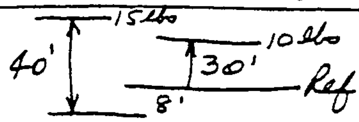
CHAPTER 2

2.1 $2\,kg \times 9.81\,\frac{N}{kg} \times 6\,m = 117.72\,N \cdot m = 117.72\,J$

2.2



For 10 lbm; $PE = 10\,lb_f \times 30\,ft = 300\,ft\,lb_f$
For 15 lbm; $PE = 15 \times 40 = 600\,lb_f\,ft$
For second reference plane
10 lbm; $10\,lb_f \times 38\,ft = 380\,ft \cdot lb_f$
15 lbm; $15\,lb_f \times 40\,ft = 600\,ft\,lb_f$

2.3 The force $= 10\,g/g_c = \frac{10 \times 16.1}{32.2} = 5.0\,lb_f$

Work $= 5\,lb_f \times 10\,ft = 50\,ft\,lb_f$

2.4 Work = Force × distance $= 9.81 \times 3 \times 10 = 294.3\,N \cdot m = 294.3\,J$

2.5 $\frac{mV^2}{2g} = \frac{3 \times (30)^2}{2 \times 32.17} = 41.96\,ft\,lb_f$

$41.96\,ft\,lb_f = 8\,lb_f \times s$

$s = 5.25\,ft$

2.6 $K.E = \frac{mV^2}{2} = \frac{5\,kg \times (10\,m/s)^2}{2} = 250\,J$

2.7 $P.E. = K.E.;\ 5 \times 9.81 \times h = 250$

$h = 5.097\,m$

2.8 $K.E. = \frac{WV^2}{2g_c} = \frac{25 \times 10^2}{2 \times 32.17} = 38.86\,ft\,lb_f$

2.9 Since $P.E. = K.E.$

$25\,h = 38.86\,ft\,lb_f$

$h = 1.55\,ft$

2.10 $P.E = 500\,kg \times 9.81\,\frac{N}{kg} \times 2\,m = 9810\,J$

$\frac{mV^2}{2} = 9810\,J;\ V = \sqrt{\frac{2 \times 9810}{500}} = 6.26\,m/s$

2.11 $KE = \frac{1}{2} mV^2 = \frac{1}{2}(1\,kg)(100\,\frac{m}{s})^2 = 5000\,N \cdot m = 5000\,J$

2.12 Work = P.E. $10 \times 100 = 1000\,ft\,lb_f$

$\therefore$ from rest, $\frac{wV^2}{2g_c} = 1000$

$V = \sqrt{2 \times 32.17 \times \frac{1000}{10}} = 80.2\,ft/s$

2.13 $K.E. = P.E.$

$\frac{wV^2}{2g_c} = wZ;\ Z = \frac{(50)^2}{2 \times 32.17} = 38.86\,ft$

$\therefore K.E. = 10 \times 38.86 = 388.6\,ft \cdot lb_f$

2.14 Work $= 3\,m \times 100\,N = 300\,J$

$\frac{mV^2}{2} = 300;\ V = \sqrt{\frac{300 \times 2 \times 9.81}{100}} = 7.67\,m/s$

2.15 $P.E/lb = 600\,g/g_c = 600\,ft\,lb_f/lb_m$

$PE = KE = \frac{mV^2}{2g_c} = 600(1)$

$V = \sqrt{2 \times 32.17 \times 600} = 196.5\,ft/s$

1.118 Absolute pressure $= 101\ kPa + \gamma h$

(a) $p_{abs} = 101 + 1.03 \times 9.806 \times 8{,}000$

$= 80{,}902\ kPa$

(b) Area $= \dfrac{\pi D^2}{4} = \dfrac{\pi (0.25)^2}{4} = 0.049\ m^2$

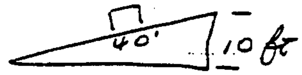
Force $= pA = 80{,}902 \times 0.049 = 3964\ kN$

