Solution Set

PHYS 310, 9/10/11

Problem Set #1

A

1.) See attached

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) I saw horrendous bravado on this question including claims to generate over 24 HP pushing a car up a 20 degree incline, to which I exclaim, “Liar, liar, pants on fire!” I don’t believe you did this experiment….

Now come on and learn by doing, guys! At least run up a flight of stairs and calculate your power by P = m*g*dH/dt. OK? I did get one nice calculation of about a kW for running 23 minutes. This super athlete even remarked, “wait this is too much power! I can’t put out this much power for this amount of time.” No, this person’s calculation was *correct.* However, they calculated their power by calories burned / unit time. This was their rate of chemical potential energy *INPUT*. It turns out that our bodies are only about 25% efficient (we get hot when we exercise, no?). This should not make us feel too humble because cars are usually well under this, and most plants turn sunlight into chemical potential energy at an efficiency of about 1%. In this student’s case, we can find 250 W a respectable, yet believable average power output.

#4. Hopefully, you had no problem taking this derivate. If you did, please visit office hours and help me do it.

5.) $P = e^{it}$

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

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

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

$$\Delta t \approx 1.1/i$$ ✓

good setup / logic

✓6.) Direct Charging a BEV, Improved Building Efficiency

7.) 1 Ton = 907 kg ✓

Latent Heat of Fusion = 334 kJ/kg ✓

$$907\,kg \times \frac{334\,kJ}{kg} = 303{,}000\,kJ = 303E6\,J$$

$$\frac{303E6\,J}{day} \times \frac{1\,Btu}{1055\,J} \times \frac{1\,day}{24\,hr} = 11967\,Btu/hr$$

$$\approx 12000\,Btu/hr$$ ✓

nice

$$\frac{303E6\,J}{day} \times \frac{1\,day}{86400\,sec} = 3507\,J/s \approx 3.5\,kW$$

✓

8.) a.) $R_{earth} = 6370\,km$

$SA_{earth} = 4\pi(6370\,km)^2$

$= 5.1E14\,m^2$

✓

$$\frac{5.1E14\,m^2}{7.5\text{ billion people}} = 68{,}000\,m^2/person$$

$= 6.8\,Ha/Person$

$\approx 17\,acres/Person$

b) Assuming noon at the equator, we would receive ~ 1000W/m^2, yielding 68 MW per person – more than enough energy to get by… *and build yourself a factory, no?* A family can easily get by with a kW of received power, but may need a MW to grow all the food they need – as described in my comments for #3 above.

c) Some places get more sunlight than others, but we can find an average: first we have to divide our maximum power by a factor of 4 because the cross sectional surface area to the sun is $A = \pi r^2$, which is distributed over the entire planet's surface area $A = 4\pi r^2$. Then we should divide by another factor of 2 for atmospheric interference. Part of this is clouds, and the other part is that when the sun comes in at a higher angle (like near the evening), it is attenuated because it passes through more atmosphere (hence the sky is red at night and morning). So, dividing by 8, I say an average solar power of about 120 W/m^2.
E = P*t ~ 120 W/m^2 * 68,000 m^2 * π*10^{7}s ~ 2.6 x 10^{14} J / person – year. Not a bad amount of energy. As a BOE (Barrel of Oil Equivalent) is about 6.1 GJ, this would correspond to the heat given off from burning about 42,000 barrels of oil. Let's say we get some solar panels with rather crappy (10%) efficiency, we could turn this solar energy to ~ 2.6 x 10^{13} J or about 7 million kWh. That's a lot of electricity – enough to displace 7,000 tons of coal that would be burned to produce this electricity in a Rankine Cycle generation facility.