Problem Set #1: PHYS 320 The World: Energy Units & Conversions, Global Energy Use
Due Wednesday, Jan 17 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:
$P = \Delta E/\Delta t = W/\Delta t$, 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)?
   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) $E = mc\Delta T$
$3.6\times10^6\,J = (1\times10^6\,g)(4.2\,J/g°C)\,\Delta T$
$\boxed{\Delta T = 0.86\,°C}$ ✓ A
e) $\boxed{15.34¢ / kWh}$ ✓ A
f) it varies ✓ → between what & what
~ 20kg ?
6 touché

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.
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 → plants → Food → ATP → KE → Heat → IR

(photo-synthesis; digestion (U_c); friction)

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?:
   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? ~ 50 kW for an average car… yes, like 50 hair driers!
   d) Make an energy diagram of this energy transformation process. OOPS! This example below, some steps were left out. In the gasoline engine, we have gasoline => thermal E => kinetic E (+ thermal energy) => then it's all turned into thermal energy in the end… breaks do it and the friction on the road and air…. => IR radiation into space!

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

b) $1\ gal = 33.4\ kWh/gal = 120.3 \times 10^6\ J = \boxed{1.203 \times 10^8\ J}$ ✓ A

c) $\frac{1.203 \times 10^8\ J}{2322\ s} = \frac{x\ J}{1\ s} = \boxed{5.18 \times 10^4\ J/s}$ ✓ A

d) Sun → plants → fossil fuel → gas → KE → Q → IR ✓ A

(photo-synthesis; life; combustion; friction)

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
c) Measure the input power and the output power
d) 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 some food – like nuts.

Note that the person who's calculations are represented below had horrendously poor efficiency in their calorimeter. I think most of you got about double that.

7) a) U_c (in candle) $\xrightarrow{\text{combustion}}$ Q $\xrightarrow{\text{conduction}}$ KE (in water) $\xrightarrow{\text{radiation}}$ Q → IR

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

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

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

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

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

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

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.

f) N/A