Chapter 1

1-1

$$1\ yr = 365 \frac{days}{yr} \times 24 \frac{hrs}{day} = 8760\ hrs$$

Average Wasted Power $P_{avg} = \frac{122 \times 10^9\ kWh/yr}{8760\ hr/yr} = 13.92 \times 10^3\ MW$

(a)

$\therefore \sim 13$ 1,100-MW generating plants running continuously provide this power.

(b) Annual Savings $= 0.12 \frac{\$}{kWh} \times 122 \times 10^9 \frac{kWh}{yr}$

$= 14.64$ Billion $\$/yr$

1-2

For the ease of solving this problem, let us assume that the system operates for 100 hrs and draws 1 kW while delivering 100% flow rate.

The percentage reduction in the power consumption is the same as the percentage reduction in the energy consumption.

The following Table shows the energy consumption using each of the three methods:

hrs of Operation	Drive	Outlet	Inlet
20 hrs @ 100%	1×20 kWh	1×20 kWh	1×20 kWh
20 hrs @ 80%	0.5×20	0.92×20	0.81×20
30 hrs @ 60%	0.3×30	0.87×30	0.7×30
10 hrs @ 30%	0.1×10	0.72×10	0.65×10
Total Energy Consumption	$E_{Drive} = 40$ kWh	$E_{outlet} = 71.7$ kWh	$E_{inlet} = 63.7$ kWh

Using an adjustable speed drive,

(a) % reduction over outlet damper $= \dfrac{E_{outlet} - E_{Drive}}{E_{outlet}}$

$$= \frac{71.7 - 40}{71.7} \times 100 \simeq 44\%$$

(b) % reduction over inlet vanes $= \dfrac{E_{inlet} - E_{Drive}}{E_{inlet}}$

$$= \frac{63.7 - 40}{63.7} \times 100 \simeq 37\%$$

Problem 1-3

$$P_o = \frac{\eta}{1-\eta} P_{loss} \qquad (1-2)$$

@ $\eta = 87\% = 0.87$

$$P_{o,1} = \frac{0.87}{1-0.87} P_{loss} = 6.69\, P_{loss}$$

@ $\eta = 95\% = 0.95$

$$P_{o,2} = \frac{0.95}{1-0.95} P_{loss} = 19.0\, P_{loss}$$

∴ The power densities (PD) are related ~~to~~ the output power

$$\frac{PD_2}{PD_1} = \frac{19.0}{6.69} = 2.84$$

∴ The improvement in power density is

$$\frac{PD_2 - PD_1}{PD_1} = \frac{PD_2}{PD_1} - 1 = 1.84$$

or the power density is 184%

Problem 1-4

Energy saved per year $= 3.8 \times 10^9 \times 0.16 \times 0.3$

$\doteq 182.4 \times 10^6$ MW-hrs

1 year $= 365 \times 24 = 8760$ hrs

$\therefore$ Power need to supply wasted energy

$$P = \frac{182.4 \times 10^6}{8760} \text{ MW}$$

$$= 20822 \text{ MW}$$

$\therefore$ Approximately 19 generating plants each with an output of 1,100 MW are needed to supply this wasted energy.

Problem 1-5

$$E_{wind} = 10.8 \times 10^9 \ \frac{MW\text{-}hrs}{year}$$

Number of Windmills $0.1 \ \dfrac{\times E_{WIND} / (\text{no. of hrs per year})}{P_{Wind\,mill} \times \text{Capacity factor}}$

$$= \frac{0.1 \times 10.8 \times 10^9 / 8760}{1.5 \times 0.3}$$

$$\simeq 2.74 \times 10^5$$

$= 274$ thousand

Problem 1-6

Power rating of power electronics $= 1{,}500\,kW/\text{windmill}$

from problem 1-5, no. of windmills $= 2.74 \times 10^5$

$\therefore$ Total rating of power electronics interface $= 1{,}500 \times 2.74 \times 10^5 \ kW$

$= 411 \ GW$

Problem 1-7

$E_{\text{Conventional}} = 3.8 \times 10^9 \times 0.19$ MW-hrs/year

$E_{CFL} = 0.25\, E_{\text{Conventional}}$

Savings in annual energy $= E_{\text{Conventional}} - E_{CFL}$

$= 0.75\, E_{\text{Conventional}}$

$= 0.75 \times 3.8 \times 10^9 \times 0.19$

$= 0.54 \times 10^9 \; \frac{\text{MW-hrs}}{\text{Year}}$

Problem 1-8

Gallons per car per year $= \frac{11,766}{22.1} = 532.4$

Gallons per hybrid per year $= \frac{11,766}{52} = 226.27$

$\therefore$ Savings per vehicle per year $= 532.4 - 226.27$

$\simeq 306$ gallons of gasoline

1 barrel of oil = 20 gallons of gasoline

$\therefore$ savings per vehicle per year $= \frac{306}{20}$

$\simeq 15.3$ barrels of oil

Problem 1-9

$$\text{Savings per year} = 150 \times 10^6 \times 306$$
$$= 45.9 \times 10^9 \text{ gallons}$$
(using Prob 1-8)
$$= 5 \times 45.9 \times 10^9 \text{ lbs of carbon}$$
$$= 229 \times 10^9 \text{ lbs of carbon}$$

