Note. [Questions 2 & 3 to be marked in detail. Completion marks for rest (1

Assignment #3

1. Car consumes 70kWh of chemical energy for 100km trip.

Electric car consumes 20kwh of electricity for same trip.

Assume this energy comes from burning gasoline in a fossil fuel plant at $\eta = 45\%$

$$\eta = \frac{|W|}{|Q_H|} \therefore |Q_H| = \frac{|W|}{\eta} = \frac{20\text{kwh}}{0.45}$$

$$= 44.4 \text{ kwh}$$

Therefore we get the same 100km with only 44.4kwh of chemical energy

Gasoline consumption is reduced by a factor $\frac{44.4}{70}$

$= 0.63$!

2. (a) Heat delivered to BC houses =

$$\frac{(2\times10^9\, m^3)\times\left(39\frac{MJ}{m^3}\right)}{3.6\, MJ/kwh} = \underline{2.17\times10^{10}} \text{ kwh}$$

Multiply by 97% = total heat

$$= (2.17\times10^{10}\text{ kwh})(0.97)$$

$$= \underline{2.1\times10^{10}\text{ kwh}}$$

*

(b) Assume we deliver same heat using heat pump w/ COP = 3.5 :

heat pump : $\eta = \frac{|Q_H|}{|W|}$ $|W| = \frac{|Q_H|}{\eta} = \frac{2.1 \times 10^{10}\ \text{kwh}}{3.5}$

$\therefore$ electrical energy (work) is 6.0×10^{9} kwh

Assuming we generate this in a gas powered plant with $\eta = 45\%$: $\eta = \frac{|W|}{|Q_H|}$

$\therefore |Q_H| = \frac{|W|}{\eta} = \frac{6.0 \times 10^{9}\ \text{kwh}}{0.45} = \underline{\underline{1.33 \times 10^{10}\ \text{kwh}}}$

The total gas required to produce this heat is

$$\text{Gas} = \frac{1.33 \times 10^{10}\ \cancel{\text{kwh}}}{39\ \cancel{\text{MJ}}/\text{m}^3} \times \left(\frac{3.6\ \cancel{\text{MJ}}}{1\ \cancel{\text{kwh}}}\right) = \underline{\underline{1.23 \times 10^{9}\ \text{m}^3}}$$

This represents $\frac{1.23}{2.00} = 61.5\%$ of current consumption.

(3) We need to produce 43000 GWh of electricity from coal with $\eta = 40\%$

* Coal energy $= \left(27\ \frac{\text{MJ}}{\text{kg}}\right) \times \left(\frac{1\ \text{kwh}}{3.6\ \text{MJ}}\right) = 7.5 \left(\frac{\text{kwh}}{\text{kg}}\right)$

Since $\eta = \frac{|W|}{|Q_H|}$ we have

$$|Q_H| = \frac{|W|}{|\eta|} = \frac{43000\ \text{GWh}}{0.4} = \underline{\underline{107{,}500\ \text{GWh}}}$$

$$|Q_H| = 1.075 \times 10^5 \text{ GWh} = \underline{1.075 \times 10^{11} \text{ kWh}}$$

Total coal required is $\dfrac{(1.075 \times 10^{11} \text{ kWh})}{(7.5 \text{ kWh/kg})}$

$= 1.43 \times 10^{10}$ kg

$= 14.3$ million tons of coal

However 1 ton of coal produces more than 1 ton of CO_2:

$$C + O_2 \rightarrow CO_2$$

molecular weight of Carbon $= 12$
Oxygen $= 16 \times 2 = 32$ (O_2

Increase in mass is $\dfrac{12+32}{12}$ = factor of 3.67

$\therefore$ Total CO_2 emitted is $\simeq \underline{\underline{52.4 \times 10^6}}$ tons

ie ~ 11.7 tons per person per year!

(based on current pop. of ~ 4.45×10^6.

