Spring 2019 Final Review
Part I

1. You are on a merry go round that has a radius of 3m. You notice that you complete a revolution every 2 minutes.

   a. What is your tangential velocity as you spin on the merry-go-round?

   $V = \omega r \quad r = 3m \quad \omega = 1 rev / 2 minutes$

   $1 rev = 2\pi$ radians $\quad \frac{1 rev}{2 min.} = \frac{2\pi}{2 min} = \frac{\pi}{1 min.} = \frac{\pi}{60s} = 0.052 rad/s$

   $V = 0.052 \cdot 3 = 0.157 \, m/s$

   b. Assuming that you are holding onto the merry-go-round, what are the forces acting on you as you are spinning on this merry-go-round? Draw them a diagram depicting them below. Make sure to label each force and indicate its direction

   F_N = Normal Force that the merry-go-round applies to you.

   F_g = Force due to gravity

   F_c = Centripetal Force

   c. Assuming you weigh 75 kg. What are the magnitudes of the forces that you experience?

   $F_g = m \cdot g = 9.8 \cdot 75 = -735N$

   $F_N = F_g = +735 N$

   $F_c = \frac{mv^2}{r} = \frac{75 \cdot (0.157)^2}{3} = 0.62N$

   d. Suppose you move in 1.5m towards the center of the merry-go-round. What is the magnitude of the force now?

   new radius means new tangential velocity

   $V = \omega r \quad \omega = 0.052 \quad r = 1.5 \cdots (3 - 1.5)$

   $V = 0.052 \cdot 1.5 = 0.078 \, m/s$

   $F_c = \frac{mv^2}{r} = \frac{75 \cdot (0.078)^2}{1.5} = 0.3042N$

2. A drainage pipe with an inner diameter of 2m, an outer diameter of 2.5 m, and a mass of 125 kg broke free from its transport truck 15 meters up a hill and is rolling down the street.

   a. Assuming it starts from a stop, what is the total energy of the pipe before it starts rolling down the hill?

   $GPE = mgh = 125 \cdot 9.8 \cdot 15 = 18{,}375\,J$ = Total Energy

   b. What is the tangential velocity of the pipe when it reaches the bottom of the hill?

   at the bottom Total Energy $= KE_t + KE_r = 18{,}375\,J$

   $KE_t = \frac{1}{2}mv^2 \quad KE_r = \frac{1}{2}I\omega^2 = \frac{1}{2}I(v/r)^2 \qquad r_1 = \frac{2}{2} = 1m$

   $\omega = v/r \qquad r_2 = 2.5/2 = 1.25m$

   $I = \frac{1}{2}m(r_1^2 + r_2^2) = \frac{1}{2}125(1^2 + 1.25^2) = 160$

   $18{,}375 = \frac{1}{2} \cdot 125 \cdot v^2 + \frac{1}{2} \cdot 160 \cdot v^2 = 62.5v^2 + 51.2v^2 = 113.7v^2$

   $v = \sqrt{v^2} = \sqrt{161.6} = \boxed{12.7\,m/s}$

   c. What is the angular velocity of the pipe?

   $\omega = v/r = 12.7/1.25 = 10.2$ rad/s

   outer radios

   d. If by some strange coincidence a solid metal column that had a radius of 2.5m fell off another truck at the same time and same place as the drainage pipe, would the drainage pipe or the solid metal column reach the bottom of the hill first? Why?

