Name: ______________________________ *Date:* ____________ *Period:* ____

Name: ______________________________ *Date:* ______________ *Period:* _____

Energy

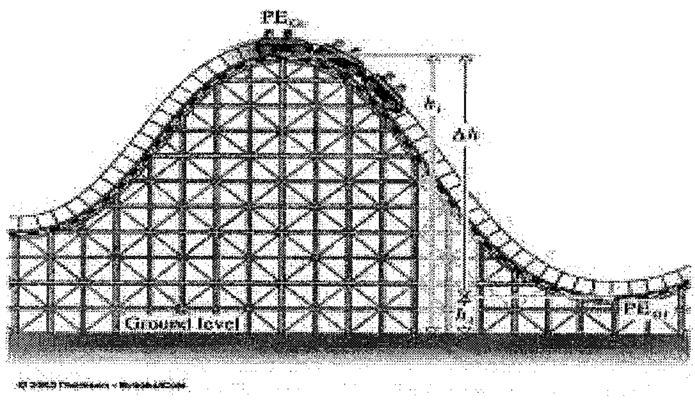
Energy is a measure of the ability to do work. Δ Energy = 0 in a closed system.

Types of Energy

1. **Gravitational Potential Energy** (PE) - measure of the ability to do work due to an object's position relative to a gravitational source. Unit = Joules (J)

$$GPE = mgh$$

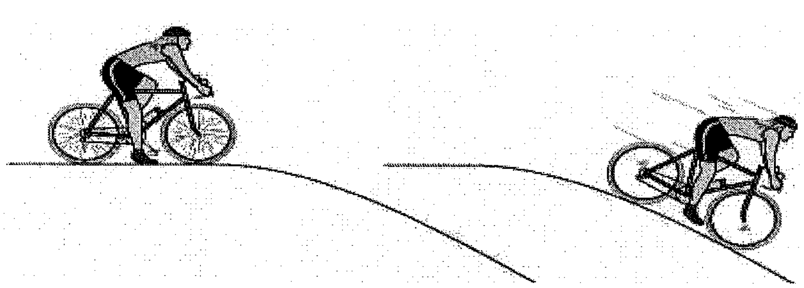
- m = mass of object, kg
- g = acc. due to gravity, 9.8 m/s^2
- h = height of object above the reference point, m



2. **Kinetic Energy** (KE) - measure of the ability of a moving object to do work, because of its mass and speed.

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

- m = mass of object, kg
- v = speed of object, m/s

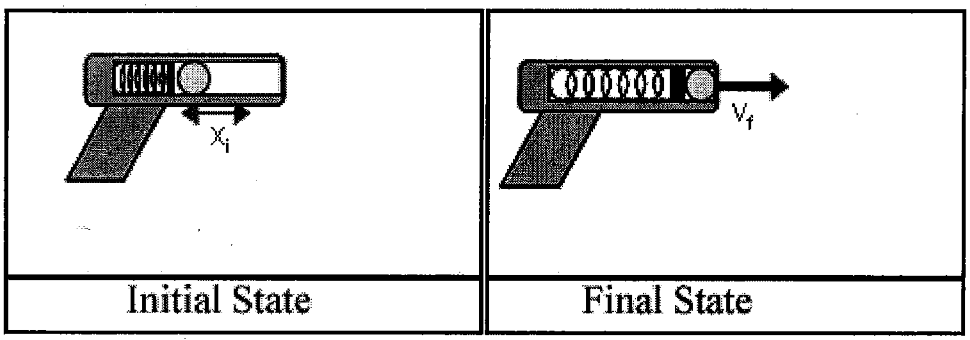


Name: ______________________ Date: ____________ Period: _____

3. **Elastic Potential Energy** (EPE) - the energy stored in elastic materials as a result of stretching or compressing.

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

- K = spring constant N/m
- X = amount of compression m



Work-Energy Theorem - states that work ↔ energy (interchangeable), so the amount of work done equals the overall change in energy level

$$Work = \Delta\ Energy$$

$$Work = \Delta GPE = GPE_f - GPE_i$$

$$Work = \Delta KE = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$Work = \Delta EPE = \frac{1}{2}k(x_f^2 - x_i^2)$$

Note: When applying theorem, only the initial and final conditions of the system are important (Δ), not what happens in between.

Name: ______________________ *Date:* ____________ *Period:* _____

Samples:

1. A 15-kg rock is on the edge of a 120 m cliff. What potential energy does the rock possess relative to the base of the cliff?

   $GPE = mgh$
   $= (15)(9.8)(120) = 17{,}640\ J$

2. What is the kinetic energy of a rock of mass 12 kg sliding across the ice at 2.0 m/s?

   $KE = \frac{1}{2} mv^2$
   $= \frac{1}{2}(12)(2^2) = 24\ J$

3. How much work must be done to accelerate an 800 kg car from 15 m/s to 30 m/s?

   $W = \Delta KE$
   $= \frac{1}{2} m(v_f^2 - v_i^2) = \frac{1}{2}\, 800(30^2 - 15^2) = 270{,}000\ J$

4. A hoist is used to raise a 40 kg block of ice from a platform 8 m above the ground, to a platform 20 m above the ground. For the block of ice:
   A. What is the initial potential energy? (3136 J)

   $GPE = mgh$
   $= (40)(9.8)(8) = 3136\ J$

   B. What is the final potential energy? (7840 J)

   $GPE = mgh$
   $= (40)(9.8)(20) = 7840\ J$

   C. What is the change in potential energy? (4704 J)

   $\Delta PE = PE_f - PE_i$
   $= 7840 - 3136 = 4704\ J$

   D. How much work does the hoist do as the block is raised to the higher platform?

   $W = \Delta PE = 4704\ J$

Name: ______________________________ *Date:* ______________ *Period:* _____

5. A horizontal spring with k = 100 N/m is compressed by 10 cm by a 100 g mass.
   a. How much elastic potential energy does the compressed spring store?

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

   $= \frac{1}{2}(100)(.1^2) = .5\ J$

   b. How much elastic potential energy would the compressed spring store if it were compressed the same distance by a 300 g mass?

   It would be the same. mass is Not part of the equation!

Section 5-3: Conservation of Energy

Recall: 3 types of mechanical energy previously studied

Gravitational Potential Energy (PE) - measure of the ability to do work due to an object's position relative to a gravitational source.

GPE = mgh

Kinetic Energy (KE) - measure of the ability of a moving object to do work, because of its mass and speed.

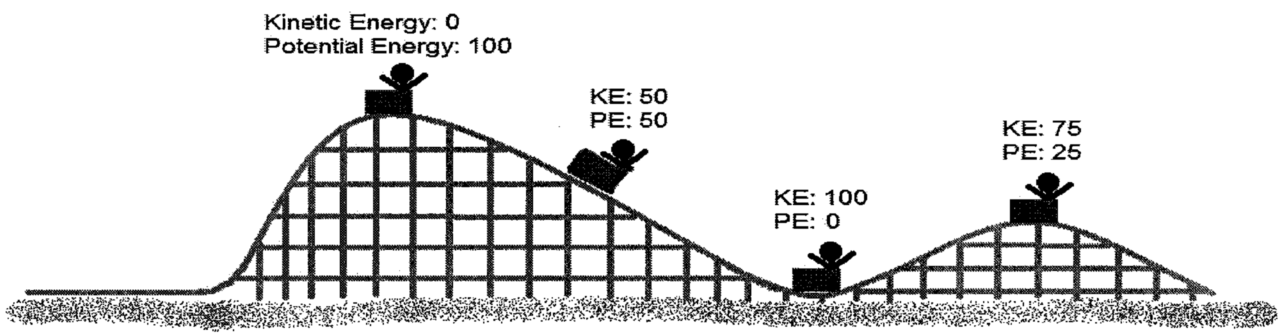
$KE = \frac{1}{2}mv^2$

Elastic Potential Energy (EPE) - the energy stored in elastic materials as a result of stretching or compressing.

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

Name: ______________________ *Date:* ______________ *Period:* _____

Law of Conservation of Energy – Energy cannot be created or destroyed. It can be transferred from one form to another, but the total amount of energy never changes.



