Worksheet 14A: Specific Heat, Latent Heat, Phase Change Graphs, and Calorimetry

Objective A: Caloric and Joule's discovery
Questions:
1. What was the caloric model?
2. How did it fail to explain the heating of drill bits when they got dull?

Objective B: Specific Heat: Q = mCΔT
Questions:
3. What is the specific heat of a substance? What does it mean?

Problems:
4. What heat is needed to raise 3.4 kg of lead from 23 ^oC to 58 ^oC? (1.5E4 J)
5. If 23.0 kg of copper at 21.0 ^oC absorbs 45.6 kJ of heat, what will be its final temperature? (26.1 ^oC)
6. If some aluminum at 57.0 ^oC, cools to 24.1 ^oC, and gives off 13.4 kJ of heat, what is its mass? (453 g)
7. A 35.0 g of a mystery substance absorbs 314 J of heat and raises its temperature by 2.14 ^oC. What is its specific heat? (4190 $J^oC^{-1}kg^{-1}$)
8. A 125 Watt 100% efficient heater is immersed in a 503 ml container full of water. In what time will the heater heat the water from 21.0 ^oC to boiling? (1330 s)
9. Another 1250 Watt heater can raise 2.35 liters of water from 14.5 ^oC to 36.6 ^oC in three and a half minutes. What is its efficiency? (.828 or 82.8%)

Some specific heats (in $J^oC^{-1}kg^{-1}$)

H2O liquid	4186
H2O ice	2100
H2O steam	2010
Aluminum	900
Iron	450
Copper	390
Lead	130

Objective C: Latent Heat: Q = mL
Questions:
10. What is the latent heat of a substance? What does it mean?
11. Why is the latent heat of vaporization almost always more?

Problems:
12. What heat does it take to melt 25 kg of solid iron already at the melting point? (7.2E6 J)
13. 2350 J of heat will melt how much lead? (94 g)
14. If it takes 45,120 J of heat to melt 172 g of a mystery substance, what is its latent heat of fusion? (2.62E5 J/kg)
15. A runner sweats away 3.5 kg of water through evaporation. What heat did they dissipate? (7.9E6 J)
16. What heat do you need to heat 2.15 Kg of ice at -34.0 ^oC to water at 75.0 ^oC? ($1.54x10^6$ J)
17. What heat do you need to heat 23.5 Kg of ice at -167.0 ^oC to water at 92.0 ^oC? ($2.51x10^7$ J)
18. What heat do you need to heat 3.61 Kg of water at 76.0 ^oC to steam at 142 ^oC? ($8.83x10^6$ J)

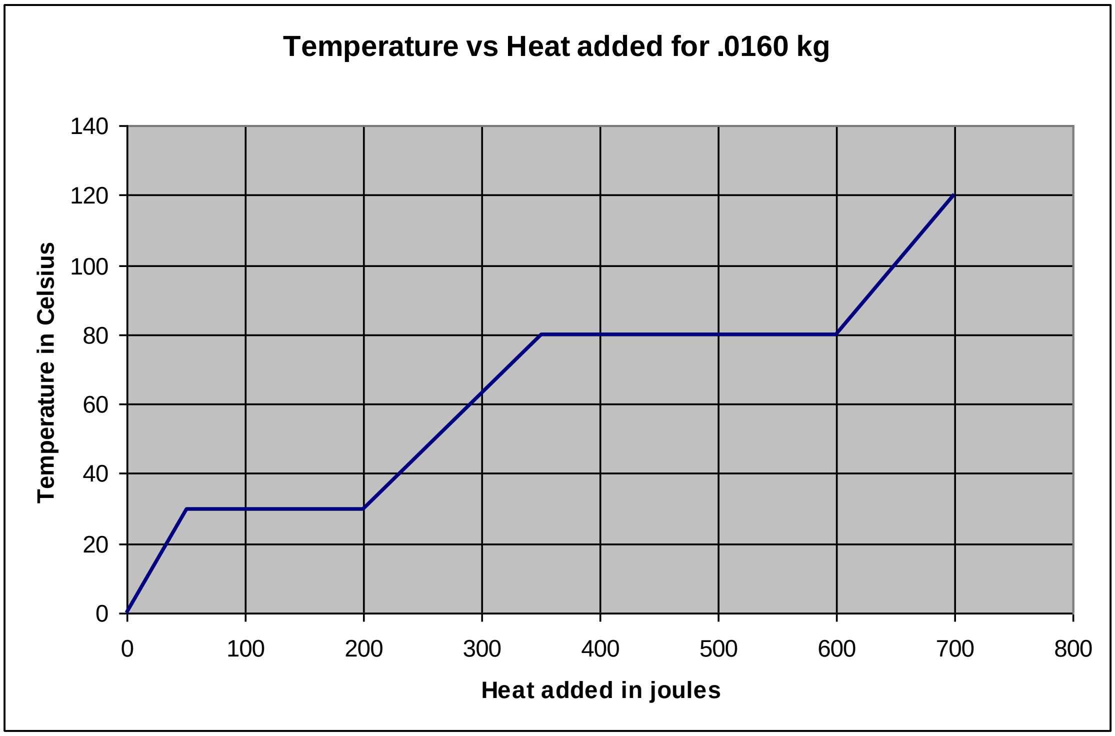
Some Latent heats (in Jkg^{-1})