1.119 Weight $= \gamma$ Volume

$\gamma = \dfrac{5.32}{32.2} \times 9.806 \times 0.7 = 1.134\ kN/m^3$

$W = 1.134 \times 2 = 2.268\ kN$ or $2268\ N$

2.16



$P.E. = 10 \times 25 = 250$ lbf ft

b) $P.E. = 250$ lbf ft

The increase in kinetic energy (assuming the body starts from rest)

c) $\frac{mV^2}{2g_c} = \frac{25 \times 10^2}{2 \times 32.17} = 38.86$ ft lbf

a) Total work = P.E + KE

$= 250 + 38.86 = 288.86$ ft lbf

2.17 50 kN, 25 m/s

$K.E = \frac{1}{2} mV^2$

$\frac{50{,}000 N}{9.81 \frac{N}{kg}} \times \frac{(25)^2}{2} = 1593$ kJ

2.18 $KE = \frac{mV^2}{2}$; $1 kJ = \frac{m(2)^2}{2}$; $m = \frac{1}{2}$

@ $4 \frac{m}{s}$, $KE = \left(\frac{4}{2}\right)^2 \times 1 = 4$ kJ

@ 6 m/s $KE = \left(\frac{6}{2}\right)^2 \times 1 = 9$ kJ

2.19 $k = \frac{100 \text{ lbf}}{5 \text{ in}} = 20 \frac{\text{lbf}}{\text{in}}$; $W = \frac{1}{2} k x^2 = \frac{1}{2}(20)(5)^2 = 250$ in lbf

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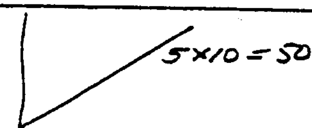
2.20 $\frac{500 N}{0.25 m} = 2000 N/m$; $W = \frac{1}{2} kx^2 = \frac{1}{2}\left(2000 \frac{N}{m}\right)(0.25 m)^2 = 62.5 J$

2.21 $\frac{1}{2} kx^2 = 2000 J = \frac{1}{2} k (0.35)^2 = 0.06125 k$

$k = \frac{2000}{0.06125} = 32.65 \frac{kN}{m}$

2.22



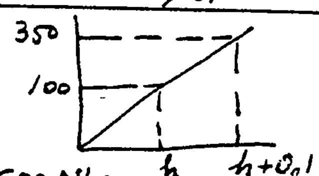
Area $= \frac{1}{2}(50)5 = 125$ in lbf $= 10.4$ ft lbf

2.23 $k = 100 \frac{N}{m} = \frac{F}{\delta}$; $\delta = 0.1 m$

$F = 0.1 \times 100 = 10 N$

$m = \frac{10}{9.81} = 1.02 kg$

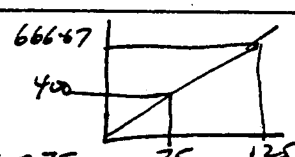
2.24 Refer to figure



$k = \text{slope} = \frac{y_2 - y_1}{x_2 - x_1}$

$k = \frac{350 - 100}{(h + 0.1) - h} = 2500 N/m$

2.25



$k = \frac{400}{.075} = 5333.3 N/m$

work $= \frac{1}{2} k\delta^2$

$\Delta W = W_2 - W_1 = \frac{1}{2}(5333.3)(0.125^2 - .075^2)$

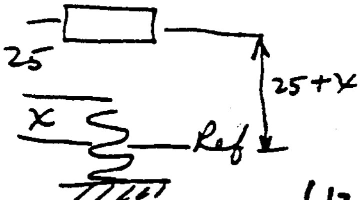
$\Delta W = 26.67 N \cdot m$

As a check

ΔWork = ΔArea

$= \frac{666.67 \times .125}{2} - \frac{400 \times .075}{2} = 26.67 N \cdot m$

2.26



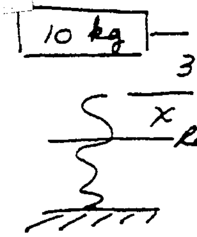
P.E. = Work done - note Reference is when body stops.