In the absence of friction, mechanical energy (sum of GPE, KE & EPE) is also conserved.

$$ME_i = ME_f$$

OR

$$GPE_i + KE_i + EPE_i = GPE_f + KE_f + EPE_f$$

Sample #1: Gravitation System (Rock falls from rest.)

a. Label the top and bottom with PE and KE as maximum or zero values.
b. Find the speed as the rock hits the base of the cliff.
c. Can you work part b) using kinematics?
d. Find the speed at a height of 20 m instead.

(B) $GPE_i + KE_i = PE_f + KE_i$

$mgh + \frac{1}{2}mv^2 = mgh + \frac{1}{2}mv^2$

$mgh + 0 = 0 + \frac{1}{2}mv^2$

$gh = \frac{1}{2}v_f^2$

$(9.8)(120) = \frac{1}{2}v_f^2$

$\sqrt{\frac{9.8(120)}{.5}} = v_f$

$48.5\ m/s = v_f$

(C) $v_f^2 = v_i^2 + 2gy$

(D) $mgh + \frac{1}{2}mv^2 = mgh + \frac{1}{2}mv^2$

$mgh + 0 = mgh + \frac{1}{2}mv^2$

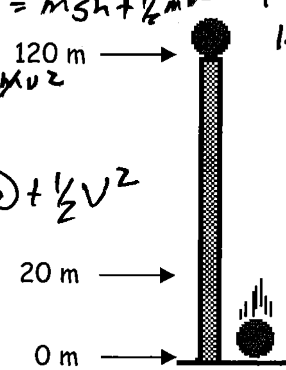
$gh = gh + \frac{1}{2}v^2$

$(9.8)(120) = (9.8)(20) + \frac{1}{2}v^2$

$1176 = 196 + \frac{1}{2}v^2$

$\sqrt{\frac{1176 - 196}{.5}} = v$

$44.27\ m/s = v$



PE max, KE = 0 (top)

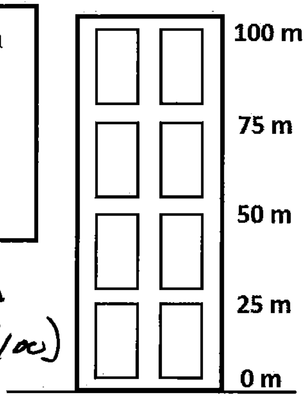
KE max, PE = 0 (bottom)

Name: ______________________ Date: ______________ Period: _____

Sample #2

A person is getting ready to drop a ball from the top of a building shown below. Fill in the potential energy and kinetic energy at each place indicated as the ball falls to the ground. Round the acceleration of gravity (9.81 m/s^2) to the closest whole number for easier calculations. (**Hint**: Find the mass of the ball with the given information.)

GPE = mgh
h = 100 m
g = 10 m/s^2
m = ?



PE = 10 J KE = 0 J

PE = 7.35 KE = 2.65 mgh = (.01)(9.8)(75) = 7.35 J

PE = 4.9 KE = 5.1 mgh = (.01)(9.8)(50) = 4.9 J

PE = 2.45 KE = 7.55 mgh = (.01)(9.8)(25) = 2.45 J

PE = 0 KE = 10 J

GPE = mgh

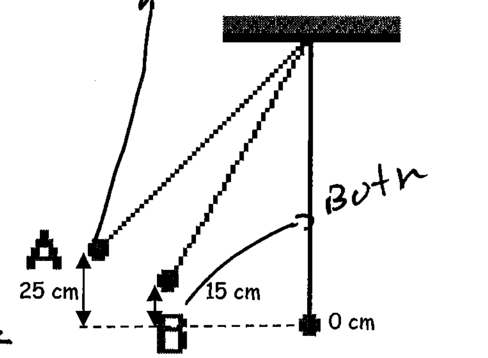
10 = m(9.8)(100)

$\frac{10}{(9.8)(100)} = m$

.01 kg = m

Sample #3: Pendulum (mass = 0.50 kg)

a. Label where PE and KE are maximum and zero values. PE max & KE = 0 at Point A
b. What is the potential energy at position A?
c. What is the maximum speed of the pendulum?
d. What is the potential energy at C?
e. What is the speed at position B?



(B) GPE = mgh
= (.5)(9.8)(.25)
= 1.22 J

(D) PE = 0
No Height

(C) PE + KE = PE + KE
mgh + 0 = 0 + ½ mv²
mgh = ½ mv²
gh = ½ v²
$\sqrt{\frac{(9.8)(.25)}{.5}} = v$
2.21 m/s = v

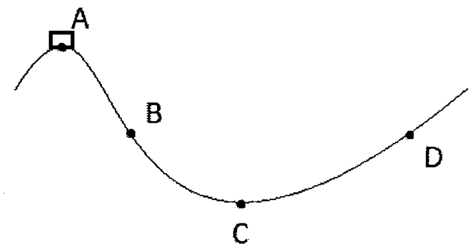
(E) PE + KE = PE + KE
mgh + 0 = mgh + ½ mv²
gh = gh + ½ v²
(9.8)(.25) = (9.8)(.15) + ½ v²
2.45 = 1.47 + ½ v²
$\sqrt{\frac{2.45 - 1.47}{.5}} = v$
= 1.4 m/s

Name: ______________________________ Date: ______________ Period: _____

Sample #4: Roller Coaster (Coaster starts from rest at A.)

The mass of the small car (including contents) is 400 kg and the height of point is 20 meters above point C. Points B and D are at the same height and are 10 meters above point C.

a. What potential energy does the car have at A?
b. If the car starts at point A, what velocity will it have at C?
c. If the car starts at point A, what velocity will it have at D?



(A) $PE = mgh$

$= (400)(9.8)(20)$

$= 78,400 \text{ J}$

(B) $PE + KE = PE + KE$

$mgh + 0 = 0 + \frac{1}{2}mv^2$

$gh = \frac{1}{2}v^2$

$(9.8)(20) = \frac{1}{2}v^2$

$\sqrt{\frac{(9.8)(20)}{.5}} = v$

$19.8 \text{ m/s} = v$

(C) $PE + KE = PE + KE$

$mgh + 0 = mgh + \frac{1}{2}mv^2$

$(9.8)(20) = (9.8)(10) + \frac{1}{2}v^2$

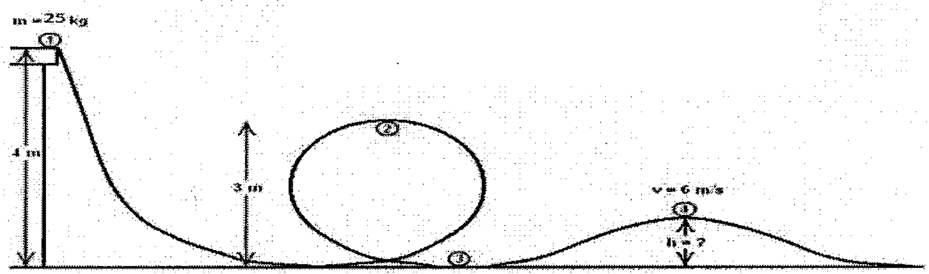
$196 = 98 + \frac{1}{2}v^2$

$\sqrt{\frac{196 - 9.8}{.5}} = v$

$14 \text{ m/s} = v$

Name: ______________________ Date: ____________ Period: _____

Sample #5



What is the total mechanical energy of the ball?

$ME = PE + KE$

$= mgh + \frac{1}{2}mv^2$

$= (25)(9.8)(4) + 0 = \underline{980\ J}$

What is the potential energy of the ball at position #2?

$PE = mgh$

$= (25)(9.8)(3) = \underline{735\ J}$

How fast is the ball moving at position #2?

$PE + KE = PE + KE$

$mgh + 0 = mgh + \frac{1}{2}mv^2$

$(25)(9.8)(4) + 0 = (25)(9.8)(3) + \frac{1}{2}(25)v^2$

$980 + 0 = 735 + 12.5v^2$

$980 - 735 = 12.5v^2$

$245 = 12.5v^2$

$\sqrt{\frac{245}{12.5}} = v = \underline{4.4 m/s}$

What is the PE at position #3?

$PE = 0$

No height

What is the height at position #4?

