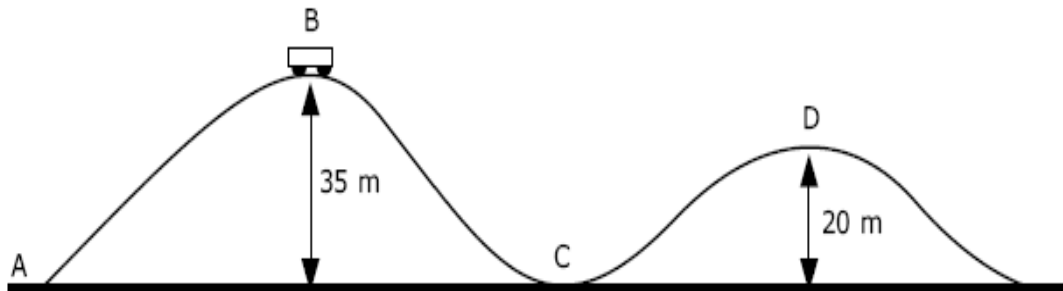
5. What work is involved in both lifting and lowering weights? Who/what does the work in either case?
6. A car of mass 800kg is moving with a speed of 15m/s.
 - a. Calculate its kinetic energy.
 - b. Calculate its kinetic energy if the speed of the car doubles. How does this compare to the original kinetic energy?
 - c. Calculate its velocity if its initial kinetic energy is doubled.
 - d. Examine your answer above and compare it to your original velocity. Use the equation to explain why doubling the original kinetic energy does not double your velocity? What, exactly, is the relationship between speed and kinetic energy?
7. If you push a 75 N block along a floor a distance of 4.2 m at a steady speed, and the coefficient of kinetic friction is 0.40, how much work will you do on the block? **Show all work.**
8. A 1.6 kg rock is dropped from a height of 15 m. With what speed will it strike the ground. Ignore air resistance. Solve using conservation of energy and NOT kinematics.

9. A projectile is shot straight up leaving the ground at 30 m/s. If air resistance is ignored:
- What will be the speed of the object when it reaches a height of 15 m? Solve using energy.
 - Same question as a), but this time solve using kinematics equations.
 - If the projectile in the previous examples has a mass of 2.0 kg and reached the height of 15 m, but only had velocity of 22.2 m/s, how much energy was dissipated as heat due to air resistance?
10. In an accident, a compact car, mass 575 kg, moving at 15 m/s hits the rear end of a car with mass 1575 kg, originally going 5.0 m/s. They lock together and slide forward.
- Using momentum, what is the new velocity of the cars?
 - Using conservation of energy, what is the new velocity of the cars?
 - Why the difference? Which is correct?
 - For what collisions can energy be used?

11. A skier starts from rest at the top of a frictionless incline of height 20 m. At the bottom of the incline, the skier encounters a horizontal surface where the coefficient of kinetic friction between the skis and snow is 0.210.
- a. How fast was the skier going at the bottom of the incline?
 - b. How far does the skier travel on the horizontal surface before coming to rest?
12. A girl runs at top speed (5.0 m/s) and grasps a 4.0 m rope hanging vertically from a tall tree at the edge of a lake.
- a) How high can she swing upward?
 - b) Does her mass affect the answer?
 - c) Does the length of the vine affect the answer?
13. A car of 1200 kg is travelling at 20 m/s when it slams on the brakes.
- a. How much kinetic energy does the car have before it hits the brakes?
 - b. Where does this energy go when the driver brakes to a stop?
 - c. What is the work done by the car's brakes?

- d. If the car brakes over a distance of 50 m before coming to rest, what is the force of friction provided by the brakes on the car?

14. The figure below shows a roller coaster. The 500 kg carriage is pulled up the first incline from ground level at A to the first peak at B. From here it then rolls freely from rest under the influence of gravity.