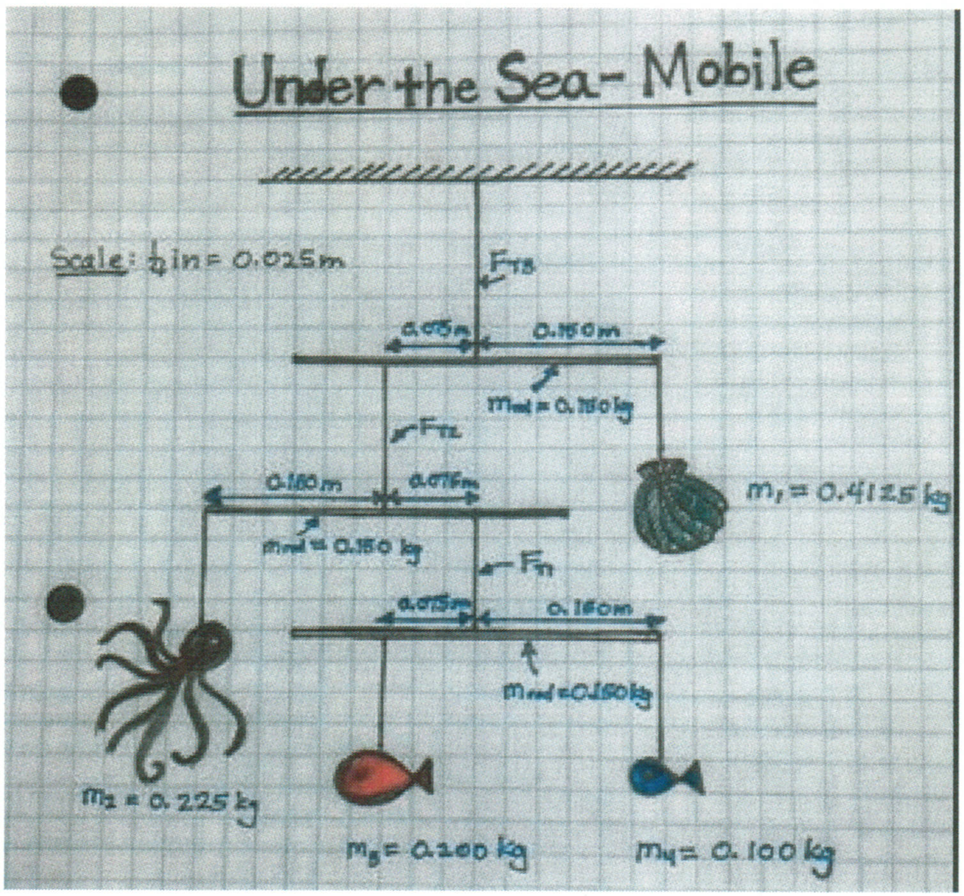
   The solid column would reach the bottom first because the solid column has a smaller moment of Inertia. Therefore the solid Column spends less of its total energy Rolling and more on its translational energy.

3. School is over and you race out the door and out to the rest of your life! If the door was 1 m wide and you exerted a 50 N force on it. Assuming the door was frictionless, what was the torque that you applied?

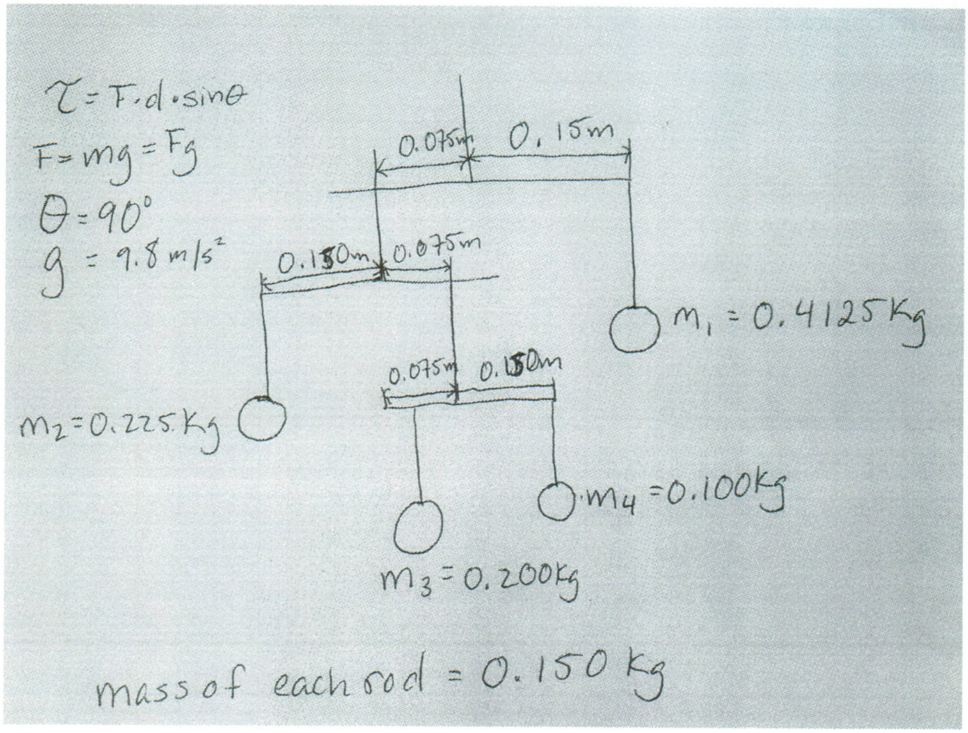
$\tau = F \cdot d \sin\theta$ $\theta = 90^\circ$ $d = 1m$