	Fusion	Vap.
H2O	3.33E5	22.6E5
Iron	2.89E5	63.40E5
Lead	0.25E5	8.70E5

Objective E: Calorimetry: Heat Lost = Heat Gained
Problems:
19. 112. grams of a mystery liquid at 83.0 ^oC is mixed with 564 grams of water initially at 22.0 ^oC. The final temperature of the mixture is 33.0 ^oC. What is the specific heat of the mystery liquid? (Assuming no heat was lost to the surroundings) (4640 J $kg^{-1}\,^oC^{-1}$)
20. A piece of lead (c = 130 J/kg/^oC) at 82.0 ^oC is mixed with 112 grams of water and an 87.5 g aluminum (c = 900. J/kg/^oC) calorimeter cup initially at 25.0 ^oC. The final temperature of the system is 56.0 ^oC. What is the mass of the piece of lead? (Assuming no heat was lost to the surroundings) (5.02 kg)
21. 89.2 g of a mystery substance is at 99.20 ^oC, and it is placed in a 95.0 g iron container holding 216 ml of water both at 21.01 ^oC. The final temperature is 23.38 ^oC. What is the specific heat of the substance? (332 J/kg/^oC)
22. A 347 g piece of copper at 98.0 ^oC is placed in a Styrofoam cup containing 259 ml of water at 18.0 ^oC. What will be the final temperature of equilibrium? (Ignore the Styrofoam) (26.9 ^oC)
23. A 13.5 g piece of aluminum at 93.9 ^oC is placed in an 82.0 g iron calorimeter containing 203 g of water both at 23.0 ^oC. What will be the final temperature? (24.0 ^oC)
24. If you drop a 16 g ice cube at 0.0 ^oC into a Styrofoam cup containing 241 ml of water at 20.0 ^oC what will be the final temperature? (13.8 ^oC)
25. You take an ice cube out of the freezer at -17.0 ^oC, and drop it into a 67.0 g aluminum cup containing 308 g of water at 23.0 ^oC. The final temperature is observed to be 12.7 ^oC. What is the mass of the ice cube? (33.0 g)

