Problem Set #1: PHYS-310 The World: Energy Units & Conversions, Global Energy Use
Due Monday, April 8 in class.

1) Spend 10 – 15 minutes on the EIA website. Printout or write down your favorite:
   a) graph
   b) statistic
   c) fun fact
2) The US consumes about a 100 Quads of primary (raw) energy a year (for a long time, this was a forth of global energy consumption, but now is less than 1/5). Using this knowledge, please estimate:
   a) The average rate of primary energy consumption (in Watts) for the average US resident.
   b) Prove it it's true or not true: "daily energy consumption of a US American is about ¼ of their body weight in oil equivalent energy."

2.) $\frac{100 \text{ Quads}}{\text{year}} \times \frac{10^{15} \text{ Btu}}{\text{Quad}} \times \frac{1055 \text{ J}}{1 \text{ Btu}} \times \frac{1 \text{ year}}{31.5 \times 10^6 \text{ sec}}$ ✓

$= 3.35E12 \text{ J/s} = 3.35E12 \text{ W}$

Assume 324 million people live in US

✓a.) $\frac{3.35E12 \text{ W}}{324E6 \text{ people}} = 10.34 \text{ kW/person}$

b.) Assume US consumes 4146 TWh of electrical energy in a year

might want to show this is true

$\frac{4146E9 \text{ kWh}}{1 \text{ yr}} \times \frac{3.6E6 \text{ J}}{\text{kWh}} \times \frac{1 \text{ year}}{31.5E6 \text{ sec}} = 4.74E11 \text{ J/s}$

$= 4.74E11 \text{ W}$

$\frac{4.74E11 \text{ W}}{324E6 \text{ people}} = 1.46 \text{ kW/person}$

c.) ✓ $\frac{10.34 \text{ kW}}{\text{person}} = \frac{10.34 \times 10^3 \text{ J}}{\text{sec.} \times \text{person}} \times \frac{86400 \text{ sec}}{\text{day}} = 8.9E8 \text{ J/person/day}$ ✓

Nice!

Assume average weight of American is 170 lb.

$\frac{1 \text{ barrel of oil}}{303 \text{ lbs}} \times \frac{170 \text{ lbs}}{\text{person}} \Rightarrow$ 1 person weighs 0.56 barrels of oil

1/4 person's body weight = 0.14 barrels of oil ✓

$(1 \text{ BOE} = 6.1 \times 10^9 \text{ J}) \times 0.14 = 8.6E8 \text{ J/person/day}$ Nice!

$\approx 8.9E8 \text{ J/person/day}$ ✓

3) Calculate your own horsepower over a short period of time or a long period of time by exerting yourself in an activity. I expect to see between 300 W and 3000 W if you are way outside this range, you have to ask yourself why, OK?

4) Show that e^{it} is a solution to $dQ/dt = iQ$, or for population = P, $dP/dt = iP$, or $d\$/dt = i\$$, where i is NOT square root of -1, but is a constant with units of $(time)^{-1}$.

Please substitute in and see what you get. It should work out.

5) What is the tripling time for exponential growth?

$P = e^{it}$

$1000 = e^{it}$ $\xrightarrow{P\times 3}$ $3000 = e^{it}$ $\xrightarrow{P\times 3}$ $9000 = e^{it}$

$\ln(1000) = it$ $\quad$ $\ln(3000) = it$ $\quad$ $\ln(9000) = it$

$t = 6.908/i$ $\quad$ $t = 8.006/i$ $\quad$ $t = 9.105/i$

$\Delta t \approx 1.1/i$ ✓

good setup / [illegible]

6) Hey, did you know that a Ton is not just a unit of mass, it's also a unit of *power* for AC or refrigeration. Back in the day, people would just buy ice to keep things cool in their insulated food space. So, if they got a ton of ice per day, then the latent heat of fusion would be absorbed each day as the ice melted. The accepted conversion is 1 T = 12,000 BTU/hr. Please show that this is about correct, and in the process, please convert to kW.

6) $P = \frac{E}{t} = \frac{Q_{fusion}}{1\,day}$

1 Ton

$Q_f = m(H_f) = 10^3 kg \cdot 334\, J/g$

$= 10^6 g \cdot 334\, J/g = 3.3\times10^8 J$

$1\,day = 24\,hr \cdot 3600\,s/hr \approx 100 \cdot 900\,s = 9\cdot10^4 s$

$P \approx \frac{3.3\times10^8 J}{9\cdot10^4 s} \approx .36\times10^4 W$

3.6 kW

$BTU \approx 1055 J \sim 10^3 J$

$P \approx \frac{3.3\times10^5 BTU}{24\,hr}$

$\approx 3.3\times10^3 \times \frac{4}{1} \frac{BTU}{hr}$

$\approx$ **13,000 BTU/hr**

7) Let's say we did the equitable thing and split up the earth's surface area equally among all people. Direct noon sunlight on the equator is about 1000 W/m^2. No calculators please.

   a) Estimate the amount of land, ocean and fresh water surface area each of us gets
   b) Estimate the amount of power each person would absorb at noon.
   c) Estimate the amount of energy each person would absorb in a year.

7) Area of Earth $= 4\pi r^2$

$\approx 4\cdot\pi\,(6.4\times10^6\,m)^2$

$\approx \underbrace{\underbrace{4\cdot\pi}_{\sim 12}\,(40}_{\sim 500}\times10^{12}\,m^2) \sim 5\times10^{14}\,m^2$

a) Area/person $\approx \dfrac{5\times10^{14}\,m^2}{7.5\times10^9\,cap} = \dfrac{2}{3}\times10^5\,m^2$

$\approx 7\times\underbrace{10^4\,m^2}_{Hectare}$

~ 7 football fields.

if earth is 71% water surface,

we have about 5 Hectare water, 2 Hectares land

$\sim\frac{1}{25}$ th of water is freshwater...

$\frac{1}{5}$ Hectare fresh water

b) ~~$10^3\,W/m^2$~~ sunlight @ noon $\sim 10^3\,\frac{W}{m^2}$

$7\times10^4\,m^2\cdot10^3\,\frac{W}{m^2} \sim 7\times10^7\,W = 70\,MW$

wow!

c) $E = P\cdot t = 7\times10^7\,W\cdot\underbrace{\pi\cdot10^7\,s}_{Year} \approx 2\times10^{15}\,J$

But we don't get sun at night or at high latitude

crosssectional surface area is only $\underline{1}\,\pi R^2$, so

$\div 4 \Rightarrow E = 5\times10^{14}\,J$ still a lot!

8) A friend once told me that each person is a 100 W lightbulb (No wonder when we're all in a room together it gets hot). If this is the case, how many calories would we need to consume daily? Is this about right? *Please see Big Exam #1 solutions*