$PE + KE = PE + KE$

$mgh + 0 = mgh + \frac{1}{2}mv^2$

$980 + 0 = (25)(9.8)h + \frac{1}{2}(25)(6^2)$

$980 = 245h + 450$

$980 - 450 = 245h$

$530 = 245h$

$530/245 = h$

$\underline{2.16 m} = h$

Name: ______________________________ *Date:* ______________ *Period:* _____

Sample #5

A 2 kg ball is dropped onto a vertical spring with a k = 1000 N/m. From what height did the ball drop if the spring was compressed by 25 cm?

$$GPE + KE + EPE = GPE + KE + EPE$$

$$mgh + 0 + 0 = 0 + 0 + \frac{1}{2}kx^2$$

$$(2)(9.8)(h) = \frac{1}{2}(1000)(.25^2)$$

$$h = \frac{\frac{1}{2}(1000)(.25^2)}{(2)(9.8)}$$

$$= 1.6\ m$$

Sample #6

A horizontal spring is used to launch a 2 kg ball. The spring is compressed by .25 m and the k = 1000 N/m. What is the maximum speed of the ball?

$$GPE + KE + EPE = GPE + KE + EPE$$

$$0 + 0 + \frac{1}{2}kx^2 = 0 + \frac{1}{2}mv^2 + 0$$

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

$$\underline{(\tfrac{1}{2})(1000)(.25^2)} = \frac{1}{2}(2)v^2$$

$$\sqrt{\frac{\frac{1}{2}(1000)(.25^2)}{\frac{1}{2}(2)}} = v = 5.6\ m/s$$

Name: ______________________ Date: ____________ Period: ____

WORK AND POWER

Work (W) is done when a **force** causes **displacement** of an object. Thus the object must **MOVE!**

$$W = Fd \cos \Theta$$

Note: If F and d are in the same direction, what is θ? **ZERO**

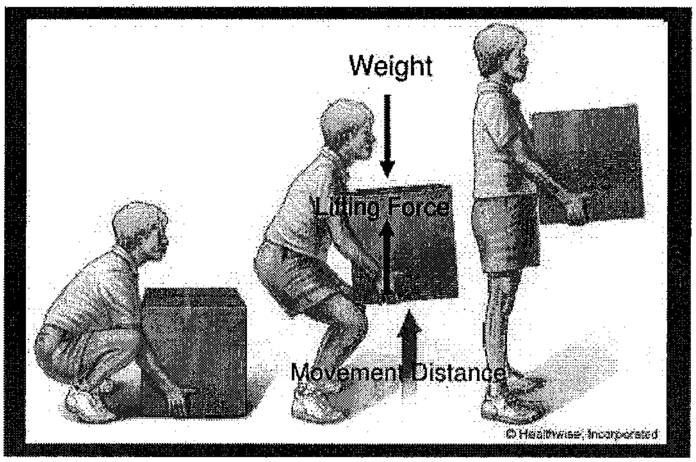
In this case **$W = Fd \cos \theta = Fd$** **(Cos 0 = 1)**

- F = force acting on object (N)
- d = displacement of object (m)
- θ = angle between direction of force and direction of displacement (°)
- Units for work = 1 J= 1 Nm

Work is a **SCALAR** quantity.

Work is done only when components of a force are **PARALLEL** to a displacement.

- **They must be in the same direction *********



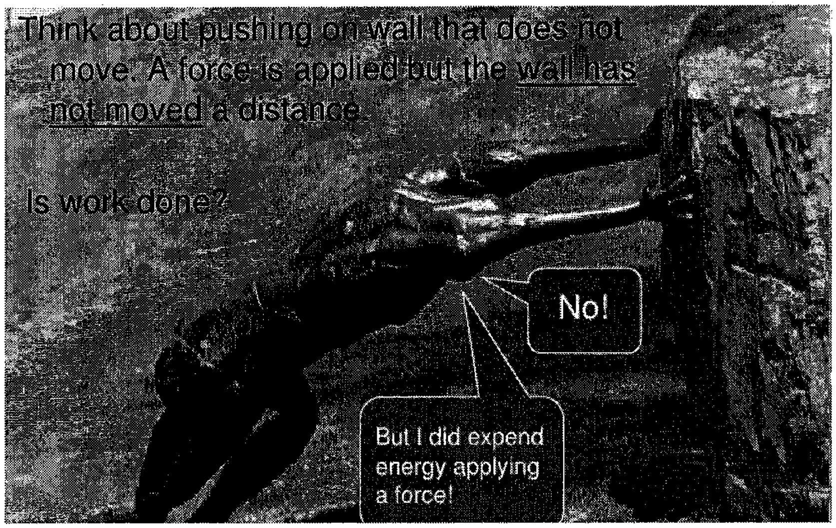
Work is NOT done every time a force is applied.

Is work being done when the box is lifted? Yes

Is work being done when the box is held? No

Is there work is the box was being carried? No

Name: ______________________ **Date:** ____________ **Period:** _____



Which situation causes more work to be done?

Lifting a 1 kg box up 1 flight of stairs or lifting a 1 kg box up 2 flights of stairs?

2 Flights of stairs

Further distance

Lifting a 2 kg box up 1 flight of stairs or lifting a 1 kg box up 1 flight of stairs?

2kg Box

- Requires greater Force

Name: ______________________ Date: ______________ Period: _____

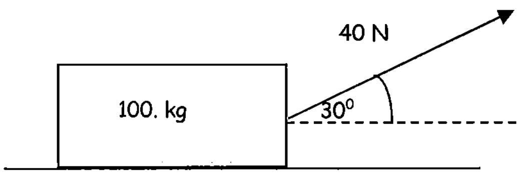
Samples:

1. Bud, a very large man of mass 130 kg, stands on a pogo stick. How much work is done as Bud compresses the spring of the pogo stick 0.50 m? (637 J)

$W = Fd\cos\Theta$
$= Fd$ * No Angle
$= Wd$ * Weight is the Force

mgd * sub mg for W
$(130)(9.8)(.50) = 637$ J

2. A 100. kg object is moved a distance of 20. m with a force of 40. N at an angle of 30.° above the horizontal. How much work is done? (693 J)



$W = Fd\cos\Theta$
$= (40)(20)\cos 30$
$= 693$ J

Power is the rate at which work gets done, OR amount of work that is done per unit of time.

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

- W = work, J
- Δt = time interval, s

Starting with the equation above, derive another equation for power (P) in terms of velocity:

$P = \frac{W}{\Delta t}$ Rearrange $P = \frac{Fd\cos\Theta}{\Delta t}$ Rearrange $P = F\frac{d}{t}$ thus $P = FV$

Note that

- power is scalar (no direction)
- units for power are **watts (W)**; 1 W = 1 J/s
- for electricity, power expressed in kilowatts (kW); 1 kW = 1000 W
- for engines, power expressed in horsepower (HP); 1 HP = 746 W

Name: ______________________________ *Date:* ______________ *Period:* _____

Samples:

1. A 65 kg student travels from the 1st floor to the 4th floor of a school (total height of 15 m).
   a. What total work did she do climbing the stairs? (9555 J)

$W = Fd = wd = mgd$

$(65)(9.8)(15) = 9555\ J$

   b. How long would this trip last if the student produced 480 W of power? (20. s)

$P = W/t$

$480 = 9555/t$

$t = \frac{9555}{480} = 20\ sec$

2. How much power does a crane develop, doing 60,000 J of work in 5.00 min? (200 W)

$P = W/t$ $\quad \frac{60{,}000}{300} = 200\ W$

$5\ min \cdot \frac{60\ s}{1\ min} = 300\ sec$

3. How long does it take a 2.5 kW electric motor to do 75,000 J of work? (30. s)

$2.5\ kW \cdot \frac{1000\ W}{1\ kW} = 2{,}500\ W$

$P = W/t$

$2{,}500 = \frac{75{,}000}{t}$

$t = \frac{75{,}000}{2{,}500} = 30\ sec$

Name: ______________________________ **Date:** ______________ **Period:** _____

Work, Power, Energy: In-Class Practice

1. A plane moves down a runway for take-off after starting from rest. The mass of the jet is 0.2×10^3 kg. If the jet's engines do 2.55×10^4 J of work to speed it up for take-off, what is the takeoff speed (final velocity)? (15.97 m/s)

$W = \Delta KE$

$2.55\times10^4 = \frac{1}{2} m(v_f^2 - v_i^2)$

$2.55\times10^4 = \frac{1}{2}(.2\times10^3)(v_f^2 - 0^2)$

$\frac{2.55\times10^4}{(\frac{1}{2})(.2\times10^3)} = v_f^2$

$\sqrt{\frac{2.55\times10^4}{(\frac{1}{2})(.2\times10^3)}} = v = 15.97$ m/s

2. A father (100 kg) and his son (50 kg) are jogging at the same speed. Which statement is true about the kinetic energy of the father and his son?