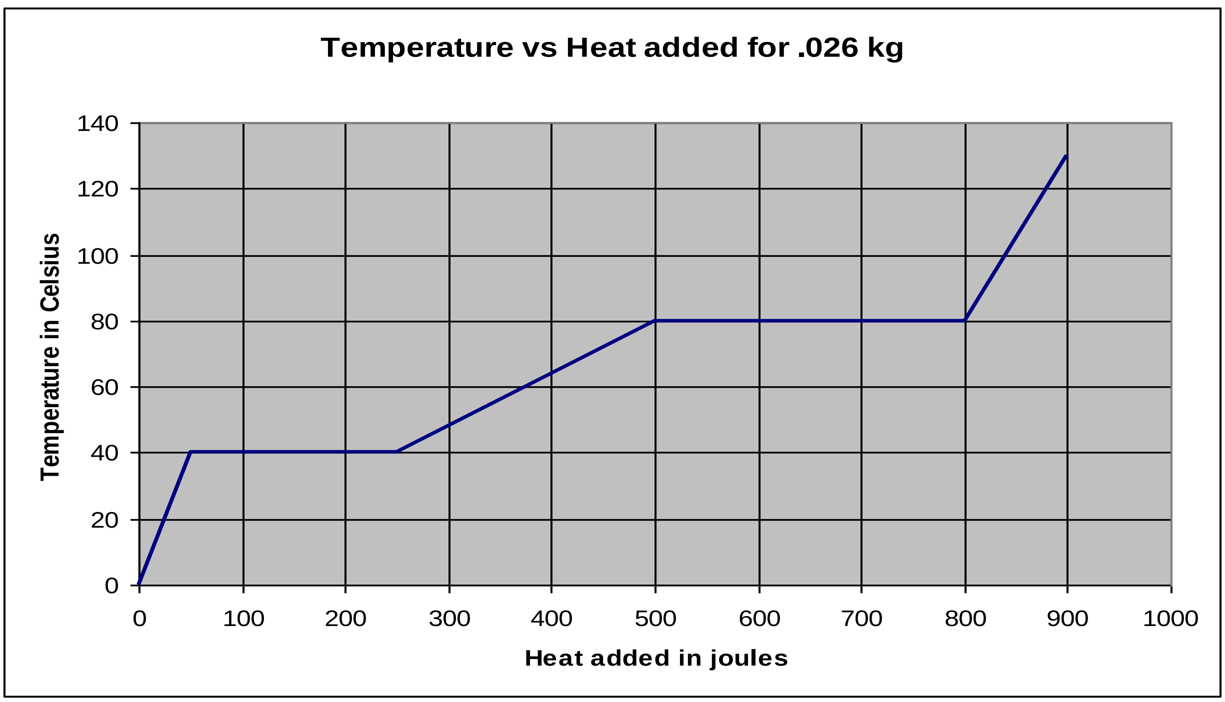
Objective D: Phase change graphs

Here is a phase change graph for 0.0160 kg of a substance that starts out as a solid at 0 ^{o}C:



26. Label the graph where the KE is increasing, and where the PE is increasing.
27. What is the melting point? What is the boiling point? (30. ^{o}C, 80. ^{o}C)
28. What is the specific heat of the solid, liquid and gas phase? (104 J/kg/^{o}C, 188 J/kg/^{o}C, 156 J/kg/^{o}C)
29. What is the latent heat of fusion and vaporisation? (9380 J/kg, 15,600 J/kg)

Here is another phase change graph for 0.026 kg of a substance that starts out as a solid at 0 ^{o}C:

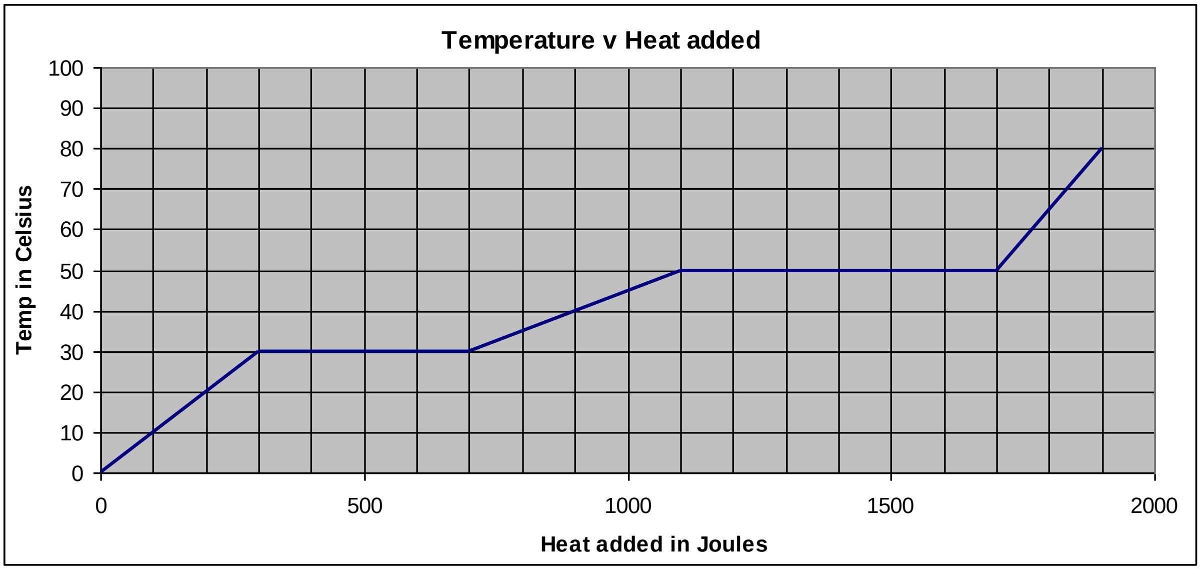


30. Label the graph where the KE is increasing, and where the PE is increasing.
31. What is the melting point? What is the boiling point? (40. ^{o}C, 80. ^{o}C)
32. What is the specific heat of the solid, liquid and gas phase? (48.1 J/kg/^{o}C, 240. J/kg/^{o}C, 76.9 J/kg/^{o}C)
33. What is the latent heat of fusion and vaporisation? (7,690 J/kg, 11,500 J/kg)

IB Physics
FA 14.1 - Heat and Calorimetry

Name____________________________

Favorite Wilderness Experience____
Show your work, and circle your answers and use sig figs to receive full credit.
When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.
This is a graph of temperature v. heat added for a 0.218 kg sample of unknown. It starts as a solid, and ends as a gas.