$F = 50$ $\tau = 50 \cdot 1 \cdot \sin(90) = 50\ Nm$

4. Look at the mobile below. Will this mobile balance? Why or why not? Justify your answer with calculations.



4. Will this Mobile Balance Continued…



<u>Lower Bar Torque Balance:</u>
0.2 x 9.8 x 0.075 = 0.147 Nm
0.1 x 9.8 x 0.15 = 0.147 Nm

The lower bar will balance

<u>Middle Bar Torque Balance:</u>
Total lower bar mass = 0.2 + 0.1 + 0.15 = 0.45 kg

0.45 x 9.8 x 0.075 = 0.331 Nm
0.225 x 9.8 x 0.15 = 0.331 Nm

The Middle Bar will balance

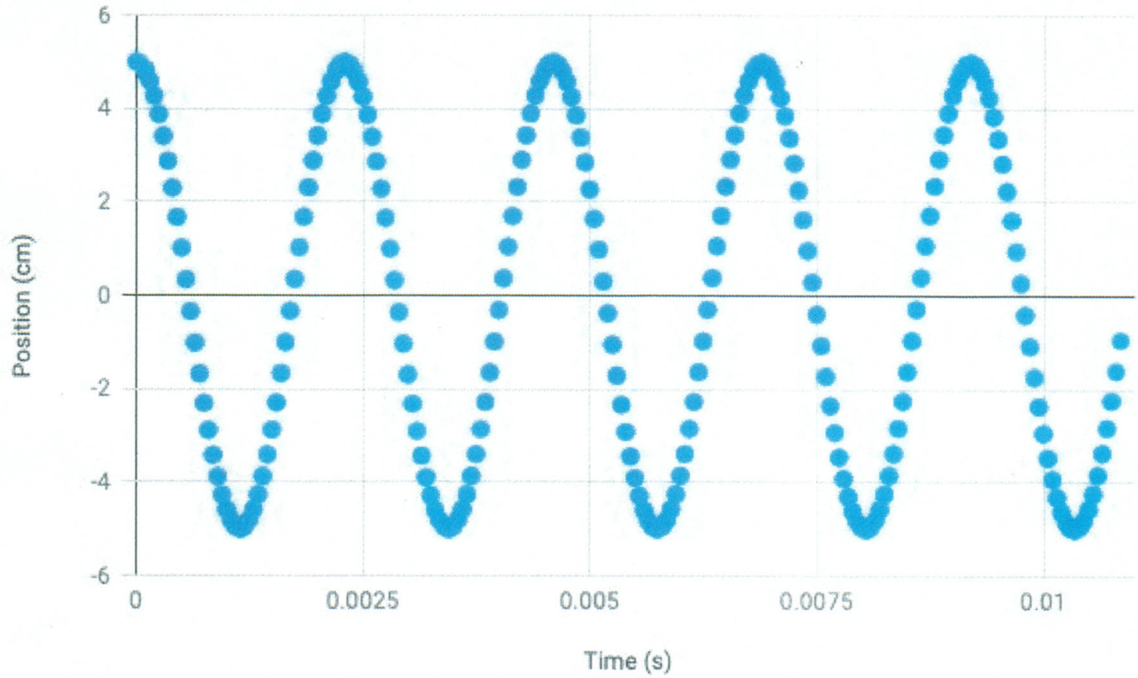
<u>Upper Bar Torque Balance:</u>
Total lower and middle bar mass
0.45 + 0.225 +0.15 = 0.825 kg

0.825 x 9.8 x 0.075 = 0.606 Nm
0.4125 x 9.8 x 0.15 = 0.606 Nm

The Upper Bar will balance

Since all bars balance the whole mobile should balance.

5. Use the wave graphed below to answer the following questions:



a. Is this a sine wave or a cosine wave?

Cosine

b. What is the amplitude of this wave?

5cm

c. What is the wavelength and frequency of this wave?