(A) $KE_{father} = 2KE_{son}$ B) $KE_{father} = \frac{1}{2} KE_{son}$ C) $KE_{father} = 4KE_{son}$ D) $KE_{father} = \frac{1}{4} KE_{son}$

$\frac{1}{2}mv^2_{Dad} > \frac{1}{2}mv^2_{son}$

$\frac{1}{2}(100)(1)^2$ | $\frac{1}{2}(50)(1)^2$

50 | 25

3. A pendulum, of mass 4.00 kg, is pulled from its equilibrium position, and then released. If the pendulum has a velocity of 3.5 m/s as it passes through the equilibrium position, find the height, h. (.625 m)

$PE + KE = PE + KE$

$mgh + 0 = 0 + \frac{1}{2}mv^2$

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

$gh = \frac{1}{2}v^2$

$(9.8)h = \frac{1}{2}(3.5^2)$

$h = \frac{(\frac{1}{2})(3.5)^2}{9.8}$

$= .625$ m

4. A 55 kg child is at the top of the giant waterslide at the Schlitterbahn in New Braunfels. The height of the water slide is 40 m above the ground. If the child starts from rest and slides all the way to the ground, what is his/her velocity at the bottom of the slide?

$PE + KE = PE + KE$

$mgh + 0 = 0 + \frac{1}{2}mv^2$

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

$gh = \frac{1}{2}v^2$

$(9.8)(40) = \frac{1}{2}v^2$

$\sqrt{\frac{(9.8)(40)}{.5}} = v$

28 m/s $= v$

Name: ______________________ Date: ______________ Period: _____

5. A man pulls his son across a frictionless floor with a constant force of 53 N. What work does the man do pulling him 159 m across the floor? (8427 J)

$W = Fd\cos$ $\quad (53)(159)$

$= Fd$ $\quad = 8{,}427\ J$

6. The spring in a dart gun has a spring constant of 20 N/m. The spring is compressed .08 m from its equilibrium position and is used to launch a .01 kg plastic dart. What is the speed of the dart as it leaves the gun?

$EPE + KE = EPE + KE$

$\frac{1}{2}kx^2 + 0 = 0 + \frac{1}{2}mv^2$

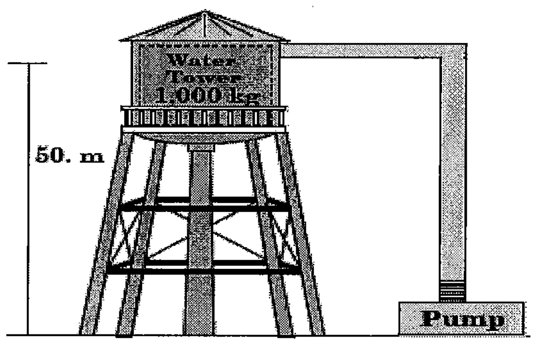
$\frac{1}{2}kx^2 = \frac{1}{2}mv^2$

$(\frac{1}{2})(20)(.08)^2 = \frac{1}{2}(.01)(v^2)$

$\frac{(20)(.08^2)}{.01} = v^2$

$\sqrt{\frac{(20)(.08^2)}{.01}} = v$

$v = 3.58\ m/s$



7. A city's water tower has a capacity of 1000 kg of water. A pump is filling the water tower to an average height of 50 m. How much work is done by the pump to fill the 1000 kg tower?

$W = \Delta PE$

$= mgh_f - mgh_i$

$= (1000)(9.8)(50) - 0$

$= 490{,}000\ J$

Name: ____________________ Date: __________ Period: _____

8. A race car driver slams on his brakes. The mass of the car is 3,500 kg. He is able to slow his car from 51.8 m/s to 3.97 m/s. What is the magnitude of the work done by the car's brakes to slow the car down? (-4668088.43 J)

$W = \Delta KE$

$= \frac{1}{2} m(v_f^2 - v_i^2)$

$= \frac{1}{2}(3500)(3.97^2 - 51.8^2) = -4.67 \times 10^6$

9. A 2.0 kg ball rolls off a 3.0 m high table traveling at 1 m/s. If it lands directly on top of an un-stretched spring with a k = 40 N/m, how far does the spring compress?

$GPE + KE + EPE = GPE + KE + EPE$

$mgh + \frac{1}{2}mv^2 + 0 = 0 + 0 + \frac{1}{2}kx^2$

$(2)(9.8)(3) + \frac{1}{2}(2)(1^2) + 0 = 0 + 0 + \frac{1}{2}(40)x^2$

$58.8 + 1 = 20x^2$

$59.8 = 20x^2$

$\sqrt{59.8/20} = x = 1.7\ m$

10. A .70 kg ball is placed on a vertical 200 N/m spring that is compressed 40 cm. When the spring is released, how high above its starting point will the ball go?

$GPE + KE + EPE = GPE + KE + EPE$ $\quad .40\ m = 40\ cm$

$0 + 0 + \frac{1}{2}kx^2 = mgh + 0 + 0$

$\frac{1}{2}(200)(.40)^2 = (.7)(9.8)h$

$16 = 6.86h$

$16/6.86 = h = 2.33\ m$

11. A worker lifts a box from the ~~third~~ 2nd shelf to the top shelf. The top shelf is 15 m above the second shelf. The clerk does 589 J of work lifting the box. What is the weight of the box? (39.27 N)

$W = \Delta PE$

$W = mgh_f - mgh_i$

$589 = mg(h_f - h_i)$

$589 = mg(15 - 0)$

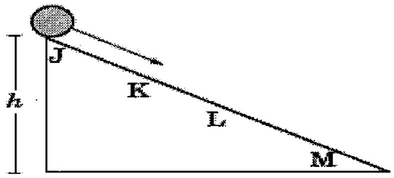
$589 = 15mg$

$589/15 = mg$

$589/15 = w = 39.27\ N$

Name: ______________________________ *Date:* ______________ *Period:* _____

12. A ball is released from the top of an Incline plane as shown below. Ignoring friction, where will GPE and KE of the ball be at a maximum?



(A) PE at J, KE at M

B PE at K, KE at L

C PE at L, KE at K

D PE at M, KE at J

13. A crate is pushed with a velocity of 3 m/s horizontally. The net force used is 30 N. What is the power used to move the crate at that velocity? (90 W)

$P = FV$

$= (30)(3)$

$= 90\ W$

14. A .6 kg arrow is shot straight up in the air with a velocity of 8 m/s. What is the height of the arrow? (3.27 m)

$PE + KE = PE + KE$

$0 + \frac{1}{2}mv^2 = mgh + 0$

$\frac{1}{2}v^2 = gh$

$\frac{1}{2}(8^2) = 9.8h$

$\frac{\frac{1}{2}(8^2)}{9.8} = h$

$3.27m = h$

15. A car with a mass of 250 kg starts at rest and accelerates to a speed of 60 m/s. What is the car's initial KE? (0 m/s)

Rest = 0 m/s   No KE

16. What is the car's Final KE? (450,000 J)

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

$\frac{1}{2}(250)(60^2) = 4.5 \times 10^5\ J$

Name: ______________________ Date: ______________ Period: _____

17. A woman runs up a hill that is 67 m high. Her mass is 15 kg. What is her change in PE? (9849 J)

$\Delta PE = mgh_f - mgh_i$

$= (15)(9.8)(67) - (15)(9.8)(0)$

$= 9849\ J$

18. A man pushes a cart with an angle of 45 degrees above the floor with a force of 350N. The man does 13,000 J of work. How far does the cart go? (52.53 m)

$W = Fd\cos\theta$

$13{,}000 = (350)(d)(\cos 45)$

$\frac{13{,}000}{(350)(\cos 45)} = d = 52.53\ m$

19. A 2.0 kg ball rolls off a 3.0 m high table traveling at 1 m/s. If it lands directly on top of an un-stretched spring with a k = 40 N/m, how far does the spring compress?