1. What is the **melting temperature** and the **boiling temperature** of this substance? Label the **solid**, **liquid** and **gaseous** phases.
(Melt = 30 ºC, Boil = 50 ºC, solid 0-300 J added, Liquid 700-1100 J added, Gas 1700-2000 J added.)

2. What is the **latent heat of vaporisation**? (Boiling)
(2750 J/kg)

3. What is the **specific heat** of the liquid phase?
(91.7 J/kg°C)

4. What heat do you need to heat 3.29 Kg of water at 21.0 °C to steam at 175 °C?
(For H_2O: C_{ice} = 2100 J/kg°C, $l_f = 3.33 \times 10^5$ J/Kg, C_{water} = 4186 J/Kg°C, $l_v = 22.6 \times 10^5$ J/Kg, C_{steam} = 2010 J/kg°C)
(9.02×10^6 J)

5. 500. grams of a mystery liquid at 45.0 °C is mixed with 300. grams of water (C = 4186 J/Kg°C) initially at 22.0 °C. The final temperature of the mixture is 33.0 °C. What is the specific heat of the mystery liquid? (Assuming no heat was lost to the surroundings)
(2.30×10^3 J/kg°C)

IB Physics
FA 13.1 - Ideal Gas Law

Name__________________________New Age Name______________________________

Show your work, round to the correct significant figures, circle your answers, and label them with units.
When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

(1 atm = 1.013×10^5 Pa = 101.3 kPa = 14.7 psi = 760 Torr; 1 m^3 = 1000 liters; $p_{absolute} = p_{gauge}$ + 1 atm;)

1. Convert 1340. Torr absolute to gauge pressure psi. Convert 87.3 kpa gauge to Torr absolute

2. Fred has 1.65 mols of methane gas at 87.2 ^oC at 56.3 kPa (1 kPa = 1000 Pa). What is the **volume** it occupies?

3. Maryland has 217 grams of Neon (molar mass 20.1797 g/mol) gas in 519 liters at **gauge** pressure of 6.97×10^4 Pa. What must the **temperature** be in **Celsius**? (1000 liters = 1 m^3)

4. An aerosol can is at an absolute pressure of 381 Boogalas when it is at 293 K. If I put it in liquid nitrogen and lower its temperature to 77.0 K, what is the new **pressure** in Boogalas? (1000 milli Boogalas = 1 Boogala) (Assume it does not leak, and the volume remains constant)

5. A Helium tank contains 3.42 kg of helium and is at a gauge pressure of 145 psi. What will be the **gauge pressure** when you have released 1.13 kg of helium?

Worksheet 13.1: Kinetic Theory and the Ideal Gas Law

Objective F: Ideal Gas Law: pV = nRT, R = 8.31 J/(mol K)

Some molar masses:	
H	1.0079
He	4.003
N	14.0067
Br	79.904
Xe	131.293

1. What is the volume of one mol of an ideal gas at standard temperature and pressure (STP)? (P = 1.000 atm = 1.013×10^5 Pa, T = 0^oC = 273.15 K) What is the volume in liters? (1 m^3 = 1000 liters) (22.4 liters)
2. George Uss has 0.34 mols of Xenon tetrafluoride in a container with a volume of 0.159 m^3 at 78.0 ^oC. What is the **pressure**? (6.2E3 Pa)
3. Hugh Jass has a volume of 143 liters and 2.56 mols of Xenon gas at a pressure of 67,120 Pa. What must be the **temperature** in Kelvins? What is the temperature in ^oC (451 K, 178 ^oC)
4. Anita Breke fills a large helium balloon with 2.18 grams of Helium gas. How many mols of He is this? What is the pressure in the balloon if the gas occupies a volume of 12.05 liters (1000 liters = 1 m^3) at a temperature of 18.0 ^oC? (Beware the ides of Celsius!) What is that pressure in atmospheres? What is the gauge pressure in Pa and Atmospheres? (0.545 mols,1.09×10^5 Pa, 1.08 atm, 8×10^3 Pa, .08 atm)
5. A reaction vessel operates at 3.14 atmospheres. What is that pressure in Pa? If the vessel has a volume of 0.113 m^3, is at a temperature of 145 ^oC, and contains pure Nitrogen gas, how many mols of nitrogen gas does it contain? How many grams of Nitrogen does it contain? (None Of Fred's Clients Bring Iron Hats – Nitrogen is a diatomic gas) (3.18×10^5 Pa, 10.3 mols, 290. g)
6. A container has a volume of 216 liters. (1000 liters = 1 m^3) If it can sustain a pressure of 13.5 atmospheres before bursting, and contains 89.1 grams of Hydrogen gas, a) what is its bursting pressure in Pa? b) how many mols of Hydrogen does it contain? and c) what is its maximum operating temperature in K and ^oC? (1.37×10^6 Pa, 44.2 mols, 804 K, 531 ^oC)
7. A 2.00 liter bottle contains 18.15 grams of Bromine gas and is at a gauge pressure of 0.153 atm. What is its temperature in Celsius? (-26 ^oC)
8. George has 205 grams of Hydrogen gas at 1275 Torr Gauge pressure and 127.0 ^oC. What must be the **volume** of the container? (1.25 m^3)
9. Jeanne has 1,529 grams of Xenon gas in 127 liters at a temperature of –16.0 ^oC. What must be the **gauge pressure in psi**? (13.7 psi gauge)