- a. Describe the energy transformations involved when the cart travels from B to C
- If track is frictionless:
 Moving from A to B: _____
 Moving from B to C: _____
 Moving from C to D: _____
 - If we include friction:
 Moving from A to B: _____
 Moving from B to C: _____
 Moving from C to D: _____
- b. If no friction forces are present, how fast will the cart be moving at location C?
- c. Upon reaching location C the cart continues to roll freely to location D. How much gravitational potential energy does the cart gain from C to D?
- d. Based on your answer above, how much kinetic energy does the cart lose from C to D? Where did the kinetic energy go?

- e. What is the final speed of the cart at location D?

- f. In reality we will always have friction. The final speed of the cart at location D is found to be only 13 m/s. What is the total amount of mechanical energy (both potential and kinetic) at location D?

- g. How much energy was “lost” overall from location B to D?

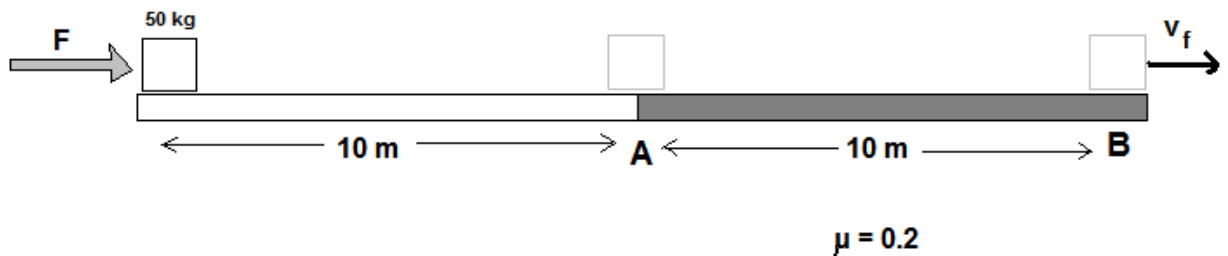
- h. Efficiency is a percentage that describes how much energy was conserved as “useful” energy between B and D. What is the efficiency of this coaster?

- 15. A pole-vaulter of mass 75 kg reaches a maximum speed of 7 m/s just before he jams his pole into the notch to launch himself over the bar. Assuming that his pole is only 80% efficient, what is the maximum height that the pole-vaulter can reach?

- 16. A pendulum bob is moving 1.8 m/s at the bottom of its swing. To what height above the bottom of the swing will the bob travel? **Show all work**

17. Tarzan grabs a vine 12 m long and swings on the end of it, like a pendulum. His starting point is 5.0 m above the lowest point in his swing. How fast is Tarzan moving as he passes through the bottom of the swing? **Show all work**

18. A 50 kg crate is pushed with a force, F , of 40 N over two different surfaces. The first 10 m is over ice (frictionless) and the last 10 m is a rough surface where the friction coefficient is 0.2.



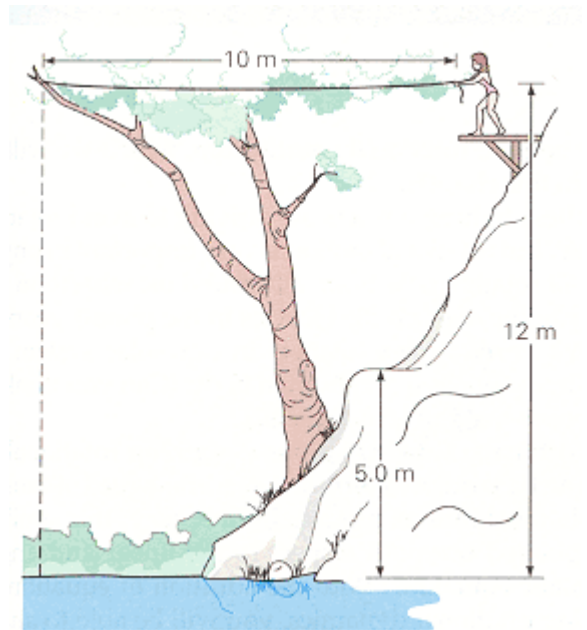
- Work is defined as a change in energy of an object. In Physics 12 we talk about kinetic energy, gravitational potential energy, and thermal energy. What two forces are contributing to the overall energy of the crate? Discuss whether they are positive or negative contributions to the overall energy of the crate.
- How much work was done on the crate have after the first 10 m? What type of energy is this manifested as?
- Determine the velocity of the crate at point A in the diagram.
- Determine the force of friction. How does this force compare to F ? Describe the motion of the crate between points A and B.