$5(25 + x) = \frac{1}{2}(25) x^2$

Solving $x = 3.37$ ft

$\left\{ \begin{array}{l} 12.5x^2 - 5x - 125 = 0 \\ x = \frac{5 \pm \sqrt{25 + 6250}}{25} \end{array} \right\}$

See also 2.26



$10 \times 9.81(3+x) = \frac{1}{2}\,1000\,x^2$

$x^2 - 0.196x - 0.588 = 0$

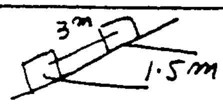
$x = 0.872\,m$

Note: Body comes to rest @ $(3+x)$

2.28 $W = (F\cos\theta)5 = (1000 \times \cos 30)5$

$W = 4330\,N \cdot m$

2.29



This is the same as lifting the block 1.5 m

$\therefore 45 \times 9.81 \times 1.5 = 662.2\,N \cdot m$

2.30 $W = \Delta K.E = \frac{1}{2} m (V_2^2 - V_1^2)$

$= \frac{1}{2}(1000)\left[\left(\frac{90 \times 1000}{3600}\right)^2 - \left(\frac{45 \times 1000}{3600}\right)^2\right]$

$= 234.38\,kJ$

2.31 $W = F \times 190 = \frac{wV^2}{2g}$

$F \times 190 = \frac{3000\left(\frac{30 \times 5280}{3600}\right)^2}{2 \times 32.17}$

$F = 475.1\,lb$

2.32 $K.E \propto V^2$; But $V \propto \frac{1}{A} \propto \frac{1}{D^2}$

$\therefore K.E \propto \left(\frac{1}{D^2}\right)^2 = \frac{1}{D^4}$

2.33 600 ft high - 600 ft lbf/lbm

$600\,ft\,lbf/lbm \times \frac{50 \times 10^6\,lbm/hr}{60\,min/hr} = \frac{ft\,lbf}{min} = 500 \times 10^6$

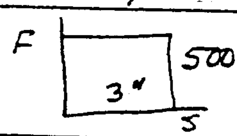
$1\,hp = 33{,}000\,ft\,lbf/min$

$\therefore \frac{500 \times 10^6}{33000} = 15{,}151.5\,hp$

$15{,}151.8 \times 0.746 = 11303\,kW$

2.34 $200\,m \times \frac{9.81}{1000} \times \frac{25 \times 10^6}{3600} = 13625\,kW$

X 2.35



$F = 100\,\frac{lbf}{in^2} \times 5\,in^2 = 500\,lbf$

Work $= F \times d = 500\,lbf \times 3\,in = 1500\,in\,lbf$

2.36 Refer to Problem 2.35 $F = PA = 500000\,\frac{N}{m^2} \times 10^{-3}\,m^2$

$W = 500\,N \times 0.1\,m = 50\,N \cdot m = 50\,J$ $F = 500\,N$

2.37 Work = Const $\ln \frac{v_2}{v_1}$

at p_1, $v_1 = 1$, $p_1 = 100$

at p_2 $v_2 = 2$ $p_2 = 50$

Work $= 100 \ln 2 = 69.3\,ft\,lbf$

2.38 @ 1000 kPa, $v = 1$ $pv = 1000$

@ 500 kPa, $v = 2$ $W = 1000 \ln \frac{2}{1} = 693.1\,kJ/kg$

2.27 $10 \times 9.81(3+x) = \frac{1}{2}(1000)x^2$

Solving quadratic: $x = 0.872$ m

2.28 $W = (F\cos\theta)5 = (1000 \times \cos 30^\circ)5 = 4330$ N·m

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2.29 Same as lifting block 1.5 m:

$45 \times 9.81 \times 1.5 = 662.2$ N·m

2.30 $W = \Delta KE = \frac{1}{2}m(V_2^2 - V_1^2) = \frac{1000}{2}\left[\left(\frac{90 \times 1000}{3600}\right)^2 - \left(\frac{45 \times 1000}{3600}\right)^2\right]$

$= 234.38$ kJ

2.31 $W = F \times 190 = wV^2/2g = \dfrac{3000\left(\frac{30 \times 5280}{3600}\right)^2}{2 \times 32.17}$

$F = 475.1$ lb.