Objective G: Combined Gas Law: $\frac{PV}{nT} = \frac{PV}{nT}$

10. An aerosol can is at an absolute pressure of 603 Boogalas when it is at 312 K. If I put it in liquid nitrogen and lower its temperature to 77.0 K, what is the new **pressure** in Boogalas? (1000 milli Boogalas = 1 Boogala) (Assume it does not leak, and the volume remains constant) (149 Boogalas)
11. Air trapped in an airtight cylinder when the piston is 34.1 inches high is at 57.0 Jukkulas. How **high** must the piston be if the pressure is later at a pressure of 115 Jukkulas? Assume temperature remains constant. (16.9 inches)
12. A Tupperware container is at 1.00 atm at 21.0 ^oC. (Convert to K) It is heated in a microwave to 99.5 ^oC with the lid on. Assuming no gas escapes, what is the pressure inside in atm? (1.27 atm)
13. A quantity of ideal gas is compressed at constant temperature from 34.5 liters to 12.4 liters. What was the <u>initial</u> pressure if the final pressure was 2.45×10^5 Pa? (8.81×10^4 Pa)
14. A balloon has a volume of 1.25 liters at 20.5 ^oC. At what temperature does it have a volume of 1.02 liters, assuming the pressure and mols remain constant? (-33.5 ^oC)
15. One mol of an ideal gas occupies 22.4 liters at STP. (P = 1.000 atm T = 0.00^oC) What volume does it occupy at 97.0 ^oC and 1.29 atm? (23.5 liters)
16. My car tire has a gauge pressure of 32.0 PSI when the temperature is 23.0 ^oC, what is the temperature in Celsius if the gauge pressure is later 48.0 PSI? (Assume that the tire does not leak, and that the volume remains constant) (124 ^oC)
17. A container with a volume of 3.7 bushels is at a **gauge** pressure of 274 kPa and 57.0 ^oC. If it does not leak, and later the **gauge** pressure is 117 kPa at 145 ^oC, what is the new **volume** of the container? (8.06 bushels)
18. An airtight container has a sliding wall, so its volume can change. When the volume is 13.7 cc, the **gauge** pressure is 0.150 ATM and the temperature is 25.0 ^oF. What must be the new **gauge pressure** if the container has a volume of 42.1 cc at 450. ^oF? (Absolute zero is -459.67 ^oF) (-0.298 atm)
19. A steel nitrogen tank has a mass of 5.36 kg. When it is at 68.0 ^oF, and 742 psi gauge, it has a mass of 9.83 kg because of the added nitrogen gas. If the gauge pressure is 347 psi, and the mass of the tank is 7.15 kg because some nitrogen was released, what must be the temperature? (170. ^oF)

Objective H:

Questions:

20. When does the ideal gas law not work, and why does it not work?
21. Why is there almost no atmospheric helium and hydrogen?

IB Physics
FA 13.2 - Kinetics

Name________________________________Outdoor School name_________________________

Show your work, round to the correct significant figures, circle your answers, and label them with units.
When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

1. Convert 77 K to ^oC Convert 72 ^oF to ^oC Convert -40.0 ^oC to ^oF

2. What is the average kinetic energy of a molecule of an ideal gas at 20.0 ^oC? What is the total internal energy of 1.00 moles ($6.02x10^{23}$ molecules) of an ideal gas at this temperature?