1 cycle almost fits in 0.0025s so an estimate of the frequency would be 1cycle/0.0025seconds $\boxed{=400\text{Hz}}$

Assuming its an EM wave $c = \lambda \cdot f \rightarrow 3\times10^8 = \lambda \cdot 400$, $\boxed{\lambda = 7.5\times10^5}$

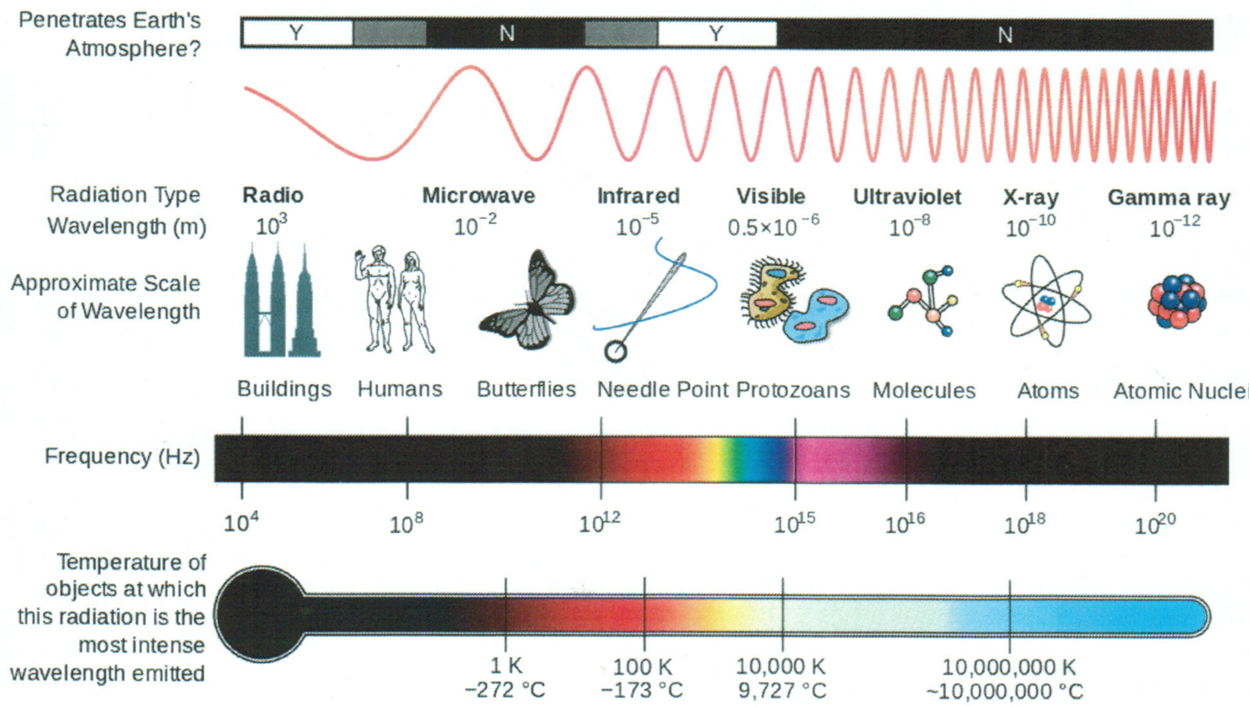
d. What is the wave equation that describes the motion of this wave?

$\omega = 2\pi f = 2{,}512$

$X = 5\cos(2{,}512t)$

Spring 2019 Final Review
Part II

6. Please use the Electromagnetic Spectrum show below to answer the following questions



a. You find out that you have been exposed to electromagnetic radiation with a frequency of $5\text{x}10^8$, should you be worried? Why or why not?

A frequency of 5×10^8 Hz would be somewhere between a microwave and a Radio wave. So not harmful at all

b. Calculate the energy of the radiation that you were exposed to. Would you rather have been exposed to electromagnetic radiation with a wavelength of $8\text{x}10^{-10}$? Justify your answer with calculations.

$E = hf = 6.626\times10^{-34} \times 5\times10^{8} = 3.31\times10^{-25}$ J

$c = \lambda f \Rightarrow f = c/\lambda \quad c = 3\times10^{8}$

$E = h\,c/\lambda = 6.626\times10^{-34} \times 3\times10^{8}/8\times10^{-10} = 2.48\times10^{16}$ J

The first radiation has 9 orders of magnitu Less energy. I would rather be exposed to the first radiation.

c. What is the type of radiation that your were exposed to?

X-Rays

7. You conducted an experiment which exposed different materials to electromagnetic radiation in visible to Infrared range. Below is the data you collected and the relevant material properties.

