Problem Set #1: PHYS 320 The World: Energy Units & Conversions, Global Energy Use
Due Monday, Jan 14 in class.

1) Print out a Graph from Gapminder *Some nice graphs here and discussion. Please let me know if you have any questions about this.*

2) Make another graph on Gapminder of something versus something else *Again, same as above.*

3) The definition of a Watt is a Joule per second. Or power is rate of change of energy: $P = \Delta E/\Delta t = Work/\Delta t$, or $\Delta E = P*\Delta t$ [yes, this is awful: W stands for work, which is energy and has units of Joules, but W is also the symbol for Watt, the unit of power, which is the same of J/s.]. Consequently, not only is 1W = 1J/s, but 1J = W*s.
   a) Please prove this second relationship to yourself by canceling units.
   b) How many Joules are in a kWh (a kiloWatt-hour)? This would be the energy used in order to power a kW device (like a hair drier) for one hour.
   c) How long would a kWh light a room with a:
      a) 100 W incandescent light bulb. *Turns out to be 10 hours*
      b) 30 W compact fluorescent bulb. *Turns out to be 33 hours*
      c) 10 W of LED (Light Emitting Diode) bulbs. *Turns out to be 100 hours, ~ 4 days.*
      ****Note that each of these lightbulbs will each light the room about the same, but a) and b) heat the room much more.
   d) How much would a kWh change the temperature of my hot tub? ~ 1 m^3 or about 1 Tonne.
   e) How much does the average Californian pay for a kWh of electricity? Many questions in this class will ask you things we haven't covered and will require you to look up.
   f) How big is a kWh battery?... its mass, its dimensions? As above, I encourage you to go shopping for batteries on the internet and see what you find.

3) a) $(1s)\,1\,W = 1\,J/s\,(1\,s) \Rightarrow 1\,J = 1\,W\cdot s$ A

b) $kWhr = 10^3 (J/s)(1\,hr)\left(\frac{60\,m}{1\,hr}\right)\left(\frac{60\,s}{1\,m}\right) = 3600\times10^3\,J = \boxed{3.6\times10^6\,J} = kWh$ A

c) a) $t = E/P = \frac{3.6\times10^6\,J}{100\,W} = \boxed{3.6\times10^4\,s}$

b) $t = E/P = \frac{3.6\times10^6\,J}{30\,W} = \boxed{1.2\times10^5\,s}$ A

c) $t = E/P = \frac{3.6\times10^6\,J}{10\,W} = \boxed{3.6\times10^5\,s}$

d) $E = m c \Delta T$

$3.6\times10^6\,J = (1\times10^6\,g)(4.2\,J/g°C)\,\Delta T$

$\boxed{\Delta T = 0.86\,°C}$ A

e) $\boxed{15.34¢/kWh}$ A

f) it varies → between what & what

6 [illegible] ~ 20kg ?

4) Remember the energy flow diagram from the "dropping the rock" video? Please consider the following process: You like to ride your electric scooter, and are pleased to charge it from the solar panel on your roof. You accelerate your scooter and then come to a stop by applying the breaks. Please make an energy diagram showing the energy conversions for your scooter ride. Then extend the flow diagram in both directions so that you begin from the primary energy source and end with the ultimate energy sink (deep space).
Radiant E. => Electrical E (+ lost thermal E.) => Chemical Potential Energy (battery) =>
Electrical E =(motor)=> kinetic E =(breaks)=> Thermal E. => radiant (IR) into space.

5) Consider one of your favorite energy conversion processes. Please make an energy flow diagram as in #4 above for this process. I request that this process be as unique as possible from that of #4 and the “dropping the rock” process.

EXERCISE

A Sun $\xrightarrow{\text{photo-synthesis}}$ plants → Food $\xrightarrow{\text{digestion}}$ ATP (U_c) → KE $\xrightarrow{\text{friction}}$ Heat → IR

From our activity, please do the following two questions without a calculator. You may need to use scientific notation if the numbers are big.