$GPE + KE + EPE = GPE + KE + EPE$

$mgh + \frac{1}{2}mv^2 + 0 = 0 + 0 + \frac{1}{2}kx^2$

$(2)(9.8)(3) + \frac{1}{2}(2)(1^2) = \frac{1}{2}(40)x^2$

$58.8 + 1 = 20x^2$

$\sqrt{\frac{59.8}{20}} = x$

$1.7\ m = x$

20. A .70 kg ball is placed on a vertical 200 N/m spring that is compressed 40 cm. When the spring is released, how high above its starting point will the ball go?

$GPE + KE + EPE = GPE + KE + EPE$

$0 + 0 + \frac{1}{2}kx^2 = mgh + 0 + 0$

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

$\frac{1}{2}(200)(.40)^2 = (.70)(9.8)h$

$16 = 6.86h$

$16/6.86 = h$

$2.33\ m = h$

Name: ______________________________ *Date:* ______________ *Period:* _____

Momentum and Impulse

Linear Momentum (ρ)

- defined as the product of an object's **mass** and **velocity**

ρ = mv

momentum = mass x velocity

- **vector** quantity (same direction as velocity)
- units are **kg m/s** or **Ns**

Momentum is a commonly used term in sports. A team that has the momentum is **on the move** and is going to **take some effort to stop.**

Momentum is a physics term; it refers to the quantity of motion that an object has. A sports team which is "on the move" has the momentum. If an object **is in motion (on the move)** then it has **momentum**.

Examples:

a) different objects moving at **same velocity** – Which has more momentum?

- small football player vs. a large football player more mess
- small car vs. a Train more mass

b) two objects with the same mass moving at different velocities –

- two football players with the same mass traveling at different velocities
  Fester one
- Tennis ball served by Pete Sampras or by Coach Richardson
  Pete Sampras ! Sorry Coach
- identical vehicles traveling at different velocities
  Fester one

So... what factors are important for determining the momentum of an object?

Both mass and velocity are important factors when considering the force needed to change The motion of an object.

Name: ______________________ *Date:* ____________ *Period:* _____

Problems: $Kg \cdot m/s = Ns$

Determine the momentum of a ...

1. 60-kg halfback moving eastward at 9 m/s.

   $P = mV \quad (60)(90) = 5400\ Ns$

2. 1000-kg car moving northward at 20 m/s.

   $P = mV \quad (1000)(20) = 20{,}000\ Ns$

3. 40-kg freshman moving southward at 2 m/s.

   $P = mV \quad (40)(-2) = -80\ Ns$

A car possesses 20 000 Kg m/s of momentum. What would be the car's new momentum if ...

A. its velocity were doubled.

$P = mV$ $= (1)(2) = 2$ $\quad 20{,}000 \times 2 = 40{,}000\ Kg \cdot m/s$

B. its velocity were tripled.

$P = mV$ $= (1)(3) = 3$ $\quad 20{,}000 \times 3 = 60{,}000\ Ns$

C. its mass were doubled (by adding more passengers and a greater load)

$P = mV$ $= (2)(1) = 2$ $\quad 20{,}000 \times 2 = 40{,}000\ Ns$

D. both its velocity were doubled and its mass were doubled.

$P = (2)(2) = 4 \quad 20{,}000 \times 4 = 80{,}000\ Ns$

Name: ______________________________ Date: ______________ Period: _____

An object's momentum will **change** if its mass and/or velocity changes.
***Most common... a change in velocity!!! What is a change in velocity called? **Acceleration!!!**

A change in momentum is called **Impulse – Δ ρ:**

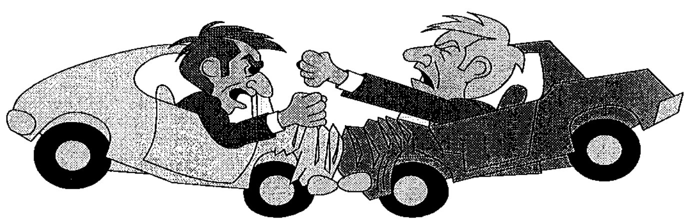
According to Newton's laws, a net force causes an object to accelerate, or change its velocity.

$F = ma$ $\quad a = \frac{V_f - V_i}{\Delta \text{time}}$ $\quad$ Substitute for acceleration: $F = \frac{m(V_f - V_i)}{\Delta \text{Time}}$

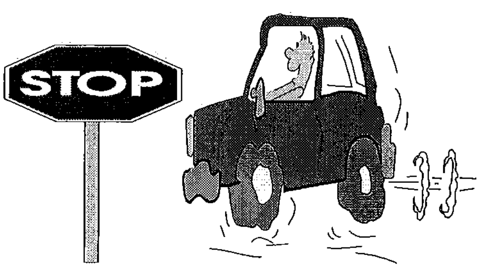
$F \Delta t = mV_f - mV_i$ or $\Delta \rho = F \Delta t$ or $\Delta \rho = mV_f - mV_i$

So what does this mean?

A 1000 kg car moving at 30 m/s (p = 30,000 kg m/s) can be stopped by 30,000 N of force acting for 1.0 s (a crash!)



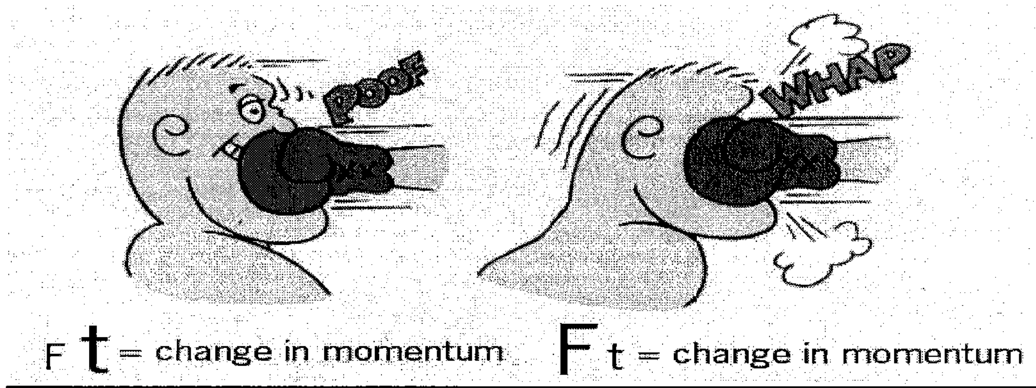
Or by 3000 N of force acting for 10.0 s (normal stop)



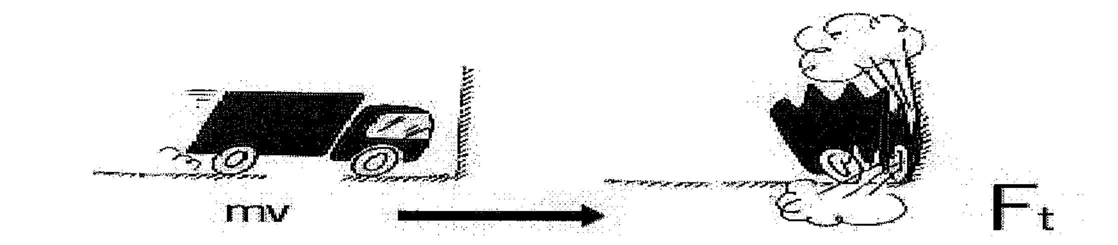
Name: ______________________________ Date: ______________ Period: ______

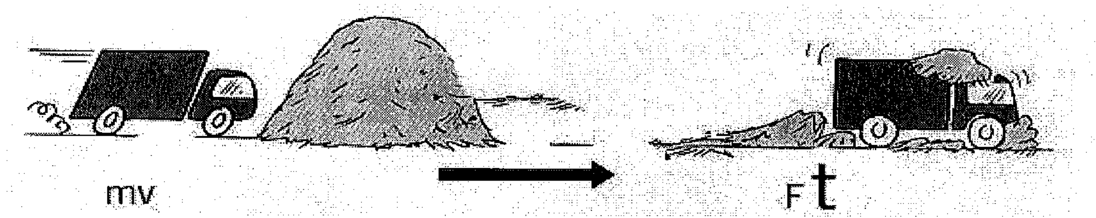
Examples: - **How does time affect these events? – less time means more force!!!! Not Good!!!**

a) Hitting a concrete wall or a haystack while in a car - concrete - less time
b) Dropping a dish on tile or plush carpet - Tile less Time
c) Bungee jumping - you stop slow



Spreading impulse out over a longer time means that the force will be less; either way, the change in momentum of the boxing glove, fist, and arm will be the same.