Material	Initial Temp (℃)	Final Temp (℃)	Specific Heat (J/kg℃)	Volume (cm^3)	Density (kg/m^3)
Liquid water	22	31	4200	1000	1000
Regular Sand	25	37	840	1000	1680
Black Sand	24	42	840	1000	1680
White Gravel	20	26	800	1000	1800

a. How much heat was transferred to each material?

All Volumes → $\frac{1000 cm^3}{1{,}000{,}000 cm^3/m^3} = 0.001 m^3$

Mass:
Water: $1000 \cdot 0.001 = 1$ kg
Reg Sand: $1680 \cdot 0.001 = 1.68$ kg
Black Sand: $1680 \cdot 0.001 = 1.68$ kg
Gravel: $1800 \cdot 0.001 = 1.8$ kg

Heat:
water: $q = 1 \cdot 4200 \cdot 9 = 37{,}800$ J
Reg Sand: $q = 1.68 \cdot 840 \cdot 12 = 16{,}934$ J
Black sand: $q = 1.68 \cdot 840 \cdot 18 = 25{,}402$ J
Gravel: $q = 1.8 \cdot 800 \cdot 6 = 8{,}640$ J

b. Explain why you believe the data has this pattern. Use definition of specific heat and how light interacts with each of these materials (absorption, reflection, scattering, and transmission) to help you justify your answer.

Water has one the smallest temperature rises but has absorbed the most heat. This is due to water absorbing the infrared radiation (visible light is transmitted). The water can absorb a lot of heat (due to its high heat capacity) before its temperature rises.

Black sand absorbs more heat than Reg Sand because of its Black color. Due this color it reflects less light and absorbs more.

White gravel absorbs the least heat and experiences the smallest temperature rise because the gravel scatters and reflects light instead of absorbing it.

8. What are the 3 types of thermodynamic systems? What type of system is Earth?

<u>Open System</u>
Mass can be transferred (things can move in and out of a system)
Energy can be transferred (Heat, light/radiation, work)

<u>Closed System</u>
Mass cannot be transferred (lid or something preventing things from moving out)
Energy can be transferred (heat, light/radiation, work)

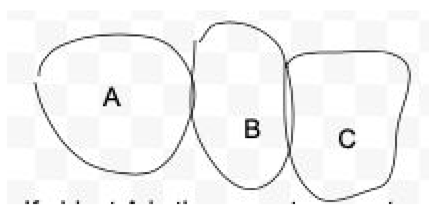
<u>Isolated System</u>
Nothing can be transferred,
No Mass transfer
No Energy transfer

Earth is an open system. However, because the mass exchanged is so small compared to the energy exchanged, we often approximate the Earth as a closed system.

9. What is temperature and why does the zeroth law exist?

Temperature is how hot or cold something is. Temperature is the average kinetic energy of the molecules/atoms inside a material. (translational kinetic energy)

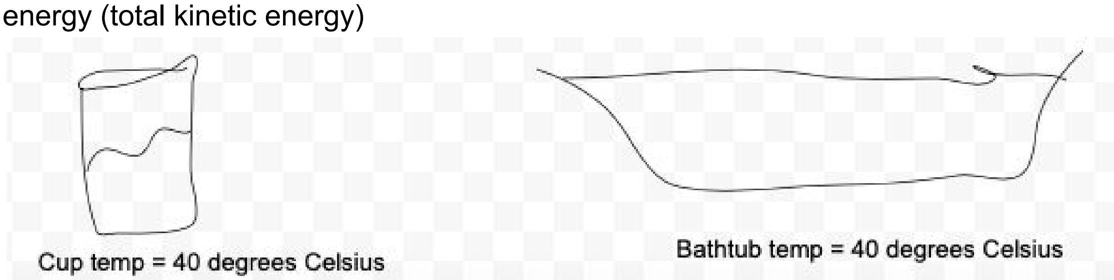
Zeroth law allows us to measure temperature.



If object A is the same temperature as object B. And object is the same temperature as object C. Then A and C are the same temperature.