2.32 $KE \propto V^2$ but $V \propto \frac{1}{A} \propto \frac{1}{D^2}$ $\therefore KE \propto \frac{1}{D^4}$

2.33 600 ft high – 600 ft-lbf/lbm

$\dfrac{600 \times 50 \times 10^6 \text{ lbm/hr}}{60 \text{ min/hr}} = 500 \times 10^6$

1 hp = 33,000 ft-lb/min $\therefore \dfrac{500 \times 10^6}{33{,}000} = 15.151.5$ hp or 11303 kW

2.34 $200\text{m} \times \dfrac{9.81}{1000} \times \dfrac{25 \times 10^6}{3600} = 13625$ kW

2.35 $KE = \frac{1}{2}mV^2 = \frac{1}{2} \times \dfrac{800}{9.806} \times \left(\dfrac{40{,}000}{3600}\right)^2 = 5{,}036$ J

To stop, Work $= F \times d = 5{,}036 = 200d$

$d = 25.18$ m

2.36 $F = pA = 500{,}000 \text{ N/m}^2 \times 10^{-3} \text{ m}^2$

$W = F \times d = 500 \text{ N} \times 0.1 \text{ m} = 50 \text{ Nm} = 50$ J

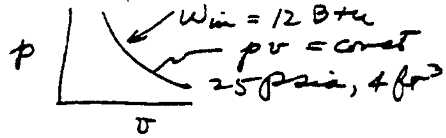
2.37 $W = (\text{Constant}) \ln\left(\frac{v_2}{v_1}\right)$ at p_1, $v_1 = 1$, $p_1 = 100$

at p_2, $v_2 = 2$, $p_2 = 50$ Work = 100 ln 2 = 69.3 ft-lbs

2.38 @ 1000 kPa, $v = 1$ $pv = 1000$

@ 500 kPa, $v = 2$ Work = 1000 ln 2 = 693.1 kJ/kg

2.39



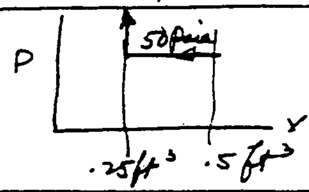
$$W = p_1 V_1 \ln \frac{p_1}{p_2}$$

$$-12 \text{ Btu} \times 778 \frac{\text{ft lb}}{\text{Btu}} = 25 \text{ psi} \times 144 \frac{\text{in}^2}{\text{ft}^2} \times 4 \text{ ft}^3 \ln \frac{p_1}{p_2}$$

$$\ln \frac{p_1}{p_2} = -0.6483$$

$$p_1/p_2 = 0.5229; \; p_2 = 47.8 \text{ psia}$$

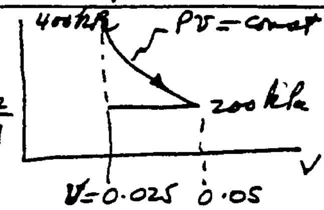
2.40



$$\text{Work} = p\Delta V = 50 \times 144 (.25 - 0.50)$$

$$\text{Work} = -1800 \text{ ft lbf (in)}$$

2.41



$$p_1 v_1 = p_2 v_2$$

$$400(0.025) = 200 \, V_2$$

$$V_2 = 0.05 \text{ m}^3$$

$$W_1 = p_1 v_1 \ln \frac{V_1}{V_2} = 400 \times .025 \ln \frac{2}{1}$$

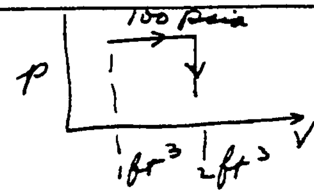
$$W_1 = 6.93 \text{ kJ}$$

$$W_2 = p(V_2 - V_1) = 200(.025 - .050)$$

$$W_2 = -5.00 \text{ kJ}$$

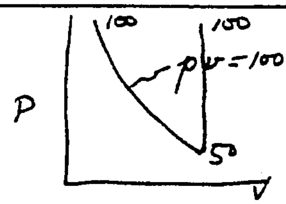
$$\text{Net work} = 6.93 - 5.00 = 1.93 \text{ kJ}$$