19. A pendulum bob is has a 2m long string attached to a 0.5 kg mass. It is released at an angle of 30° to the vertical.
- Draw a sketch showing the angles. Use the sketch to determine the launch height. **Show all work**

- How fast is the pendulum moving at the bottom, of the swing?

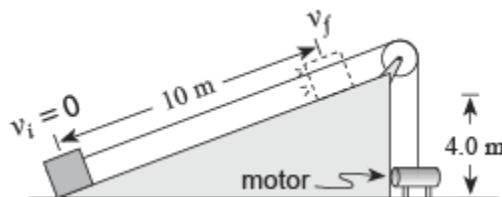
20. Jane (60 kg) grabs a rope 10 m long and swings on the end of it, like a pendulum. Her starting point is on the platform shown.

- How fast is Jane moving as she passes through the bottom of the swing? Show all work

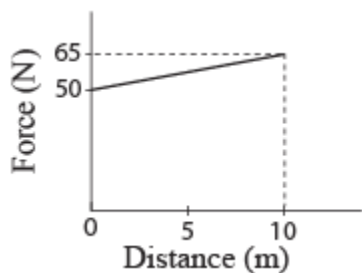


- At the bottom of the swing her speed is found to be 12 m/s. How much energy was lost?

21. An electric motor and a rope are used to pull a 10 kg crate of car parts up an inclined plane as shown below. The crate starts out from rest on the ground and ends up with speed v_f at a height of 4.0 m above the ground.



The graph below shows the force exerted on the crate by the motor as it is pulled 10 m up the inclined plane.



- Using the graph above, determine the work done on the crate by the motor. Show that the units for your calculation are equivalent to the units for work.
- During the crate's ascent up the ramp it heats up. Since $W = \Delta E$, discuss the type(s) of energy that is given to the crate through this process.
- The thermal energy produced amounts to 150 J. Use your answer above to determine the final velocity of the crate.

Power:

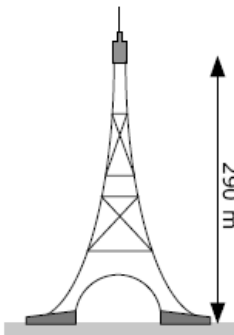
1. A helicopter is used, with a pulley and a rope, to lift a 650 N load up by 12 m in a time of 11 s. What is the power output of the motor in Watts and Horsepower?

2. The power of a light bulb is the amount of electrical energy it consumes in one second. A 40 W bulb, for example, uses 40 J of electrical energy in 1 s. What is the power rating of a light bulb that consumes 4 200 J of electrical energy in 70.0 s?

3. A 68 kg student runs up a flight of steps. Each step is 20 cm high. What is her power output if she can do 14 steps in 4.8 seconds?

4. Power is a pretty simple concept if you understand energy, as you just need to determine the energy used (no matter what kind) then divide it by _____.

5. The observation platform at the top of the Eiffel tower is 290m above the ground.



- a. How much work must the average person perform to climb to this level? Assume that an average person has a mass of 70 kg.

- b. Would the amount of work done above be different if you stopped for a rest from time to time? Explain your answer.

- c. Would the amount of work change if you ran up some stairs and walked up others? Explain your answer.

- d. Repeat (b) and (c) above by replacing the word “work” with power.

