Energy & the Environment

Hwk #3

Ch 7. 34, 36, 40
8. 31, 34, 39
9. 31, 34, 36, 40

(34) Given ice on a hot plate
water in a beaker

0.5 kg water
1.000 kg ice

- temp of ice water = 32°F, 0°C

Reason : Only @ this temp can you simultaneously have ice & water

- time to raise temp to 20°C w/ 1200 watt hot plate

500 g w, 1000 g ice → 1500 g water @ 20°C

Amt of heat to add = Amt to melt ① ice + Amt to heat water ②

① $H_{melt} = (1000\,g)(333\ J/g)$

$= 3.33\times10^5\ J$

② $H_{0-20^\circ C} = (20^\circ C)(4.186\ \frac{J}{g^\circ C})(1500\ g)$
$= 1.26\times10^5\ J$

Total Heat to Add $= 4.59\times10^5\ J$

②

$$\text{Time} = \frac{\text{Amt Heat}}{\text{Power}} = \frac{4.59 \times 10^5\,\text{J}}{1200\ \text{J/s}} = 382\ \text{seconds}$$

$$\boxed{\text{Time to heat to } 20^\circ\text{C} = 382\ \text{seconds}}$$

(36)

input 3500 J → 2500 J work

→ 1000 J waste heat

$\boxed{\text{– does 2500 J work}}$

$$- E = \frac{\text{work done}}{\text{energy input}} = \frac{2500}{3500} = \boxed{71\% = E}$$

use Carnot eqn

$$71\% = \frac{T_B - T_A}{T_B} \qquad T_A = \cancel{27^\circ C}\ 300\,^\circ K$$

$$.714\,T_B = T_B$$

$$300 = .286\,T_B$$

$$\boxed{T_A = \text{high temp reservoir} = 776^\circ C}$$

↑ seems high

If assume

↳ input 2500 J → work 1500 J

→ 1000 J waste

$\boxed{\text{– does 1500 J}}$

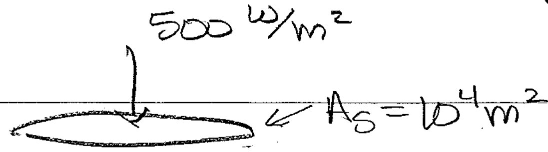
$$\boxed{E = 1500/2500 = 60\%}$$

$$0.60\,T_B = T_B - 300\,^\circ K$$

$$\boxed{T_A = 477^\circ C}$$

↑ more realistic

7.40



Max theoretical power = Power input * Area

$= (500\ W/m^2)(10^4\ m^2)$

$\boxed{\text{max power} = 5\times10^6\ W = 5{,}000\ kW}$

$E = \frac{T_B - T_A}{T_B} = \cancel{\frac{30-15}{30} = 0.5}$

use °K, not °C

Actual power

$\boxed{E = \frac{303-288}{303} = 4.95\times10^{-2}}$

$\text{Power} = (5{,}000\ kW)(4.95\times10^{-2})$

$\boxed{\text{Power} = 248\ kW}$

8.31 Given Generation cost = \$.04/KWH

Transport = \$.0002/KWH/km

local trans = \$.0016/KWH/km

Total Cost = .04 + .0002(250) + .0016(25)

= .04 + .05 + .04

$\boxed{\text{Total cost} = 0.13\ \$/KWH}$

b) 4/13 = 31% Gen

5/13 = 38% L.D. Trans

4/13 = 31% Local trans.

8.31 cont'd

c) If it costs \$.13/KWh & sold for \$.06 or \$0.10 it will lose money could make money @ \$0.10 if substation were closer

$$\text{min cost} = .04 + .0002\left(\begin{array}{c}250\\+\\25\end{array}\right) = \$0.095/\text{kWh}$$

8.34 $\#\text{Hrs/year} = 365(24) = 8{,}760 \ \text{hrs/yr}$

Nuclear = 95% online , 1000 MW
Oil = 85% online = (1-.15) , 940 MW
Gas turbine = 15% online , 200 MW

(use fig. 8.15)

- Calculate hrs of operation

$$N = .95(8760) = 8320 \text{ h}$$
$$O = .85(8760) = 7{,}450 \text{ h}$$
$$G = .15(8760) = 1{,}310 \text{ h}$$