3. At what temperature in Celsius is the average kinetic energy of an ideal gas molecule $5.00x10^{-21}$ J?

4. What is the RMS speed of a nitrogen molecule (m = 2x14 = 28.0 u) at 30.0 ^oC?

5. At what temperature in Celsius is the RMS speed of oxygen molecules (m = 2x16 = 32 u) 470. m/s?

Worksheet IB8.1: Energy Production

Fuel	Specific energy/ $MJ\,kg^{-1}$	Energy density/ $MJ\,m^{-3}$
Wood	16	1×10^4
Coal	20–60	$(20–60) \times 10^6$
Gasoline (petrol)	45	35×10^6
Natural gas at atmospheric pressure	55	3.5×10^4
Uranium (nuclear fission)	8×10^7	1.5×10^{15}
Deuterium/tritium (nuclear fusion)	3×10^8	6×10^{15}
Water falling through 100 m in a hydroelectric plant	10^{-3}	10^3

Energy Density and Efficiency

1. What is the energy content of 10.0 g of petrol (gasoline)? (450 kJ)
2. How many grams of coal must you burn to get 125 kJ of heat energy? Use an specific energy of 40.0 MJ kg^{-1}. (3.13 g)
3. How many grams of petrol must you burn to raise the temperature of 750. ml of water (C_{water} = 4186 J kg^{-1} $^oC^{-1}$) from 15.0 ^oC to 100.0 ^oC? if the stove is 100% efficient? What if it is 65.0% efficient? (5.93 g, 9.12 g)
4. A gas water heater contains 189 liters of water at 15.0 ^oC. If it is 55.0% efficient, and it burns 0.889 kg of natural gas, what is the <u>final</u> temperature of the water? (49.0 ^oC, the delta T is 34.0 ^oC)
5. An on demand water heater needs to heat 17.0 liters of water per minute from a temperature of 13.0 ^oC to 54.3 ^oC. How many grams of natural gas will it burn in one minute if it is 58.0% efficient? (92.1 g)
6. A gas water heater can raise the temperature of 178 liters of water from 21.0 ^oC to 65.0 ^oC by burning 1.10 kg of natural gas. What is its efficiency? (54.2%)
7. A power plant generates 125 MW of power. How much energy does it generate in a day? If it is 37.0% efficient, what is the energy input in a day? How many kilograms of coal would it burn to produce that amount of energy? (Use an specific energy of 40.0 MJ kg^{-1}) How many kilograms of Uranium would it go through in a day? (1.08×10^{13} J, 2.92×10^{13} J, 7.30×10^5 kg or 730 metric tons, 0.365 kg of Uranium)
8. A power plant is 37.0% efficient and burns 4190 kg of natural gas a day. What is its average power output? (987 kW)
9. A natural gas generation plant generates a power output of 0.850 MW. It consumes 159 kg of natural gas per hour. What is its efficiency? (35.0%)
10. How many kg of natural gas will a 145 MW natural gas electrical generation plant that is 34.0% efficient burn in a year? (2.45×10^8 kg)

Wind Turbines

11. A giant wind turbine has a radius of 43.9 meters, and operates where the average wind speed is 6.64 m/s, and the air density is 1.31 kg m^{-3}. What is the maximum amount of power available to it? What power does it capture if the air exiting the turbine is still going 5.14 m/s? If the electrical generator is 89.0% efficient, what electrical power does it create? (1.16 MW, 622 kW, 554 kW)
12. A wind turbine slows air with a density of 1.25 kg m^{-3} from 7.12 m/s to 6.50 m/s and needs to capture 26.5 kW of power. What radius does it need to be? How many of these would you need to capture 1.20 MW of power? (12.5 m, about 45, I suppose 46 to be more than that)
13. A wind turbine with 15.0 m blades captures 45.8 kW of power from air with a density of 1.35 kg m^{-3} initially moving at 6.15 m/s. What is the speed of the air leaving the turbine? (5.15 m/s)
14. A wind farm operates in air with a density of 1.30 kg m^{-3}. The individual turbine blades are 45.1 m long, and the average wind speed is 5.40 m/s. If the turbines have an overall efficiency of 41.5%, what is its average power output of a single turbine? How many of these turbines would you need if you wanted to generate 120. MW? (271 kW, about 442)
15. A wind turbine with 35.0 m long blades slows air with a density of 1.30 kg m^{-3} from 8.15 m/s to 7.25 m/s. What power does it capture from the wind? If the electrical generator is 92.0% efficient, what is the power output? (401 kW, 369 kW)

Pumped Storage

16. A pumped storage system allows water to fall through a vertical distance of 270. m at a rate of 450. kg s^{-1}. What is the total power being transformed? If the generation system has an overall efficiency of 56.0 % what is the electrical power output? (1.19 MW, 667 kW)
17. You are designing a pumped storage system. You can raise the reservoir a height of 85.0 m above the generation site, and the overall efficiency is 62.0%. What flow rate in kg s^{-1} do you need to have to generate 125 kW? (242 kg s^{-1})
18. A pumped storage facility is generating 860. kW of electrical power with a flow rate of 712 kg s^{-1}, and an overall efficiency of 67.0%. What height is the reservoir above the generation site? (184 m)
19. A pumped storage system is generating 413 kW of electricity with a reservoir that is 312 m above the generation site, and is operating a flow rate of 237 kg s^{-1}. What is its overall efficiency? (56.9%)
20. A 72.0% efficient pumped storage plant operates with a vertical displacement of 185 m, and lets 2740 kg of water per <u>minute</u> into the generator. What is its power output? (59.7 kW)