Question (b):

Question (c):

6. An express lift (elevator) takes a 70 kg passenger from street level to the top of a 400 m sky-scraper in 4 minutes. The mass of the elevator itself is 500 kg.
- How much gravitational potential energy does the passenger gain on the way up?
 - At what rate (energy per second) is the passenger gaining potential energy?
 - At what rate is the lift plus the passenger gaining potential energy?
 - What power is the lift plus the passenger experiencing as it climbs?
 - The motor driving the lift has an efficiency of only 25%. At what rate is the motor working as the lift is going up?
7. How much work will a 4.0 HP (3 kW) motor do in half an hour? **Show all work.**

Efficiency:

1. We know that energy is never created or destroyed, so where does the wasted energy in an inefficient device usually go?
2. To lift a 1200 N motorcycle a vertical height of 1.3 m onto a pickup truck, a motocross rider pushes the bike up a ramp 2.4 m, requiring an effort force up the ramp of 820 N. What is the efficiency of the ramp?
3. A 1500 W kettle warms 1.00 kg of water from 18°C to 88°C in a time of 3.6 min. How efficient is the kettle?
4. A 100 g rubber ball is thrown down at 4.0 m/s from a height of 2.5 m. If the ball bounces to a height of 2.7 m, calculate the efficiency.
5. Explain a situation where the efficiency of a device would change based on a redefinition of what is considered useful energy.

6. One difficulty that HVAC (Heating Ventilating and Air-Conditioning) technicians have when replacing a furnace for a customer is that the customer often feels that the technicians are “ripping them off” by giving them much smaller furnace than they originally had.
 - a. The old furnace is 60% efficient and is sized at 180000 btu (don’t worry too much about the units). How much energy (in btu) was heating the house before the exchange.
 - b. The new furnace is 92% efficient. What size of furnace is needed to produce the same heat energy to the house (in btu)?
7. A motor using 3.7×10^3 W is 81% efficient. This motor is pulling a 450 kg block along a horizontal surface at a steady speed. If the coefficient of friction is 0.35, what is the speed of the block?(ans: 1.94 m/s)



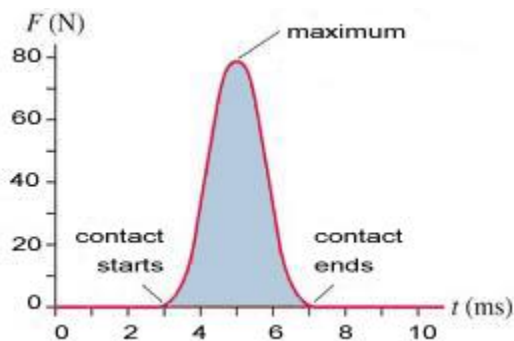
Momentum:

1. Since momentum is based on the same concepts as Newton’s laws, why do we find it necessary (and/or convenient) to work with the concept of momentum?
2. Describe the difference between elastic and inelastic collisions.
3. Derive the general conservation of momentum for two objects involved in an elastic collision starting with $p_{\text{before}} = p_{\text{after}}$.

4. Derive the general conservation of momentum for two objects involved in an inelastic collision starting with $p_{\text{before}} = p_{\text{after}}$.
5. Derive the general conservation of momentum for an object exploding into two objects starting with $p_{\text{before}} = p_{\text{after}}$.
6. An atomic nucleus at rest decays radioactively into an alpha particle and a smaller nucleus. The alpha particle is observed to move off at a speed of 3.8×10^5 m/s. What will be the speed and direction (relative to the alpha particle) of the recoiling nucleus if the daughter nucleus is 57 times more massive than the alpha particle? **Show your work.**
7. A 145 kg astronaut (including space-suit) acquires a speed of 2.50 m/s by pushing off with her legs from an 1850 kg space capsule. a) What is the change in speed of the space capsule? b) If the push lasts for 0.500 sec, what is the average force exerted by each on the other? Consider a reference frame in which the space capsule is at rest before the pushing off. **Show your work.**
8. Suppose there are three astronauts outside a spaceship, and two of them decide to play catch with the third man. All the astronauts weigh the same on earth and are equally strong. The first astronaut throws the second one toward the third one and the game begins. Describe the motion of the astronauts as the game proceeds. How long will the game last?