- get annual cost/KW from 8.15

$$N = 450 \ \$/\text{KW}$$
$$O = 350 \ \$/\text{KW}$$
$$G = 100 \ \$/\text{KW}$$

- Calculate total cost

$$N_{cost} + O_{cost} + G_{cost}$$

$$(10^6 \text{ KW})(450 \ \$/\text{KW}) + (9.4\times10^5 \text{ KW})(350 \ \$/\text{KW}) + (100 \ \$/\text{KW})(2\times10^5 \text{ KW}) = 8.00\times10^8 \ \$$$

$$\text{Total Cost} = 4.5\times10^8\ N + 3.3\times10^8\ O + 0.2\times10^8\ G$$

$$\boxed{\text{Total Cost} = 8.0\times10^8\ \$/\text{yr}}$$

- total power produced (KWH)

$$= N + O + G$$

$$= (10^6\ \text{kW})(8{,}320\ \text{h}) = 8.32\times10^9\ \text{kWH}$$

$$(9.4\times10^5\ \text{kW})(7{,}450\ \text{h}) = 7.0\times10^9\ \text{KWH}$$

$$(2\times10^5\ \text{kW})(1310\ \text{h}) = 2.6\times10^8\ \text{KWH}$$

$$1.56\times10^{10}\ \text{kWh}$$

$$\text{Unit Cost} = \frac{8\times10^8\ \$/\text{yr}}{1.56\times10^{10}\ \frac{\text{kWh}}{\text{yr}}} = 0.051\ \$/\text{kWh}$$

Needs to charge at least ~~$~~ 0.051 $/kWh.
Will need to transmission & administrative cost

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⑧.39 Assume slope of line is due to fuel costs.
Adjust slope of line by factor

$11/4 = 2.75$

Check slope, @ 6000 hrs

$\text{Cost} = 340\ \$/\text{kW}$

@ 0 hrs

$\text{Cost} = 20\ \$/\text{KW}$

$= 320\ \$/6000\ \text{kWh} = .053\ \$/\text{kWh}$

8.39 cont'd

Calculate oil cost @ \$0.11/kwh

@ 3000 hrs

$$\text{Gas Cost} = \overset{\text{fixed}}{\left(20\,\tfrac{\$}{\text{kw}}\right)} + \overset{\text{variable}}{(3000)\left(0.11\,\tfrac{\$}{\text{kwh}}\right)}$$

$$\boxed{\text{Gas cost @ 3000 hrs} = 350\,\$/\text{kw}}$$

Redrawing gas line on plot gives an intersection @ roughly 2000 hrs

$= 22.8\%$ operation

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9.31

20-year life time

$$\text{Cost} = \text{Bulb Cost} + \text{Energy Cost}$$

Tungsten

$$= (20\text{ yrs})\left(\frac{1\text{ bulb}}{\text{year}}\right)\left(0.50\,\$/\text{bulb}\right) + (20\text{ yr})(2000\text{ hr/yr})(.075\text{ kw})(0.10\,\$/\text{kwh})$$

$$\boxed{\text{Tung} = \$10.00 + \$300.00 = \$310.00}$$

CFL

$$= (20\text{yr})\left(\frac{1\text{ bulb}}{10\text{ year}}\right)(\$10/\text{bulb}) + (20)(2000)(.010\text{ kw})(0.10\,\$/\text{kwh})$$

$$\boxed{\text{CFL} = \$20 + \$40 = 60\,\$}$$

\$250 savings over 20 years

9.34

**Assumptions**

Runs 25% time during
Jun, Jul, Aug, Sept.

Run time $= (120\,\text{days})\left(\frac{6\,\text{hrs}}{\text{day}}\right) = 720\,\frac{\text{hrs}}{\text{yr}}$

Assume AC sizing $= \frac{8000\,\text{BTU/h}}{330\,\text{ft}^2} = 24\,\frac{\text{BTU/h}}{\text{ft}^2}$

Assume house size $= 2000\,\text{ft}^2$

AC size $= \left(24\,\frac{\text{BTU}}{\text{ft}^2}\right)(2000) = 48{,}500\,\text{BTU/h}$

50,000
1000 hrs

$\boxed{\text{Say } 50{,}000\ \text{BTU/h}}$

$5.2\times10^{7}\,\frac{\text{BTU}}{\text{yr}}$

$3.6\times10^{7}$

Avg. Eff. Cost for 14 years

Energy Cost $= (14\,\text{years})\left(50{,}000\,\frac{\text{BTU}}{\text{h}}\right)\left(720\,\frac{\text{hrs}}{\text{yr}}\right) *$
$\left(\frac{1\,\text{kW}}{1000\,\text{W}}\right)\left(\frac{1}{8.7}\,\frac{\text{Wh}}{\text{BTU}}\right)(0.10\,\$/\text{kWh})$

Avg.

