SOLUTION

ENGR290: Renewable Energy

Homework 1: Power and Energy Units and Calculations

Assigned: May 15, 2014
Due: May 22, 2014

Notes:

Unit	Measure	Derivation	Description
Second (s)	Time	Fundamental	
Meter (m)	Distance	Fundamental	
kilogram (kg)	Mass	Fundamental	amount of matter in an object
Newton (N)	Force	$kg * m/s^2$	Force required to accelerate 1 kg $1m/s^2$
Joule (J)	Energy	$N * m$	Energy expended pushing 1 N of force for 1 meter
Watt (W)	Power	J/s	Rate of consuming (or delivering power)
kilowatt-hour (kWh)	Energy	kW*h	Energy expended consuming 1000W for 1 hour

Table 1: Common Energy-Related SI Units

Quantity	Measure	Description
gravity (g)	$9.8\frac{m}{s^2}$	Acceleration due to gravity
Kinetic Energy (J)	$\frac{1}{2}mv^2$	Energy stored in moving mass
Potential Energy (J)	mgh	Energy stored by elevating a mass
Electrical Power (W)	$Volts * Amps$	Power transferred by electrical current
Power to Energy	$E = Pt$	Energy is power times the time over which it is applied
Energy to Power	$P = E/t$	Power is the amount of energy transfered in an amount of time
	$1kWh = 3600kJ$	Conversion from kWh to Joules

Table 2: Common Energy-Related formulas

Energy is a measure of the capacity of a system to do work. It can be considered as "stored up work" and therefore it has the same units as work. Energy is always conserved, it cannot be created or destroyed, it can only be transferred from one object to another, or changed from one type to another such as electricity into heat, kinetic energy of the wind into electrical energy in a turbine and electro-magnetic radiation energy into electricity in a PV cell. Energy can be stored, like in a battery or flywheel, and then used at a later time.

Power is the rate of change of energy in a system. Power is an instantaneous value. It is how much energy is being put into (or removed from) a system at one instant in time. Power cannot be stored. It is a rate of change.

A good, simple example for energy and power is an old fashioned grandfather clock. These clocks were powered by large weights in the back. To wind the clock you pull a chain that lifts the weight up to the top of the cabinet. Then the weight powers the clock as it slowly lowers back down to the bottom of the cabinet. When you wind the clock, you apply power to the weight to move it up. How much power is required depends on how fast you wind it, but the amount of energy stored is the same no matter how fast you wind, since the weight ends up the same height. Then as the clock unwinds, it uses the energy you stored in it to power to clock. The power the clock uses is much less than what you put in to wind it since it happens over a much longer time, but at the end, all of the energy you stored is used up.

To calculate the change in energy in a system you must integrate the power over a time. If the power is constant, then you simply multiply power by time to get energy. For example, if a 1200 Watt microwave oven heats your food for 10 minutes then it transfers $1200W * 10min * \frac{60sec}{1min}) = 720000J = 0.2kWh$ of energy from the electrical supply into the food.

Problem Solving strategy

Problem solving ability is critical to all engineering. Think of a problem, whether it is a homework or test question or a real-life job, as a jigsaw puzzle. You are given (or have to lookup for yourself) a set of facts. These are the puzzle pieces. You also need to know what you are looking for. This is the picture the puzzle is supposed to look like. Your job is to assemble the pieces to get the correct answer.

1. Start with what you know. Write down all of the information that you know for the problem. These are the pieces to the puzzle. Some may be missing, and you will have to look them up or find them somewhere else.

2. Identify what the answer should look like. Are you looking for power, energy, voltage or what? Especially note what the units of the answer is, since that will indicate how to proceed.

3. Assemble the pieces into an equation that will give you the answer. Find any missing pieces that you need to get to the desired result. For example you may be given inputs in miles, but you need meters to calculate work, so you need to know (or find) the conversion from miles to meters.

Problem 1

You are planning a road trip to Houston, TX to visit the NASA facility there for a summer internship. It is 885 miles. You can average 75 miles per hour and at that speed your car gets 25 miles per gallon of gas. The average price of gas along the way is \$3.45 per gallon.

1. How many hours will you have to drive (neglecting stops)?

$\frac{hr}{75mi}$ 885mi = 11.8 hr

2. How many gallons of gas will it take?

$\frac{gal}{25mi}$ 885mi = 35.4 gal

3. How much money will you spend on gas?

$\frac{\$3.45}{gal}$ 35.4gal = \$122.13

Problem 2

Your living room lights burn 240 Watts of power and the electricity rate from PNM is \$0.13/kWh

1. If you are a good citizen and care about the environment so you only have your lights on for an average of 4 hours each night, how much money does it cost to light your living room for one year?

$\frac{\$0.13}{kWh}$ $\frac{1kW}{1000W}$ 240W $\frac{4hr}{day}$ $\frac{365day}{yr}$ = 45.55 \$/yr

2. If you don't care about the environment and you just leave your lights on all the time, how much money does it cost to light the living room for one year?

$\frac{\$0.13}{kWh}$ $\frac{1kW}{1000W}$ 240W $\frac{24hr}{day}$ $\frac{365day}{yr}$ = 273.31 \$/yr

Problem 3

A Trojan J185 lead-acid battery stores 200 Amp-hours at 12 volts. Your RV uses these batteries to power a refrigerator which averages 50 Watts continuously and lights which consume 30 Watts for about 3 hours each night.

1. How much energy is stored in the battery (kWh)?

remember 1W = 1A · 1V

so 200A·h · 12V = 2400Wh
= 2.4kWh

2. How much energy is used each day (kWh)?

50W · $\frac{24hr}{day}$ + 30W · $\frac{3hr}{day}$ = 1290 $\frac{Wh}{day}$ = 1.29 $\frac{kWh}{day}$

3. How many days can you camp before the battery dies?

$\frac{1day}{1.29kWh}$ 2.4kWh = 1.9 days.