9. A 5.0 g air pellet is fired into a 495 g sandbag, which is suspended by a string to form a pendulum. If the sandbag plus the imbedded pellet move off at 2.0 m/s immediately after the pellet hits the sandbag, what was the speed of the pellet just before it hit the sandbag?). **Show your work** as shown in the lessons.
10. A boy and his skateboard have a combined mass of 64 kg. If he is moving with a speed of 3.2 m/s, and collides with a stationary skateboarder whose mass (including his skateboard) is 96 kg, with what speed will the two skateboarders move immediately after the collision? Assume they are hopelessly entangled, but their wheels point in the same direction). **Show your work** as shown in the lessons.
11. The Titanic hit an iceberg estimated to be half of her mass. Before hitting the iceberg, the Titanic was estimated to be going 22 kts (11.3 m/s). After hitting the iceberg, the Titanic was estimated to be going about 6.0 knots (3.1 m/s). How fast was the iceberg going after the collision? Assume a head-on collision. **Show your work** as shown in the lessons.

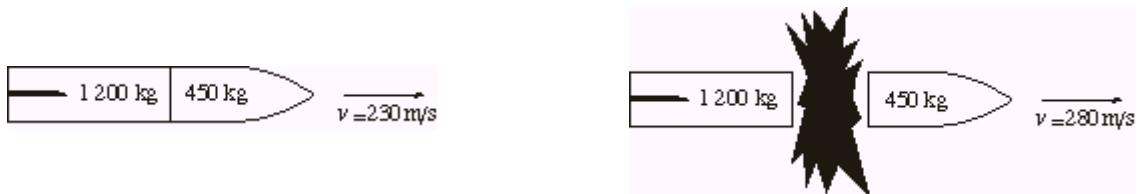
12. A volleyball is hit so that its incoming velocity of $+40 \text{ m/s}$ is changed to outgoing velocity of -21 m/s . The mass of the volleyball is 0.35 kg . What impulse does the player apply to the ball?
13. A golfer hits a golf ball off the tee giving the ball a velocity of $+38 \text{ m/s}$. The mass of the ball is 0.045 kg , and the duration of the impact with the golf ball is 0.003 s . a) What is the change in momentum of the golf ball? b) Determine the average force applied to the golf ball by the club.
14. What is the average force applied by a baseball bat to a 0.12 kg ball if the ball changes in velocity from 40 m/s towards the batter to 50 m/s away from the batter following a 0.02 second contact?
15. What is the impulse applied to the ball if the bat applied a force as described in the graph below?



16. Explain(in terms of Impulse and momentum) why coaches in baseball, hockey, boxing, tennis, golf, and many other sports, spend a lot of time on the idea of a good “follow-through?”
17. A BC Ferry ($m = 13000.0$ tonnes) is traveling at 11 m/s when the engines are put in reverse. The engines produce a force of $1.0 \times 10^6 \text{ N}$ for a period of 20.0 seconds.
- a) What is the magnitude of the impulse from the engine?
 - b) What is the new momentum of the ferry?
 - c) What is the new velocity of the ferry?
18. A rail car of mass $20\,000 \text{ kg}$ is moving at 5.0 m/s toward a second rail car of mass $40\,000 \text{ kg}$ moving in the same direction at 1.8 m/s . They collide and the first car is seen moving backward at 1.5 m/s . What must be the final velocity of the second car?

19. Ms. Grisham is rear-ended at a stop light by Mr. Nelson, and sues to make him pay her medical bills. He testifies that he was only going 35 km/hr when he hit Ms. Grisham. She thinks he was going much faster than that. The cars skidded together after the impact, and measurements of the length of the skid marks and the coefficient of friction show that their joint velocity immediately after the impact was 19 km/hr. Mr. Nelson's car weighs 2100 kg, while Ms. Grisham's weighs 2600 kg. Is Mr. Nelson telling the truth?