Observe that the <u>greater</u> the <u>time</u> over which the collision occurs, the **smaller the force** acting upon the object. Thus, to minimize the effect of the force on an object involved in a collision, the time must be increased; and to maximize the effect of the force on an object involved in a collision, the time must be decreased.

Name: ______________________________ *Date:* ______________ *Period:* _____

Problems

A 0.50-kg cart (#1) is pulled with a 1.0-N force for 1 sec; another 0.50 kg cart (#2) is pulled with a 2.0 N-force for 0.50 seconds.

A. Which cart (#1 or #2) has the greatest acceleration? Explain.

Cart #1: a = F/m = 1 N / 0.5 kg = 2 m/s^2

Cart #2: a = F/m = 2N / 0.5 kg = 4 m/s^2

B. Which cart (#1 or #2) has the greatest impulse? Explain.

Impulse

Cart #1 FΔt = 1N · 1s = 1 N·s

Cart #2 FΔt = 2 N · 0.5s = 1 N·s

Same impulse for both carts

C. Which cart (#1 or #2) has the greatest change in momentum? Explain.

Momentum is same for both carts

FΔt = mΔv = Δ ρ = 1 N·s

Which has a greater mass, a heavy truck at rest or a rolling skateboard?

Truck

Which has greater momentum?

skateboard - It's moving

What is the momentum of a 50 kg carton that slide at 4.0 m/s across an icy surface? (2.0 x 10^2 kg·m/s)

$P = mV$

$= (50)(4) = 200 \rightarrow 2.0 \times 10^2$ kg·m/s

Name: ______________________________ *Date:* ______________ *Period:* _____

Rhonda, who has a mass of 60.0 kg, is riding at 25.0 m/s in her sports car when she must suddenly slam on the brakes to avoid hitting a dog crossing the road. She strikes the air bag, which brings her body to a stop in 0.400 s. What average force does the seat belt exert on her? (3750 N)

$$F\Delta t = m\Delta v$$
$$F(.4) = (60)(25-0)$$
$$= \frac{(60)(25)}{.4}$$
$$= 3750\ N$$

If Rhonda had not been wearing her seat belt and not had an air bag, then the windshield would have stopped her head in 0.001 s. What average force would the windshield have exerted on her? (1,500,000 N)

$$F\Delta t = m\Delta V$$
$$F(.001) = (60)(25-0)$$
$$= \frac{(60)(25)}{.001}$$
$$= 1.5\times10^{6}\ N$$

Name: ______________________________ Date: ______________ Period: _____

Conservation of Momentum

When two objects interact (collide) with each other, momentum is **<u>CONSERVED ALWAYS!!!!!</u>**.
$\Delta p = 0$ in a closed system.

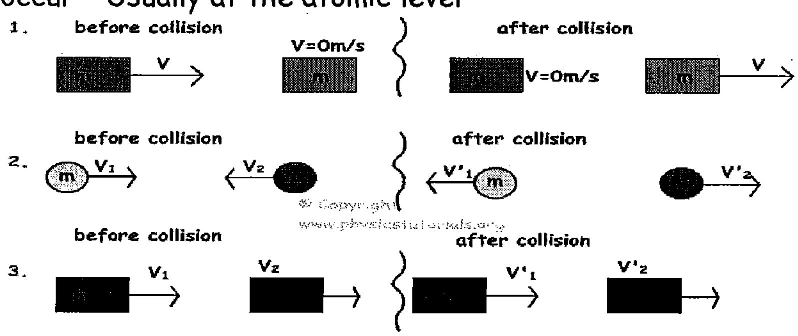
<u>MOMENTUM of the objects before collision</u> = <u>MOMENTUM of objects after collision</u>

Formula:

$$m_a v_a + m_b v_b = m_a v_a + m_b v_b$$

<u>Types of collisions:</u>

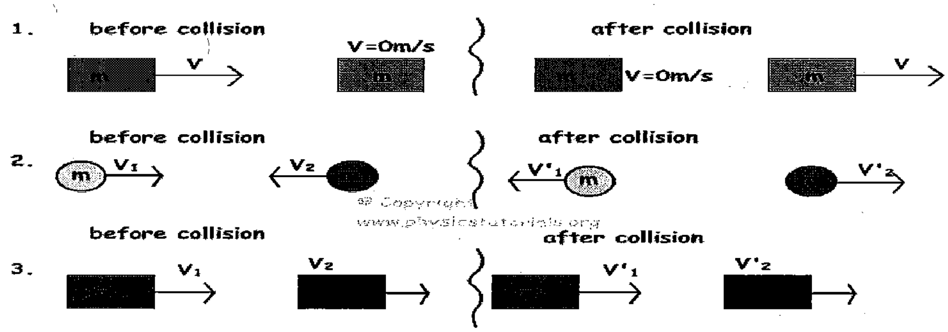
- **Elastic**: Collide and separate;
  - Momentum conserved
    - $m_a v_a + m_b v_b = m_a v_a + m_b v_b$
  - *KE* conserved $KE_i = KE_f$
    - $\frac{1}{2}mv^2 + \frac{1}{2}mv^2 = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$
  - Rarely occur - Usually at the atomic level



Name: ________________________ Date: ____________ Period: ______

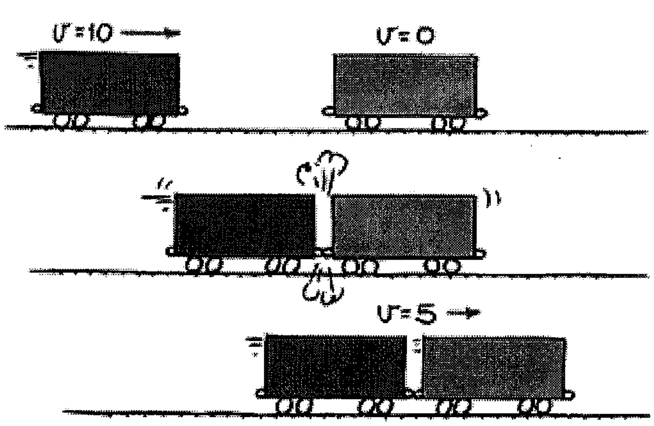
- **Inelastic**: Collide then separate deformed
  - Momentum conserved
    - $m_a v_a + m_b v_b = m_a v_a + m_b v_b$
  - *KE* is not conserved
    - $\frac{1}{2} mv^2 + \frac{1}{2} mv^2 = \frac{1}{2} mv^2 + \frac{1}{2} mv^2$

  In the Inelastic collisions some of the kinetic energy is converted into
    1) internal energy of the objects when they deform.
    2) Heat produced from friction
    3) Sound



- **Perfectly Inelastic**: Collide and stick together, then move with common velocity.
  - Momentum conserved
    - $m_a v_a + m_b v_b = (m_a + m_b)V_f$
  - KE is not conserved
    - $\frac{1}{2} mv^2 + \frac{1}{2} mv^2 = \frac{1}{2} mv^2 + \frac{1}{2} mv^2$

  In the Inelastic collisions some of the kinetic energy is converted into
    1) internal energy of the objects when they deform.
    2) Heat produced from friction
    3) Sound



Name: ____________________ Date: ______________ Period: _____

Problems:

1. m_A = 2.0 kg, v_A = +3.0 m/s and m_B = 4.0 kg, v_B = 0 find the velocity after the collision if both masses are **together** after the collision. ($v_a = v_b$ after the collision)

$m_A V_A + m_B V_B = m_{A+B} V_{A+B}$

$(2)(3) + 0 = (2+4) V_{AB}$

$6 = 6V$

$6/6 = V$

$1\ m/s = V$

Perfectly Inelastic

2. m_A = 5.0 g, v_A = +10 m/s and m_B = 10 g, v_B = 0 after the collision, v_{Af} = - 1.0 m/s, find v_{Bf}. Is KE conserved in 1 or 2?