Solar

21. A house has solar panels that measure 1.65 m by 0.991 m, and are 22.3% efficient. If the sunlight has an intensity of 850. W m^{-2}, what is the electrical power generated by a single panel? How many panels would you need to generate at least 4 kW? (310. W, 13)
22. A house has 12 solar panels with an efficiency of 21.5% that measure 1.57 m by 1.05 m, and are generating 4020 W of power. What is the intensity of the solar radiation? (945 W m^{-2})
23. You need to generate 5.60 kW of power for a house with solar panels that have an efficiency of 23.0% and the average intensity of sunlight is 450. W m^{-2}. What area do you need? (54.1 m^2)
24. Some solar panels measure 1.60 m by 1.02 m, each one generating 275 W of power when the sunlight intensity is 750. W m^{-2}. What is the efficiency of the panels? (22.5%)
25. A house has 35.0 m^2 total area of solar panels with an efficiency of 24.0%. What is the power output when the sunlight intensity is 1020 W m^{-2}? (8570 W)

IB Physics
FA IB8.1 – Energy Production

Name____________________________

Favorite Analogy____

Show your work, and circle your answers and use sig figs to receive full credit.

When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

1. A 57.0% efficient gas water heater contains 175 liters of water at 18.0 ^oC. What is the temperature of the water (c = 4186 J kg^{-1} $^oC^{-1}$) after it has burned 0.784 kg of natural gas? (The specific energy of natural gas is 55 MJ kg^{-1})

2. A 42.0% efficient power plant burns coal and generates an average power output of 2.60 MW. How many kilograms of coal will it burn in a year? (The specific energy of the coal used is 47.0 MJ kg^{-1})

3. Air with a density of 1.28 kg m^{-3} enters a 24.0 m radius wind turbine at 7.30 m/s and exits at 6.10 m/s. It generates 160. kW of electrical power. What is the efficiency of the generator in turning the captured wind energy into electrical energy?

4. You are designing a pumped storage electrical generation site. It needs to generate 950. kW of electrical power with a flow rate of 860. kg s^{-1}. What height above the generation site does the reservoir need to be if such systems are typically 65.0% efficient?

5. A solar panel measures 2.74 m by 1.35 m, and generates 547 W of power when the sunlight intensity is 800. W m^{-2}. What is the efficiency of the panels?

Name____________________________

Favorite Metaphor____

Show your work, and circle your answers and use sig figs to receive full credit.

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1-2: A solar water heater has an albedo of 0.112. It measures 1.30 m by 2.15 m, and on a particular day, the intensity of the sun is 1150 W m^{-2}.

1. What is the intensity of the reflected light, and the absorbed light?

2. What is the maximum energy it could absorb in an hour?

3. A particular star has a peak black body wavelength of 517 nm. What is its temperature in Kelvins?

4. A power adapter has an outside area of 0.00540 m^2, an emissivity of 0.720, and is dissipating 45.0 mW of heat by black body radiation to a room that is at a temperature of 20.0 ^oC. What is the temperature of the power adapter?

5. A planet has an upper atmosphere with an albedo of 0.170. Radiation from the star it orbits strikes the side facing the star with an intensity of 1370 W m^{-2}. If there is no greenhouse effect, what would be the equilibrium temperature of the planet with space?

Worksheet IB8.2: Black Body Radiation, Wien, and The Greenhouse Effect

Objective 14F: Basic Heat Transfer

Questions:

1. List ways you can help/prevent heat transfer via conduction, convection, evaporation, and radiation.
2. Why is it that the earth can exchange heat with the rest of the universe only by radiation?

Objective 14I: Wien Displacement law

Questions:

3. In the night sky, there are reddish stars, and bluish stars. Which are the hotter stars? (Look up the visible light spectrum. Note that the red is the long wavelength end of the spectrum, and blue is the short)

Problems:

4. The sun's surface temperature is 5,778 K. What is the peak black body radiation emitted by the sun? What part of the EM spectrum does this wavelength come from? (Use your Google machine) (502 nm - visible)
5. The average temperature of the Earth is 14 ^oC. What is that in Kelvins, and what is the peak black body radiation for that temperature? What part of the EM spectrum does that radiation come from? (287 K, 10.1 μm - IR)
6. A distant star had a BBR peak of 410 nm. What is the temperature of the surface of the star in K? (7,070 K)
7. Another star has a BBR peak of 780 nm. What is the temperature of the surface of the star in K? (3720 K)

Objective 14J: Radiative Heat Transfer

Questions:

8. How is it possible for the ground to get colder than the air on a cold clear night?
9. Why does making something silvery or polished reduce the heat transfer by radiation?