10. What is thermal energy? How is it different from temperature?

Thermal Energy is the total amount of Kinetic Energy in a system. The bathtub and the cup have the same temperature (average kinetic energy) but the bathtub has more thermal energy (total kinetic energy)

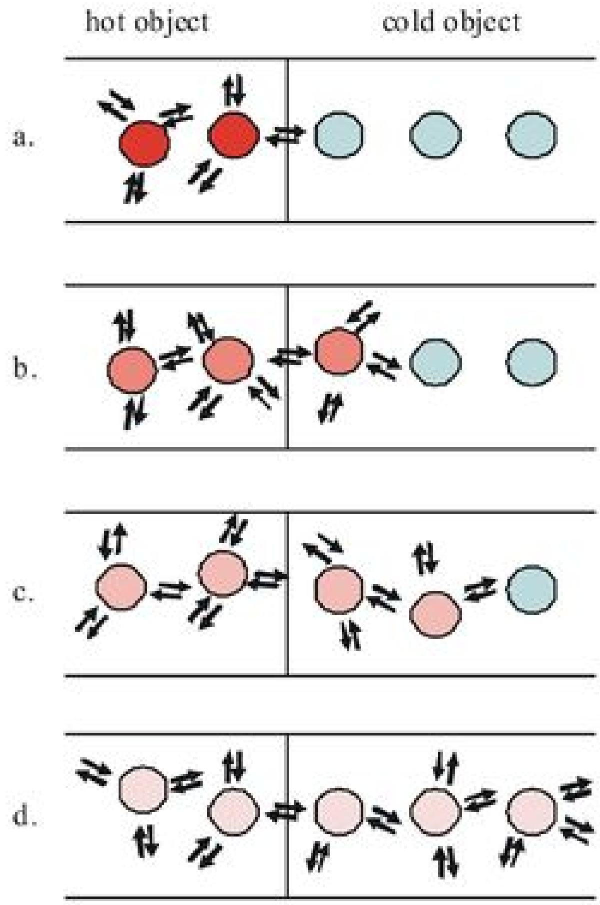


11. What is heat? How is it transferred? Use words and pictures to describe both

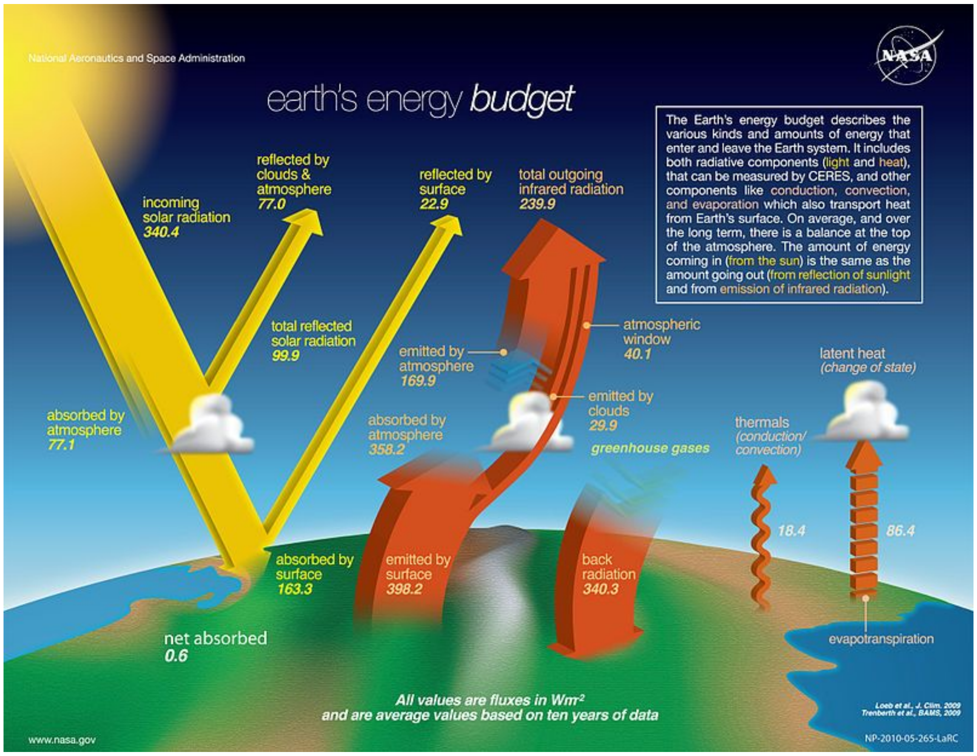
Heat is thermal energy that is transferred from a region of higher temperature (greater thermal energy) to a region of lower temperature (less thermal energy).

Heat can move through bond vibrations or can move through molecular/atomic collisions.

Heat transfer will continue until the two regions (or objects) are at the same temperature. That temperature will be lower that the original hot objects temperature but higher than the original cold objects temperature.