Problem 1-10

$$\text{Savings of barrels of oil} = 15.3 \times 150 \times 10^6$$
$$= 2295 \times 10^6 / \text{year}$$

Problem 1-11

$$E_{\text{Fuel Cells}} = 5 \text{ kW} \times 25 \times 10^6 \times \underset{\text{hrs/year}}{8760} \; \frac{\text{kW-hrs}}{\text{year}}$$
$$\simeq 10^9 \; \frac{\text{MW-hrs}}{\text{Year}}$$

Problem 1-12

Energy needed to cook $= 0.55 \times 2$ kW-hrs

$\therefore$ Energy needed by Induction cookers

$$= \frac{0.55 \times 2}{0.8} \text{ kW-hrs}$$

$$= 1.375 \text{ kW-hrs}$$

$\therefore$ Energy saved $= (2 - 1.375) \times 20 \times 10^6$ kW-hrs

$$= 12.5 \times 10^6 \text{ kW-hrs}$$

$$= 12.5 \times 10^3 \text{ MW-hrs}$$

Problem 1-13

$$P_{PV} = 800 \times 0.1 = 80 \text{ W/m}^2$$

$$\therefore \text{Area} = \frac{1000 \times 10^6}{80} \text{ m}^2$$

$$= 12.5 \times 10^6 \text{ m}^2$$

$$= 3535 \times 3535 \text{ m}^2$$

Problem 1-14

From Problem 1-13, Area $= 12.5 \times 10^6 \ m^2$

$$\therefore \text{ no. of homes} = \frac{12.5 \times 10^6}{40}$$

$$= 312.5 \text{ thousand}$$

Problem 1-23

$V_{in} = 12\,V, \quad V_o = 9\,V, \quad f_s = 400 \text{ kHz}$

Using Eqs. 1-3 & 1-4

$$d_A = \frac{V_o}{V_{in}} = \frac{9}{12} = 0.75$$

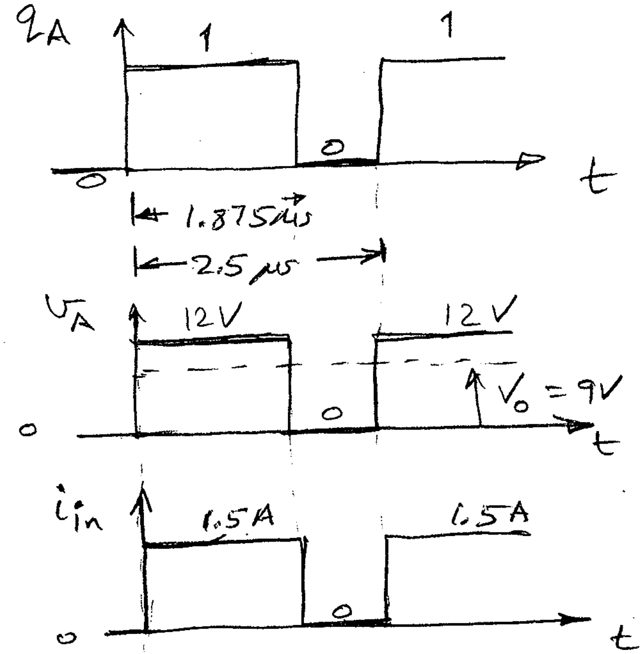
and,

$$T_{up} = d_A T_s = d_A \left(\frac{1}{f_s}\right)$$

$$= 1.875 \mu s$$

Problem 1-24

From problem 1-15, $T_S = 2.5\mu s$, $T_{up} = 1.875\mu s$



Problem 1-25

$V_{in} = 12V$, $V_o = 9V$, I_o = not given

$\therefore$ Voltage dropped across the linear regulator $V_{reg} = 12 - 9 = 3V$

$$\therefore \eta_{max} = \frac{9V \times I_o}{12V \times I_o} = \frac{9}{12} = 75\%$$

1-26 Modify Lab Experiment-4 of PSpice at www.cusp.umn.edu under Power Electronics Course

1-27 Same as Prob 1-26 except modify Lab Experiment-1.

Chapter 2

Problem 2-1

Similar to figs. 2-5 & 2-7.

Problem 2-2

$$P_{sw} = \frac{1}{2} V_{in} I_o (t_{c,on} + t_{c,off}) f_s$$

$$t_{c,on} = t_{ri} + t_{fv}$$

$$t_{c,off} = t_{rv} + t_{fi}$$

$$\therefore \quad t_{c,on} + t_{c,off} = (20 + 15 + 20 + 15)\,\text{ns} = 70\,\text{ns}$$

$$P_{sw} = \frac{1}{2} \times 42 \times 5 \times 70 \times 10^{-9} \times 400 \times 10^{-3}\ \text{W}$$

$$= 2.94\ \text{W}$$

$$P_{in} = V_{in} I_{in}, \quad I_{in} = D\, I_o = 0.3 \times 5 = 1.5\ \text{A}$$

$$\therefore \quad P_{in} = 42 \times 1.5 = 63\ \text{W}$$

$$\therefore \quad \eta_{\text{due to } P_{sw}} = \frac{P_{in} - P_{sw}}{P_{in}} = \frac{63 - 2.94}{63} = 95.33\%$$

$\therefore$ 4.67% reduction in efficiency due to switching losses.