6) What is the rate of energy consumption of your car in Watts? This is difficult, but we will solve it little by little:
   a) How long does it take you to burn a gallon of gas while driving?
   b) How many joules of energy are in a gallon of gas?
   c) What rate of energy consumption does this correspond to?
   d) Make an energy diagram of this energy transformation process.

6. a) $30\ \text{mi/gal}\left(\frac{1\ \text{hr}}{60\ \text{mi}}\right) = 0.5\ \text{hr/gal}\left(\frac{60\ \text{m}}{\text{hr}}\right)\left(\frac{60}{\text{m}}\right) = 1800\ \text{s/gal}$

b) $\left(\frac{9.5\ \text{kWh of gasoline}}{\text{L}}\right)\left(3.78\ \frac{\text{L}}{\text{g}}\right) = 36.3\ \frac{\text{kWh}}{\text{g}}\left(3.6\times10^{6}\ \text{J/kWh}\right)$

$= 1.305\times10^{8}\ \text{J}$

c) $\frac{1.305\times10^{8}\ \text{J}}{0.5\ \text{hr}} = 2.61\times10^{8}\ \text{J/hr} = 7.25\times10^{4}\ \text{W}$

d) radiant energy (sun) $\xrightarrow{\text{photosynthesis}}$ chemical energy → thermal energy (gas) → kinetic energy $\xrightarrow{\text{friction}}$ thermal energy → IR

(6) a) $42\ \text{mi/gal}\left(\frac{1\ \text{hr}}{65\ \text{mi}}\right) = .65\ \text{hr/gal}\left(\frac{60\ \text{m}}{\text{hr}}\right)\left(\frac{60\ \text{s}}{\text{m}}\right) = \boxed{2322\ \text{s/gal}}$ A

b) $1\ \text{gal} = 33.4\ \text{kWh/gal} = 120.3\times10^{6}\ \text{J} = \boxed{1.203\times10^{8}\ \text{J}}$ A

c) $\frac{1.203\times10^{8}\ \text{J}}{2322\ \text{s}} = \frac{x\ \text{J}}{1\ \text{s}} = \boxed{5.18\times10^{4}\ \text{J/s}}$ A

d) Sun $\xrightarrow{\text{photo-synthesis}}$ plants $\xrightarrow{\text{life}}$ fossil fuel $\xrightarrow{\text{combustion}}$ gas → KE $\xrightarrow{\text{friction}}$ Q → IR A

7) Make a calorimeter: Make a calorimeter by burning a candle and heating some water with it! The goal is to measure the input and output energy so you can calculate the efficiency of the energy conversion process.

a) Draw the energy conversion flow chart for your calorimeter.

b) Measure the input energy and the output energy of the burning.

c) Calculate the input power and the output power.
d) Was all the heat absorbed by the water, or was a considerable amount of heat lost? Estimate the efficiency of the energy conversion in your calorimeter
e) How could you make your calorimeter more efficient – that is it would lose less energy?
f) If you had enough time, please use your calorimeter of known efficiency to measure the energy density (caloric content) of something else such as wood.
You all got slightly different efficiencies. The person below had an efficiency that is on the low side.

7) a) $\underset{\text{in candle}}{U_c} \xrightarrow{\text{combustion}} Q \xrightarrow{\text{conduction}} \underset{\text{in water}}{KE} \xrightarrow{\text{radiation}} Q \rightarrow IR$ A

$Q \xrightarrow{\text{radiation}}$ environment

b) input energy: $E = m\rho_e = 0.1g \times 43100 J/g = \boxed{4310 J}$ A

output energy: $E = mc\Delta T = 10g \times 4.2 J/g°C\,(11.5°C) = \boxed{483 J}$

c) input power: $\frac{4310 J}{48.66 s} = 88.57 J/s = \boxed{88.57 W}$ A

output power: $\frac{483 J}{48.66 s} = 9.926 J/s = \boxed{9.926 W}$

d) efficiency $= \frac{9.926 W}{88.57 W} \times 100 = \boxed{11.2\%}$ A

e) We could make it more efficient by holding the test tube closer to the candle's flame so that not as much heat is lost to the environment. A

f) N/A