9/9/08

HAND IN ASSIGNMENT #1

ASSIGNMENT #2 POSTED

NOTES 9/4/08 POSTED

ENERGY CONVERSION AND POWER
SI SYSTEM    INTERNATIONAL STANDARD SYSTEM

ADOPTED ALMOST EVERYWHERE EXCEPT IN US

ENERGY UNIT:   JOULE

1 JOULE = 1 J = 1 kg m$^2$/s$^2$

EXAMPLE:    RAISE 5 kg MASS BY 2 METERS

NOTE $m$ = METER (UNIT) & $M$ SYMBOL FOR MASS

$$E_g = M \cdot g \cdot H = (5 \text{ kg}) (9.8 \text{ m/s}^2) (2 \text{ m}) = 98 \text{ JOULES} = 98 \text{ J}$$
UNITS OF ENERGY

DIFFERENT UNITS ARE USEFUL AND HAVE BEEN IN USE HISTORICALLY

HEAT

1 calorie (cal) = 4.186 J

1 kilocalorie (kcal) = 4,186 J

1 kilocalorie = 1 Calorie (Cal) = “FOOD CALORIE”

1 BRITISH THERMAL UNIT (BTU) = 1,055 J = 252 cal

HANDOUT CALORIES AND WATTS
RELATION TO TEMPERATURE

1 kcal
HEAT (ENERGY) TO RAISE 1 kg OF WATER
BY 1 DEGREE CELSIUS (C)

1 BTU
RAISES 1 lb OF WATER
BY 1 DEGREE F

C = (F - 32) × 5/9

OR

F = 9/5 × C + 32
EXAMPLE

MINIMUM ENERGY IN calories EXPENDED BY A 70 kg PERSON (1 pound = 16 oz = 0.454 kg) “WALKING” UP THE ARCH

- HEIGHT ARCH 630 ft

- 1 m = 3.28 ft

- HEIGHT ARCH = 630 ft x (1 m) / (3.28 ft) = 192 m

- SUPPLY \( E_g = M g H = (70 \text{ kg}) (9.8 \text{ m/s}^2) (192 \text{ m}) \)

\[ = 131,712 \text{ J} \times (1 \text{ kcal} / 4,186 \text{ J}) = 31.46 \text{ kcals} = 31.46 \text{ Cal} \]

- CHECK: \( H \approx 200 \text{ ft} \) \& \( g \approx 10 \) SO \( E_g \approx 70 \times 10 \times 200 \text{ J} = 14 \times 10^4 \text{ J} \)

- CHECK CONVERSION \( E_g \approx 14 \times 10^4 / (4 \times 10^3) \text{ Cal} \) √
ANOTHER EXAMPLE

“HAPPY MEAL” HAMBURGER 269 kcals
REGULAR FRIES 220 kcals
12 OZ SODA 155 kcals
TOTAL 644 kcals

MOST OF THE ≈ 2000 kcals WE EAT EACH DAY USED FOR?
GENERATING HEAT & RUNNING OUR BODIES
NOTE EVEN 3 TIMES WALKING UP THE ARCH < FRIES
CHECK HANDOUT FOOD CALORIE TABLE
FIRST ASSIGNMENT: DAILY INTAKE (AVERAGE) / CONVERSIONS
POWER!

POWER ⇒ ENERGY / TIME

CAN BE ENERGY EXPENDED OR GAINED

USEFUL QUANTITY:

IDENTIFIES - CAPACITY AT A POWER SOURCE

- “APPETITE” OF POWER CONSUMER

ALSO USEFUL FOR AVERAGING

- ENERGY USED BY A CITY IN 24 HRS
SI: POWER ⇒ watt (W)

\[ 1 \text{ watt} = 1 \text{ J} / (1 \text{ s}) \]

OTHER COMBINATIONS: BTU / HR OR kcals / DAY

CONSIDER FOOD ENERGY INTAKE:

\[
\frac{2000 \text{ kcal}}{\text{day}} = \frac{2000 \text{ kcal}}{\text{day}} \frac{4186 \text{ J}}{\text{kcal}} \approx 97 \text{ W}
\]

1 PERSON ≈ 100 W LIGHT BULB!
## CONVERSIONS

<table>
<thead>
<tr>
<th>Unit</th>
<th>Equivalent in W</th>
<th>Check</th>
<th>Other Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 BTU/HR</td>
<td>0.293 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 hp</td>
<td>746 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>kW</td>
<td>10^3 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MW</td>
<td>10^6 W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW</td>
<td>10^9 W</td>
<td></td>
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</tbody>
</table>