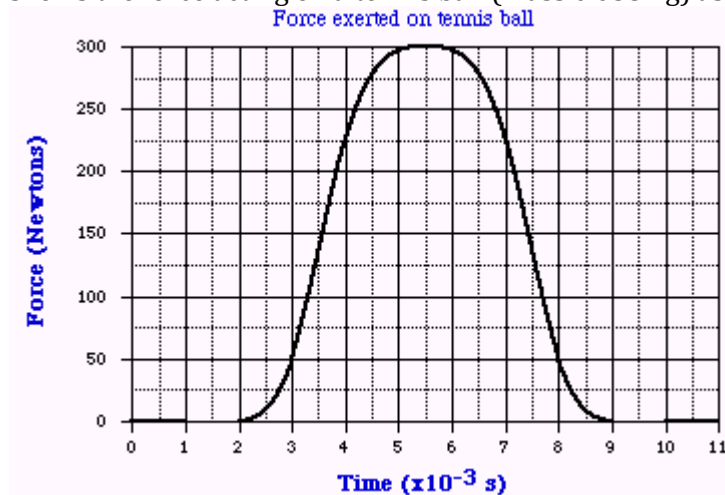
20. A space vehicle made up of two parts is travelling at 230 m/s as shown. An explosion causes the 450 kg part to separate and travel with a final velocity of 280 m/s as shown.



- Is this considered to be elastic or inelastic?
Look up these definitions and support your decision with these.
- For ANY collision or explosion what two quantities are ALWAYS conserved? Be specific.
- After the explosion shown above we see that the front nose increases its velocity from 230 m/s to 280 m/s. What do you predict will happen to the rear of the space vehicle? How does your prediction support your answer to (b) above?

- d. Determine the final velocity of the rear piece.
- e. Calculate the change in momentum of both the front a rear pieces separately. Be careful with the signs. What did you discover for explosions (and collisions) involving two masses?
- f. What is the Impulse that acts on each piece during the explosion? Use above to help.
- g. Explain why your answers to (f) make sense if we consider the equation $I = F_{\text{avg}}t$ as opposed to $I = \Delta p$. Be sure to refer to the appropriate of Newton's Laws to assist in your explanation (no calculations are necessary).

21. The graph below shows the force acting on a tennis ball (mass 0.055 kg) as a function of time.



- a. Determine what the units would be for the area under the curve. What does this area represent (pay attention to the units)?
- b. Do your best to estimate the area under this curve by counting squares and partial squares.
- c. What is the impulse given to the ball?
- d. Assuming the ball was initially at rest, what was the final speed of the ball after the force acted on it?
- e. Determine the average Force that acts on the ball over this time interval. Draw a horizontal line on the graph at this point and label it F_{avg} .

22. A 0.05 kg bullet moving vertically upwards at 125 m/s hits a stationary 2.6 kg block hanging from a 5.00 m long string. The block then soars upward until it reaches a maximum height (you may assume that the bullet remains within the sandbag).

- a. What physics concept applies for the collision between the bullet and the block? Calculate the speed the block has immediately after the collision.
- b. What kind of energy does the block have after the collision? Where does this energy go once it soars into the air and reaches its maximum height?
- c. Calculate the maximum height reached by the block.

23. Compare the total kinetic energy before and after for each of the situations below. Discuss what happens to the energy.

Situation	Total kinetic energy after (compared to before) – circle choice	If there is a change in Kinetic Energy where does this energy go or come from?
Elastic collision	Increases / decreases / same	
Inelastic collision	Increases / decreases / same	
Explosion	Increases / decreases / same	

24. Discuss why there are no seatbelts in a passenger train. What would happen to the passengers if the train were to collide with a car on the tracks?

2D Momentum:

1. A 0.25 kg pool ball is moving at 5.0 m/s [E] toward a second identical ball at rest. After the collision, the first ball is seen moving at 1.0 m/s [E]. What is the final velocity of the second ball?
2. A stationary 20.0 kg mass explodes into three fragments. As shown in the diagram below, the 5.0 kg fragment moves north with an initial speed of 7.0 m/s. The 9.0 kg fragment moves off at 38° S of W with an initial speed of 4.0 m/s.



- a. What must the total momentum for all three pieces be after the explosion? State the law that justifies your answer.
- b. Any collision or explosion must adhere to the Law of Conservation of Energy. Collisions that are perfectly elastic are ones in which Kinetic Energy is Conserved. Is it possible for an explosion such as this to be elastic? Is kinetic energy gained or lost? Briefly explain.
- c. State how energy is conserved in an explosion like this? Be specific.

- d. What is the velocity (magnitude and direction) of the 6.0 kg fragment after the explosion? Solve this question using both the trigonometric and the component methods.