12. Using words and pictures explain the feedback cycle that is causing arctic amplification and how this impacts the rest of the earth.



Sunlight enters our atmosphere, some of it is scattered by clouds, some radiation (most of the UV) is absorbed by the atmosphere, but a large portion reaches the earth. A lot of this is visible light. This light is absorbed by the earth. Depending on the material some is reflected is also back or scattered. Ice, solid water, reflects or scatters a lot of the visible light back to space, and that light passes easily through our atmosphere back out to space.

Light that is absorbed becomes heat in materials on the earth's surface. Those materials then radiate infrared energy back out into the atmosphere. Greenhouse gases in our atmosphere really like to absorb infrared energy. So the more greenhouse gases, the more energy that is absorbed. The greenhouse gases heat up and radiate infrared energy back to the earth which absorbs it and re-radiates it back into the atmosphere.

The heat energy is then trapped in this cycle, which warms the earth. A warming earth means that the ice melts in the arctic which causes less of visible light to be reflected or scattered back. This leads to more of the sun's energy entering this thermal feedback loop. Less solid water (ice) and more liquid water also leads to more storage of the sun's energy due to the high heat capacity of water. The ocean's then increases in temperature due to the increase in exposure to the sun's radiation and the warming atmosphere.

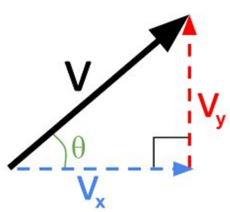
This effect is amplified in the arctic due to the melting land and sea ice. This is causing the arctic to warm at 4 times the rate of the rest of the planet. This effect is causing sea level rise, wreaking havoc on our ocean ecosystems, and causing the extreme weather patterns seen all over the world. There also is the problem of the melting permafrost and the tons of methane that is stored in it. If that is release the amount of greenhouse gases in the atmosphere will rise dramatically and cause even more warming.

Equations:

Translational

Displacement:	$x(t) = x_0 + v_0t + ½\ at^2$
Velocity:	$v(t) = v_0 + at$
Velocity (ang velocity):	$v = \omega r$
Final Velocity (time):	$v_f = v_0 + at_f$
Final Velocity (displacement):	$v_f^2 = v_0^2 + 2ax_f$
Force:	$F = ma$
Acceleration due to gravity:	$9.8\ m/s^2$
Momentum:	$p = mv$
Impulse:	$F(t_2 - t_1) = m(v_2 - v_1)$
Kinetic Energy:	$KE = ½mv^2$
Gravitational Potential Energy:	$PE = mgh$

Use a right triangle and sine and cosine to Calculate V_x and V_y



Rotatational

Angular Displacement:	$\boldsymbol{\theta}(t) = \boldsymbol{\theta}_0 + \boldsymbol{\omega}_0 t + ½\ \boldsymbol{\alpha} t^2$
Angular Velocity:	$\boldsymbol{\omega}(t) = \boldsymbol{\omega}_0 + \boldsymbol{\alpha} t$
Angular Velocity (time):	$\boldsymbol{\omega}_f = \boldsymbol{\omega}_0 + \boldsymbol{\alpha} t_f$
Angular Velocity (displacement):	$\boldsymbol{\omega}_f^2 = \boldsymbol{\omega}_0^2 + 2\boldsymbol{\alpha\theta}_f$
Angular Velocity (trans. velocity):	$\boldsymbol{\omega} = v/r$
Centripetal Acceleration:	$a_c = v^2/r$
Centripetal Force:	$F = ma_c = mv^2/r$
Torque:	$\boldsymbol{\tau} = I\boldsymbol{\alpha}$
Kinetic Energy:	$KE = ½I\boldsymbol{\omega}^2$
Moment of Inertia (hollow cylinder)	$I = \frac{1}{2}m(r_1^2 + r_2^2)$
Moment of Inertia (solid cylinder)	$I = \frac{1}{2}mr^2$

Waves and Electromagnetic Radiation

Simplified Wave Equation	$x = Asin(\omega t)$, $x = Acos(\omega t)$
Angular Velocity to Frequency	$\omega = 2\pi f$
Energy of an EM Wave	$E = hf$
Speed of Light	$c = \lambda f$
Speed of Light (value)	$c = 3 \times 10^8 m/s$

Thermodynamics

First Law	$\Delta U = Q - W$
Heat	$q = mC_p\Delta T$
Temperature Change	$\Delta T = T_{final} - T_{initial}$