Problem Set #1: PHYS 320 The World: Energy Units & Conversions, Global Energy Use
Due Monday, Jan 13 in class.

Please do your work without a calculator, and estimate your answers best you can. You can check with a calculator afterwards if you really want to. Usually if you are within 20%, that is fine. Please start a list of constants and equations that you find helpful – this can be your notes for exams. Please expect that your answers will differ because you will estimate differently, and you will have to look up values online – and may find that you access different answers from other students.

Proper canceling of units. We will be learning how to properly cancel units, and work problems out with a pencil (or pen) to make sure that units work… this is VERY important because the world conspires to make life difficult with units that vary from Watts and meters to Horse Power and miles. Please show all units all the way through a problem with proper canceling.

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/Δt, 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·s ✓ A

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

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

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

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

d) $E = mc\Delta T$

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

$\boxed{\Delta T = 0.86\ °\text{C}}$ ✓ A

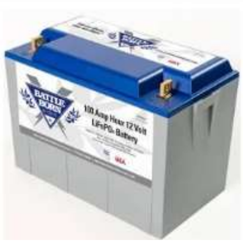
e) $\boxed{15.34¢/\text{kWh}}$ ✓ A

f) it varies ✓ → between what & what

~ 20kg ?

6 touché

Below is a battery I found on the internet for about $1000. This is a Lithium Iron Phosphate battery. This one below can hold 1.2 kWh… interesting that it costs $1000 to hold $0.15 of electricity… but you can hold this electricity and get it back many times. The weight of the battery is 29 lbs, or about 13 kg.

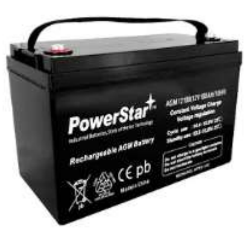


Battle Born 12V 100Ah (1,200Wh) LiFePO4 Deep Cycle Battery

$949.00 Continuous Resources

Battle Born 12V 100Ah (1,200Wh) LiFePO4 Deep Cycle **Battery** - Solar Power Systems, Solar Power Components, vendor-unknown ...

Below is a lead acid battery with the same 1.2 kWh capacity. It is considerably cheaper, but larger and has a mass of 30 kg (66 lbs), more than twice the mass of the Lithium Iron Phosphate battery above.. This is what you'd find in a car.



PowerStar 12V 100AH 45978 Sealed Lead Acid Battery - HIGHEST WARRANTY 2 YEAR WARRANTY

$199.37 Big Time Battery 95% positive (1,547)

Voltage: 12V Capacity: 100Ah Group Size: 27 L =13 x W = 6.6 x H = 8.62 inches Common Uses Consumer Electronics, Electric ...

12-volt · Disposable · Golf Cart

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). Red below is the extended part of the energy transitions.
Radiant E. => Electrical E (in Solar panel + lost thermal E.) => Chemical Potential Energy (in battery + lost thermal E) => Electrical E (in battery + lost thermal E) => kinetic E (in motor +lost thermal E) => Thermal E. (in breaks) => 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.

In the transition below, the student eats some veggies and runs around:

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 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.

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

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) Make a drawing of your experiment
b) Draw the energy conversion flow chart for your calorimeter.
c) Show the calculation and explain how you got the energy density
d) Show a calculation and explain how you got the power output of the candle.
e) Look up the energy density of wax… is it close to what you measured/calculated? About how efficient was your calorimeter?

6) 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.

· Candle → tube filled w/ water → steam → thermometer

Candle ↓ thermal energy; tube filled w/ water ↓ heats up; steam ↓ given off due to water heating up; thermometer ↓ temp increased due to water heating up w/ candle

Activity:
Starting temp: 22°c
After 1:30min: 46°c
> 24°c

Candle mass:
- beginning: 0.84g
- After 1:30min: 0.67g
> 0.17g

$E = (13.5g)(4.2 J/g°c)(24°c) = 1,383.48J$ (m, C_{H_2O}, ΔT)

$P_w \text{ (wax)} = \frac{1,383.48J}{0.17g} = 8,138.12 J/g$

$Power = \frac{1,383.48J}{90s} = 15.4W$

6.) Calorimeter problems

a) find P_{wax}

$$P_w = \frac{\Delta E}{m}$$

$$= \frac{mc\Delta T}{m}$$

$$= (22.72g)\frac{Cal}{g°C}(50.7° - 22.5°)$$

$$= (22.72g)\frac{Cal}{g°C}(28.2°C)$$

$$= \frac{640.704 \text{ cal}}{m_{wax} \text{ used}}$$

$$= \frac{640.704 \text{ cal}}{(0.92 - 0.72g)}$$

$$= \frac{640.704 \text{ cal}}{.2g} = \boxed{3,203.5 \frac{cal}{g}} \times \frac{4.2J}{cal} ='$$

b) $P_{candle} = \frac{J}{S}$

$$3,203.5 \text{ cal} \cdot \frac{4.19 J}{1 \text{ cal}}$$

$$= \frac{13,422.749 J}{180.22 \text{ sec}}$$

$$= \boxed{74.48 W}$$

c) ε calorimeter

$$= \frac{13,422 J/g}{42,000 J/g}$$

$$= 0.319$$

$$= \boxed{32\% \text{ efficient}}$$