Trig. Method (include a vector diagram)

Component Method (show all work)

3. A 98.0 kg hockey player skating at 2.12 m/s 32° S of W is body checked by an 87.0 kg opponent who is skating at 1.40 m/s 42° N of E. They collide inelastically and stick together.
- a. What is the velocity of the pair immediately after the collision? Solve using both methods. .

Trig. Method (include a vector diagram)

Component Method (show all work)

- b. Determine the impulse imparted to the 98.0 kg player. Show a complete vector diagram and label your answer.
- c. From what you know about Impulse, what would the Impulse for the 87.0 kg player be? Provide both magnitude and direction. (you need not calculate if you understand the concepts)
- d. State what you found out for questions b and c above and justify your results using $I = F_{avg} t$. State any of the appropriate Newton's Laws to help explain. No calculations are necessary. Simply justify what you found out from (b) and (c) by using the other equation for Impulse, $I = F_{avg} t$.

Answers:

Work & Energy:

1) 0.43Nm 2) 41.5Nm, gravity 3) 1320J, 4x 4) 1375J 5) person, gravity 6) $9 \times 10^4 \text{ J}$, $3.6 \times 10^5 \text{ J}$, four times bigger, 21.2 m/s, root(2) 7) 130J 8) 17m/s 9) 25m/s, 113J 10) 7.7m/s, 8.9m/s 11) 20m/s, 97m 12) 1.3m 13) $2.4 \times 10^5 \text{ J}$, heat, $-2.4 \times 10^5 \text{ J}$, 4800N
 14) a) i) AB: $W \rightarrow E_p$ BC: $E_p \rightarrow E_k$ CD: $E_k \rightarrow E_p + E_k$ ii) AB: $W \rightarrow E_p + W_f$ BC: $E_p \rightarrow E_k + W_f$ CD: $E_k \rightarrow E_p + E_k + W_f$ b) 26.2m/s c) $9.8 \times 10^4 \text{ J}$ d) $-9.8 \times 10^4 \text{ J}$ e) 17.1m/s f) $1.4 \times 10^5 \text{ J}$ g) $3.1 \times 10^4 \text{ J}$ h) 82% 15) 2m 16) 0.17m 17) 9.9m/s 18) b) 400J c) 4m/s d) 98N 19) a) 0.27m b) 2.3m/s 20) 14m/s, 1560J 21) a) 575J c) 2.6m/s

Power:

1) 710W, 0.95 HP 2) 60W 3) 390W 4) time 5) $2.0 \times 10^5 \text{ J}$, same, no, changes, changes 6) $2.74 \times 10^5 \text{ J}$, 1140J/s, 9310J/s, 9310W, $3.72 \times 10^4 \text{ W}$ 7) $5.4 \times 10^6 \text{ J}$

Efficiency:

2) 79%, 3) 91% 4) 81% 6) 108000btu, 117000btu 7) 1.94 m/s

Momentum:

6) 6700 m/s 7) a) -0.02 m/s b) 725 N 8) 2 9) 200 m/s 10) 1.28 m/s 11) 16.4 m/s
 12) 21.4 Ns 13) a) 1.71Ns b) 570N 14) 540N 15) 0.16 Ns 16) $\uparrow \Delta t$ 17) a) $-2.0 \times 10^7 \text{ Ns}$ b) $1.23 \times 10^8 \text{ kgm/s}$ c) 9.5m/s 18) 5.1 m/s [right] 19) No, 42.5 km/h
 20) a) inelastic d) 211.25 m/s e) 22500kgm/s f) 22500 kgm/s, and -22500 kgm/s
 21) a) Ns, Impulse b) almost 1 Ns c) 1 Ns d) 18.1 m/s e) 143 N 22) a) 2.36 m/s c) 0.28 m
 23) same, decrease, increase 24) small Δv

2D Momentum

1) 4 m/s [E] 2) a) zero d) 5.19 m/s at 66° east of south 3) a) 0.488 m/s @ 18.5° SofW
 b) 161.8 kgm/s @ 36.1° N of E