$m_A V_A + m_B V_B = m_A V_A + m_B V_B$

$(.005)(10) + 0 = (.005)(-1) + (.01) V_f$

$.05 = {}^{-}.005 + .01 V_f$

$.05 - {}^{-}.005 = .01 V_f$

$.05 + .005 = .01 V_f$

$.55 = .01 V_f$

$.55/.01 = V_f = 5.5\ m/s$

① No Perfectly Inelastic

② $KE_i = KE_f$

$\frac{1}{2}mv^2 \neq \frac{1}{2}mv^2 = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$

$\frac{1}{2}(.005)(10^2) + 0 = \frac{1}{2}(.005)(-1^2) + \frac{1}{2}(.01)(5.5^2)$

$.25 = .01 + .15125$

$.25 \neq .16125$

Not Equal – Not conserved

3. A loaded railway car of mass 6000. kg is rolling to the right at 2.0 m/s when it collides and couples with an empty freight car of mass 3000. kg, rolling to the left on the same track at 3.0 m/s. What is the speed and direction of the pair after the collision (they are stuck together)?

$m_A V_A + m_B V_B = m_{A+B} V_{A+B}$

$(6000)(2) + (3000)(-3) = (6000 + 3000) V_f$

$12{,}000 + {}^{-}9000 = 9000 V_f$

$3000 = 9000 V_f$

$3000/9000 = V_f$

$.33\ m/s = V_f$

Right (Positive)

Name: ______________________________ Date: ______________ Period: _____

4. A 100. g ball moving at a constant velocity of 200 cm/s strikes a 400. g ball that is at rest. After the collision, the first ball rebounds straight back at 120 cm/s. Calculate the final velocity of the second ball. (80.0 cm/s [forward]) DRAW A PICTURE!

$m_A v_A + m_B v_B = m_A v_A + m_B v_B$

$(.1)(2) + 0 = (.1)(\bar{1}.2) + (.4)(v_f)$

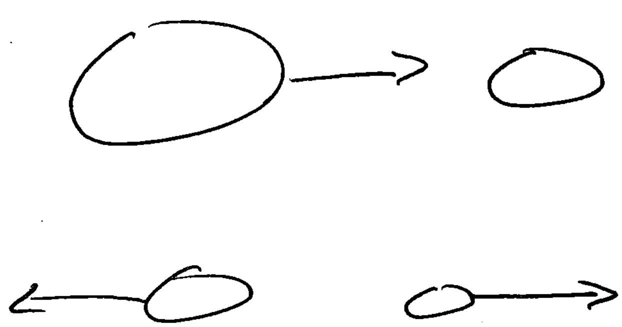
$.2 = {}^{-}.12 + .4 v_f$

$.2 - {}^{-}.12 = .4 v_f$

$.32 = .4 v_f$

$.32 / .4 = v_f$

$.8 \text{ m/s} = v_f$



Name: ______________________________ Date: ______________ Period: _____

MOMENTUM PRACTICE PROBLEMS

1. When the force of impact on an object is extended in time, does the impulse increase or decrease?

Increase $\Delta P = F\Delta t$

2. Does the impulse equal momentum, or change in momentum?

Change in momentum

3. For a constant force, suppose the duration of impact on an object is doubled. How much is the impulse increased?

Impulse $= F\Delta t$ It is doubled

4. How much is the resulting change in momentum increased?

It is also Doubled

5. In a car crash, why is it advantageous for an occupant to extend the time during which the collision takes place?

The longer the time, The more the Force is decreased.

6. If the impact in a collision is extended by 4 times, how much does the force of impact change?

It is decreased by $\frac{1}{4}$ $\Delta P = Ft$

$\frac{1}{4} = F$

7. Why is it advantageous for a boxer to "ride with the punch"?

By Increasing the time, It lessens the Force to him

Why should he avoid moving into an oncoming punch?

That would Decrease the time, Thus Increasing the Force to him.

8. Why is more impulse delivered during a collision when a rebound occurs than during one when it doesn't?

In a rebound collision, The time is less. So There is more Impulse.

Name: ______________________ Date: ______________ Period: _____

9. What is the momentum of an 8.00-kg bowling ball rolling at 2.00 m/s?

$P = mV$

$(8)(2) = 16 \text{ kg} \cdot \text{m/s}$

10. If the bowling ball in Problem #9 rolls into a pillow and stops in 0.50 s, calculate the average force it exerts on the pillow.

$F\Delta t = \Delta P$

$F(.50) = 16$

$F = 16/.50$

$= 32N$

What average force does the pillow exert on the ball?

$32N$

11. What is the momentum of a 50.0-kg carton that slides at 4.00 m/s across an icy surface?

$P = mV$

$=(50)(4) = 20 \text{ kg} \cdot \text{m/s}$

12. The sliding carton in Problem #11 skids onto a rough surface and stops in 3.00 s. Calculate the force of friction it encounters.

$F\Delta t = \Delta P$

$F\Delta t = 200$

$F(3) = 200$

$F = 200/3 = 66.7N$

13. What impulse occurs when an average force of 10.0 N is exerted on a cart for 2.5 s?

$\Delta P = F\Delta t$

$= (10)(2.5)$

$= 25 \text{ kg} \cdot \text{m/s}$

What change in momentum does the cart undergo?

$25 \text{ kg} \cdot \text{m/s}$

14. If the mass of the cart in Problem #13 is 2.00 kg and the cart is initially at rest, calculate its final speed.

$F\Delta t = m(V_f - V_i)$

$(10)(2.5) = 2(V_f - 0)$

$25/2 = V_f$

$V_f = 12.5 \text{ m/s}$

Name: ______________________________ Date: ______________ Period: _____

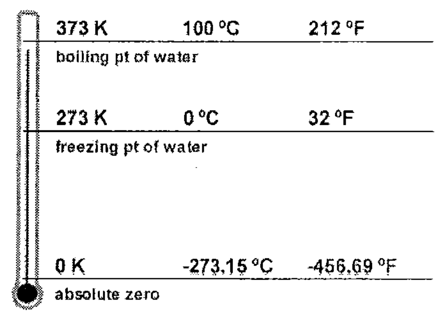
Heat

- the sum of the kinetic energies of molecules and the latent energy (phase) OR simply said, the energy that transfers from one object to another because of the temperature differences between them.
- flows from an object at a higher temperature to an object at a lower temperature
- (without an exchange of work) is the spontaneous flow of thermal energy from one object to another caused by a difference in temperature between the two objects.

$$Q = mc\Delta t$$

- Q = heat energy in Joules
- m = mass in kg
- c = specific heat capacity in J/kg°C
- ΔT = temperature difference in °C

Temperature is the measure of an object's kinetic energy and temperature measures how hot or how cold an object is with respect to a standard.



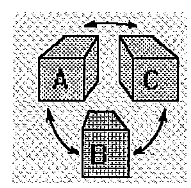
Temperature Scales:

- Celsius
- Fahrenheit
- Kelvin (based on absolute zero) $-273.15^0C = 0$ K

$$T(K) = T(°C) + 273.15$$

Zeroth Law of Thermodynamics – Thermal Equilibrium

- If objects A and B are each in thermal equilibrium with object C, then objects A and B are in equilibrium with each other.
- The 0th Law is the basis for the thermometer



Problems:

1. If you take a bite of hot pizza, the sauce may burn your mouth while the crust, at the same temperature, will not. Explain. The sauce is made of more H_2O so it holds it heat longer.