Problems:

10. The Sun has a surface temperature of 5,778 K, a radius of $6.96\text{x}10^8$ m. Assuming it is a perfect black body, calculate the total power output of the sun. ($3.85\text{x}10^{26}$ W)
11. The earth has an average surface temperature of 287 K and a radius of $6.38\text{x}10^6$ m. At what rate does it radiate energy to space? ($1.97\text{x}10^{17}$ W)
12. A 100. Watt incandescent light bulb has a filament temperature of 2810 K. What is the area of the filament in m^2 if the emissivity is 0.55? (What is the peak BBR for this filament? Visible light is 400 to 700 nm...) ($5.1\text{x}10^{-5}$ m^2, $1.0\text{x}10^{-6}$ m or 1.0 μm)
13. A person with a skin surface area of 1.6 m^2 and temperature of 32 ^oC is in a room where the dark absorptive walls are at a temperature of 18 ^oC. What is the net rate of heat transfer if the emissivity of their skin and clothing is about 0.68? ($P = e\sigma A(T^4 - T^4)$) (92 W)
14. A radiator in a room is radiating energy at a rate of 345 Watts through a radiant area of 1.80 square meters. It has an emissivity of 0.890, and the room it is in has an ambient temperature of 18.0 ^oC. What is the temperature of the radiator in degrees Celsius? (50.6 ^oC)

Objective 14K: Albedo

Problems:

15. An aluminum roof has an albedo of 0.890. If 1200 Wm^{-2} of solar radiation is incident on the roof, what is the reflected intensity, and what is the absorbed intensity? (1070 Wm^{-2} reflected, 132 Wm^{-2} absorbed)
16. A black asphalt roof has an albedo of 0.0900. If 1200 Wm^{-2} of solar radiation is incident on the roof, what is the reflected intensity, and what is the absorbed intensity? (108 Wm^{-2} reflected, 1092 Wm^{-2} absorbed)
17. What should the albedo be of a solar heater if it is to absorb 95.0% of the incoming light? (0.050)
18. A piece of metal lying in the sun measures 0.680 m by 0.543 m and has an albedo of 0.68. If it is absorbing 416 Wm^{-2}, what must be the intensity of the light hitting it? (1300 Wm^{-2}) What amount of energy will it absorb in a minute? (9.22 kJ)
19. A solar water heater has an albedo of 0.0452. What area must it have if it is to absorb 11.6 MJ in one hour when the intensity of the solar radiation is 1150 W m^{-2}? (2.93 m^2)

Objective 14L: The Greenhouse Effect

Problems:

20. A star has a radius of $3.50\text{x}10^8$ m and a temperature of 4280 K. What is the power output of the star? (Its luminosity) What is the intensity of light from it in Wm^{-2} if you are $1.30\text{x}10^{11}$ m from it? ($2.93\text{x}10^{25}$ W, 138 Wm^{-2})
21. The intensity of a star is 1650 Wm^{-2} from a distance of $1.40\text{x}10^{11}$ m. What is the power output of the star? What is the temperature of the star's surface if it has a radius of $9.30\text{x}10^8$ m? ($4.06\text{x}10^{26}$ W, 5070 K)
22. 1450 Wm^{-2} of energy is incident on a planet whose upper atmosphere has an albedo of 0.230. What intensity of light gets through the upper atmosphere, and what is the average intensity over the whole surface of the planet? (1116.5 Wm^{-2}, 279 W/m^{-2})
23. A planet has an average absorbed incoming energy intensity over its entire surface of 295 Wm^{-2}, and its upper atmosphere has an albedo of 0.330. What is the energy intensity incident from space on the upper atmosphere? (1761 Wm^{-2})
24. What would be the equilibrium temperature of the earth if is absorbing on the average 258 Wm^{-2} from the sun (it isn't), and we ignored the greenhouse effect? (we can't) (260. K)
25. A planet with no atmosphere has an average surface temperature of 316 K. What is the average absorbed energy intensity over the surface of the planet from the star it orbits? What is the maximum intensity incident on planet? (565 Wm^{-2}, 2261 Wm^{-2})
26. A planet has an upper atmosphere albedo of 0.105 and is at an equilibrium temperature of 13.0 ^oC with space. What is the incoming solar intensity from the star it orbits? (Assume there is no greenhouse effect due to the atmosphere) (1699 Wm^{-2})