4-11. Temperature of Surrounding room if $COP = 0.98$ is 13% of COP_{max}

$$C.O.P._{max} = \frac{T_C}{\Delta T} = \frac{C.O.P}{0.13}$$

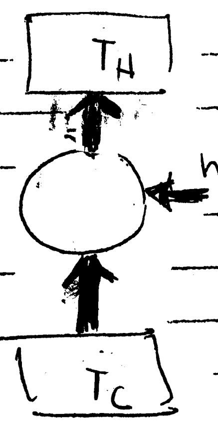
where $T_C = -12°C$.

$$\therefore \quad \Delta T = T_C \cdot \frac{0.13}{0.98} = (273-12)\frac{0.13}{0.98}$$

$$= 34.6$$

$$T_H = T_0 + 34.6 = 22.6°C.$$

4-14. heat pump $C.O.P. = \frac{|Q_H|}{|W|}$



where $|Q_C| + |W| = |Q_H|$

$$\therefore C.O.P. = \frac{Q_H}{Q_H - Q_C} = \frac{1}{1 - Q_H/Q_C}$$

Now use 2nd Law

$\Delta S \geq 0$ where $\Delta S_0 = -\frac{|Q|_C}{T_C}$ heat removed

$\Delta S_1 = +\frac{|Q_H|}{T_H}$ heat added

$$\Delta S = \Delta S_1 + \Delta S_2$$

$$\therefore \quad \frac{|Q_H|}{T_H} - \frac{|Q_C|}{T_C} \geq 0 \qquad \therefore \quad \frac{T_C}{T_H} \geq \frac{|Q_C|}{|Q_H|}$$

and $C.O.P. \leq \frac{1}{1 - T_0/T_1}$.

Question 16 from text

Assume both light bulbs burn for 5 hrs / day

Find total cost vs time for each, including initial purchase cost.

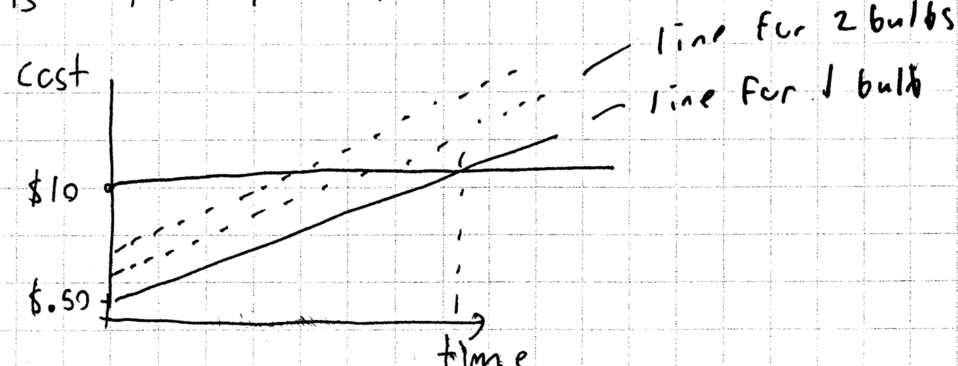
60w bulb $\quad Cost_{60} = \$0.5 + (.06kw)(5h) \times \frac{\$.10}{kwh} \times t \quad (days)$

① $\therefore cost_{60} = \$0.5 + \$0.03t$

15w bulb $\quad Cost_{15} = \$10.00 + (.015kw)(5h) \times \frac{\$.10}{kwh} \times t \quad (days)$

② $\therefore cost_{15} = \$10 + \$0.0075t$

Graphically:
(not necessary to show this)



Find intersection point when $cost_{60} = cost_{15}$

ie. $\quad 0.5 + .03t = 10 + .0075t \quad$ (neglecting units for clarity)

$\therefore \quad .0225t = 9.5$

$\therefore t = \frac{9.5}{.0225} = \underline{422 \text{ days}} \Rightarrow \underline{14 \text{ months}}$

Note that this is an overestimate because the life time of the incandescent bulb is only 1000hrs but we have total time of 2110 hrs. This has the effect of reducing t somewhat

Question 16 continued.

(not required for full mark)

To get the correct answer we must calculate assuming the second curve

Assume we replace the incandescent bulb after 1000hrs

the new equation for the incandescent bulb (after 1000h) is

$$Cost_{60} = \$1.00 + \$.03\,t$$

set equal to $cost_{15}$:

$$\therefore \$1.00 + .03t = \$10 + .0075t$$

$$\therefore \$.0225t = \$9$$

$$t = 400 \text{ days} = 2000 \text{ hrs}$$

$$\cong \underline{13 \text{ months}}$$