2. Campers in the winter sometimes heat up objects in the campfire to put in their sleeping bag at night for warmth. Is it better to heat a 10 kg rock or a 10 kg jug of water to the same hot temperature? Explain. Water – It holds it heat longer

3. After 2.0 kg of mercury gained 2.52×10^4 J of thermal energy, its final temperature was 130°C. What was its initial temperature? Specific Heat of mercury is 1.4×10^2 J Kg °C

$Q = mc\Delta t$

$2.52 \times 10^4 = (2)(1.4 \times 10^2)\Delta t$

$\frac{2.52 \times 10^4}{(2)(1.4 \times 10^2)} = \Delta t = 90°C$

$\Delta t = t_f - t_i$

$90 = 130 - t_i$

$t + 90 = 130$

$t = 130 - 90$

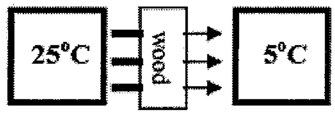
$= 40°C$

Name: ______________________ **Date:** ______________ **Period:** ______

Methods of Heat Transfer:

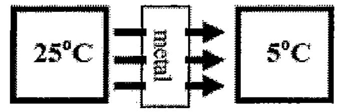
Heat always transfers from **hot to cold**. Heat does not rise (hot air rises).

Insulators slow down heat transfer. Materials with air pockets are good insulators.



slow transfer

Conductors easily allow heat transfer. Most metals are good conductors.

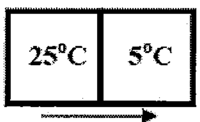


fast transfer

Thermal energy (heat) is transferred in three ways: Conduction; Convection; Radiation.

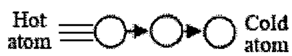
Conduction

Conduction transfers heat through objects touching.



conduction

All atoms are vibrating (moving), which means they have kinetic energy. Hot atoms have more E_k. When hot atoms bump into cold atoms they transfer some energy.



Conduction transfers heat by atoms colliding and transferring energy.

Heat transfer continues until both objects are at *thermal equilibrium*: the same temperature.

Closer atoms mean more collisions. So solids *tend* to transfer heat better than liquids or gases. Gases tend to make good insulators. Sometimes, though a liquid (water) can speed up conduction with an insulator (your skin).

High density ←→ *Low density*

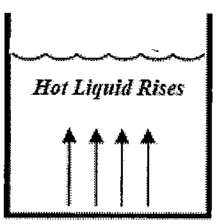
Solid **Liquid** **Gas**

Better conductors ←→ *Better insulators*

Convection

Convection transfers heat through moving currents in gases or liquids.

No currents—No convection

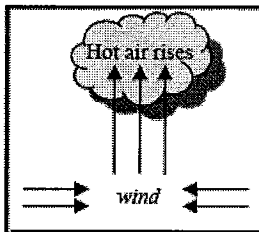


Heat Source

Hot liquids (and gases) are less dense and rise, causing ***convection currents***. These currents transfer heat throughout the liquid (or gas).

Gases transfer heat poorly through conduction. Convection currents speed up thermal transfer.

Convection currents can only happens in gases (like air) or liquids (like water), not in solids because solids can't move.

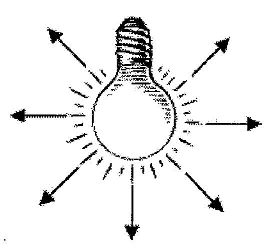


Cold air is pulled in causing wind.

Much of the weather on earth comes from convection currents. The sun warms air at the surface of the earth. Warm air rises, causing winds. When the air cools it falls back to the ground.

Radiation

Radiation transfers heat through electromagnetic radiation; occurs even in a vacuum (empty space).



Radiation transfers heat through electromagnetic waves — pure thermal energy.

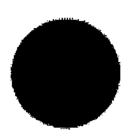
Radiation transfers heat in all directions—even down. Convection currents always rise.

Radiation requires no contact—convection and conduction require touching.

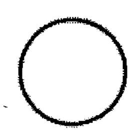
Radiation can go through transparent materials (barriers) like glass.

All energy on earth comes originally from the sun. Space is a vacuum (no matter at all). So only radiation can travel through space to the earth.

Dark objects absorb more radiation than light objects.
Dull objects absorb more radiation than shiny objects.



High absorption of radiation. Heats fast.



Low absorption of radiation. Heats slowly.

www.aisd.net/smurray

Name: ______________________ Date: ____________ Period: _____

HEAT PROBLEMS

1. Write down the formula for heat.

$Q = mc\Delta t$

2. a. What is the unit for heat?

J or Caloric

b. What is the unit for specific heat?

J/kg °C

3. Find the amount of heat needed to raise the temperature of 5 Kg of a substance from 20 °C to 30 °C if the specific heat of the substance is 2010 J/kg °C.

$Q = mc\Delta t$

$= (5)(2010)(10) = 100{,}500\ J$

4. A metal with a specific heat of 780 J/kg °C requires 45 J of heat to raise its temperature by 2 °C. What is the mass of the metal?

$Q = mc\Delta t$

$45 = m(780)(2)$ $\quad \frac{45}{(780)(2)} = m \quad = .029\ kg$

5. A substance requires 50 J of heat to raise its temperature by 6 °C. If the mass of the substance is 10 Kg, what is the specific heat of the substance?

$Q = mc\Delta t$

$50\ J = (10)(c)(6)$ $\quad \frac{50}{(10)(6)} = c \quad = .83\ J/kg\,°C$

6. A metal with a specific heat of 700 J/kg °C and a mass of 8 Kg absorbs 48 J of heat. What will be the temperature change of the metal?

$Q = mc\Delta t$

$48 = (8)(700)\Delta t$ $\quad \frac{48}{(8)700} = \Delta t \quad = 8.57 \times 10^{-3}$

7. How much heat is needed to raise the temperature of .8 kg of lead by 10 °C?

Lead → c = 128 J/kg

$Q = mc\Delta t$

$= (.8)(128)(10)$

$= 1024\ J$

Name: ______________________ Date: ______________ Period: _____

8. The temperature of a .250 kg ball of iron increases from 19 °C to 32 °C. How much heat did the iron ball gain?

Iron - 448 J/kg

$Q = mc\Delta t$

$= (.250)(448)(13)$

$= 1456$ J

9. The temperature of a .100 kg block of ice increases by 3 °C. How much heat does the ice receive?

H_2O -> 4180 J/kg

$Q = mc\Delta t$

$= (.100)(4180)(3) = 1254$ J

10. .01 kg of steam absorbs 60 J of heat. What is the temperature increase of the steam?

H_2O = 4180 J/kg

$Q = mc\Delta t$

$60 = (.01)(4180)(\Delta t)$

$60/(.01)(4180) = \Delta t = 1.44$ °C

11. A piece of lead loses 78 J of heat and experiences a decrease in temperature of 9 °C. What is the mass of the piece of lead?

Lead = 128 J/kg

$Q = mc\Delta t$

$78 = m(128)(9)$

$\frac{78}{(128)(9)} = m = .067$ kg

12. The temperature of a .700 kg bar of iron decreases by 10 °C when the iron is plunged into .100 kg of water. What is the temperature increase of the water, assuming that no that no heat is lost in the transfer?

$Q = mc\Delta t$

$= (.700)(448)(10)$

$= 3136$ J

$Q = mc\Delta t$

$3136 = (.100)(4180)(\Delta t)$

$\frac{3136}{(.100)(4180)} = \Delta t = 7.5$ °C

Name: ______________________________ **Date:** ______________ **Period:** _____

13. How much heat is required to raise the temperature of .0035 kg of water from 12 °C to 35 °C?

$Q = mc\Delta t$

$= (.0035)(4180)(23)$

$= 336\ J$

14. How much heat is needed to heat .02 kg of lead from 20 °C to 150 °C?

$Q = mc\Delta t$

$= (.02)(128)(130)$

$= 332\ J$

15. If you add the same amount of thermal energy to each of the substances in the table below, which will undergo the largest change in temperature?
    A. Substance 1
    B. Substance 2
    (C.) Substance 3

SUBSTANCE	SPECIFIC HEAT (J /kg °C)
1	1.00
2	0.41
3	0.04

$Q = mc\Delta t$

Name: ______________________________ ***Date:*** ______________ ***Period:*** _____