Total $= \$\,5{,}790\ \$/14\ \text{years}$

Yearly $= \$\,414/\text{year}$

High Eff $= (14\,\text{years})\left(50{,}000\,\frac{\text{BTU}}{\text{h}}\right)\left(720\,\frac{\text{hrs}}{\text{yr}}\right) *$
$\left(\frac{1}{1000}\right)\left(\frac{1}{16.4}\right)(0.10) = \$3{,}070$

High

Total Cost $= \$3{,}070$ | Yearly Cost $= \$\,\frac{220}{\text{year}}$

1st law efficiency for

$$\frac{16.4\ \text{BTU}}{\text{Wh}} = \frac{16.4\ \text{BTU}}{\text{Wh}}$$

work

$$= \frac{16.4\ \text{BTU}}{3600\ \text{J}}$$

1 BTU = 1055 J

$$E = 4.56\times10^{-3}\ \frac{\text{BTU}}{\text{J}}$$

$$1\ \text{BTU} = 1055\ \text{J} = \frac{1055}{3600} = 0.293\ \text{Wh}$$

@ 100% efficiency

$$\frac{1\ \text{BTU}}{0.293\ \text{Wh}} = \frac{3.41\ \text{BTU}}{\text{Wh}}$$

Check $1\ \text{Wh} = 3600\ \text{J}$

$$= \frac{3600\ \text{J}}{1055\ \text{J/BTU}} = 3.41\ ✓$$

$$E\quad \text{1st law efficiency} = \frac{16.4}{3.41} = 481\%\ !!$$

E&E ②
Hwk #3

9.36

@ year 0, spend \$500 to get fridge that uses 440 $\frac{kwh}{yr}$ rather than 1140 kwh/yr

Energy savings = $\left(1140-440\ \frac{kwh}{yr}\right)\left(0.10\ \frac{\$}{kwh}\right)$

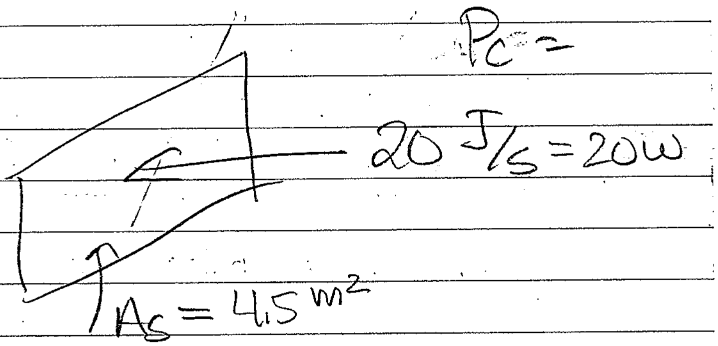
$\boxed{\text{Assume } \$0.10/kwh}$

= \$70.00

time for payback = $\frac{\$500}{70} = 7.1$ yrs

takes 7.1 years to save the \$500 purchase price

9.40



$R = 2.5\ \frac{m^2 °C}{W} = 2.5\ \frac{m^2 °C}{J/s} = 2.5\ \frac{m^2 °C\, s}{J}$

$\left(\frac{J}{s}\right)$ ~~Heat Flow~~ $\rightarrow P_C$ = $\frac{\Delta T A_s}{R}$ $\frac{(\cancel{°C})(\cancel{m^2})}{\frac{\cancel{m^2 °C}}{\boxed{J/s}}}$

$\left(\frac{P_C R}{A_s}\right) = \Delta T$

$$\Delta T = \frac{P_C R}{A_S} = \frac{\left(20 \frac{J}{s}\right)\left(2.5 \frac{m^2 \, ^\circ C}{J/s}\right)}{4.5}$$

$$\boxed{\Delta T = 11.1 \, ^\circ C}$$