Helpful for second problem of Assignment #2
WE HAVE SEEN DEMONSTRATED THAT A PERSON CAN GENERATE MECHANICAL ENERGY AT A RATE ON THE ORDER OF 100 WATTS.
WE KNOW THAT CLIMBING THE ARCH TAKES ABOUT 150,000 JOULES.
WE CAN REARRANGE $P = \frac{E}{T}$ INTO THE FORM
$T = \frac{E}{P}$ TO FIND THAT A PERSON SHOULD BE ABLE TO CLIMB THE ARCH IN ABOUT

$$T = \frac{150,000 \text{ J}}{100 \text{ W}} = 1,500 \text{ s} \text{ OR}$$

$$T = \frac{(1500 \text{ s})}{(3600 \text{ s/HR})} \text{ A LITTLE LESS THAN HALF AN HOUR.}$$
CONSISTENCY CHECK:

1 GALLON OF GASOLINE = 125,000 BTU

1 GALLON MIGHT YIELD

30 MILES AT 60 MPH IN A 100 hp CAR

TIME ⇒ 30 MILES / 60 MPH = 0.5 HR = 1,800 s

\[ E = PT = (100 \text{ hp}) \times (1,800 \text{ s}) \]
\[ = (100 \text{ hp} \times 746 \text{ W/ hp}) \times (1,800 \text{ s}) \]
\[ = 1.34 \times 10^8 \text{ J} \times (0.949 \times 10^{-3} \text{ BTU/J}) = 1.27 \times 10^5 \text{ BTU} \quad \square \]

SCIENTIFIC NOTATION OK?
WATER FALLS AT SOME RATE

NOTATION: $\Delta \Rightarrow \text{CHANGE}$

SO $\frac{\Delta M}{\Delta T} = \text{HOW MUCH WATER/ HOW MUCH TIME}$

IN $\Delta T$ GENERATOR GETS $\Delta E = (\Delta M \cdot g \cdot H)$

SO POWER $P = \frac{\Delta E}{\Delta T} = g \cdot H \cdot \frac{\Delta M}{\Delta T}$
POWER UNITS

EXAMPLE: \( \text{mass/} \text{time} \times \text{energy/} \text{mass} \)

OR \( \Delta \text{mass/} \Delta \text{time} \times \Delta \text{mass} \text{ g/} \Delta \text{mass} \)

INSTEAD OF MASS SOMETHING ELSE FOR EXAMPLE CHARGE
ELECTRICAL POWER

CHARGE (ELECTRONS) MOVES THROUGH THE CIRCUIT, MAKING A CURRENT $I$ OF CHARGE PER UNIT TIME

\[ I = \frac{\text{charge}}{\text{time}} \]

BATTERIES PRODUCE A CONSTANT VOLTAGE $V$, WHICH IS ENERGY PER UNIT CHARGE

\[ P = \frac{\text{Energy}}{\text{charge}} \cdot \frac{\text{charge}}{\text{time}} = VI \]
MORE ELECTRIC POWER

VOLTAGE  \( V = \frac{\text{ENERGY}}{\text{CHARGE}} \)

1 VOLT = 1 J / COULOMB

COULOMB UNIT OF CHARGE (STUFF = CHARGE)

CURRENT  \( I = \frac{\text{CHARGE}}{s} \)

1 COULOMB / s = 1 AMP

STUFF PER SECOND GOING THROUGH:

POWER  \( P = \frac{\text{ENERGY}}{\text{STUFF}} \times \frac{\text{STUFF}}{\text{TIME}} \)

= ENERGY / CHARGE X CHARGE/TIME = V X I
EXAMPLE

HAIRDYER DRAWS 3 AMPS AT 120 V

THEN $P = 120 \text{ V} \times 3 \text{ A} = 360 \text{ W}$

ENERGY UNIT

$1 \text{ kWhr} = 1 \text{ kW} \times \text{ hr} = 1000 \text{ W} \times \text{ hr} = 1000 \text{ J} / \text{s} \times \text{ hr}$

$= 1000 \text{ J} / \text{s} \times 3600 \text{ s} = 3.6 \times 10^6 \text{ J}$

$= \text{POWER} \times \text{TIME} = \text{ENERGY}$

CHECK YOUR ELECTRICITY BILL

WORK SECOND PROBLEM (SEE TABLE)