2.42



$$W = 100 \times 144 (2-1) = 14\,400 \text{ ft lbf}$$

2.43



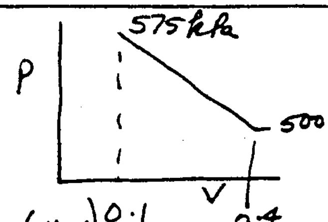
Work = area under P-v curve

Work of constant volume = 0

$$\int P dv = 100 \ln \frac{v_2}{v_1} = 100 \ln \frac{P_1}{P_2}$$

$$\therefore W = 100 \ln 2 = 69.3 \text{ ft lbf}$$

2.44



$$p = -250V + 600$$

$$p = -250(0.4) + 600$$

$$p = 500 \text{ kPa}$$

$$W = \text{area} = \frac{(575+500)}{2}(0.4 - 0.1)$$

$$W = 161.25 \text{ kJ}$$

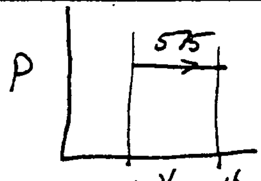
Alternate

$$\int P dv = -\frac{250V^2}{2} + 600V \Big|_{V_1}^{V_2}$$

$$= -\frac{250}{2}(0.4^2 - 0.1^2) + 600(.4 - .1)$$

$$= 161.25 \text{ kJ}$$

2.45



$$W = 575(0.4 - 0.1) = 172.5 \text{ kJ}$$

2.46 $p_2 = \dfrac{p_1 v_1^{1.3}}{v_2^{1.3}} = \dfrac{10 \times 144\,(2.2)^{1.3}}{(1.0)^{1.3}} = 4013.4\ \text{lb/ft}^2$

$$w = \frac{p_2 v_2 - p_1 v_1}{1-n} = \frac{4013.4\,(1.0) - 1440\,(2.2)}{-0.3} = -2818\ \frac{\text{ft-lb}}{\text{lb}}$$

2.47 $p_2 = \dfrac{p_1 v_1^{1.4}}{v_2^{1.4}} = \dfrac{50 \times 144\,(1.5)^{1.4}}{(2.5)^{1.4}} = 3521.63\ \text{lb/ft}^2$

$$w = \frac{p_2 v_2 - p_1 v_1}{1-n} = \frac{3521.63\,(2.5) - 7200\,(1.5)}{-0.4} = 4990\ \frac{\text{ft-lb}}{\text{lb}}$$

2.48 $p_2 = \dfrac{p_1 V_1^{1.4}}{V_2^{1.4}} = \dfrac{500\,(0.2)^{1.4}}{(0.4)^{1.4}} = 189.46\ \text{kPa}$

$$W = \frac{p_2 V_2 - p_1 V_1}{1-n} = \frac{189.46\,(0.4) - 500\,(0.2)}{-0.4} = 60.54\ \text{kJ}$$

2.49 $p_2 = \dfrac{p_1 V_1^{1.3}}{V_2^{1.3}} = \dfrac{1000\,(0.2)^{1.3}}{(0.5)^{1.3}} = 303.86\ \text{kPa}$

$$W = \frac{p_2 V_2 - p_1 V_1}{1-n} = \frac{303.86\,(0.5) - 1000\,(0.2)}{-0.3} = 160.23\ \text{kJ}$$

2.50 $V_2^{1.3} = \dfrac{p_1 V_1^{1.3}}{p_2} = \dfrac{50 \times 144\,(0.5)^{1.3}}{100 \times 144} = 0.203 \qquad V_2 = 0.29\ \text{ft}^3$

$$W = \frac{p_2 V_2 - p_1 V_1}{1-n} = \frac{100 \times 144 \times 0.29 - 50 \times 144 \times 0.5}{-0.3} = -1920\ \text{ft-lb}$$

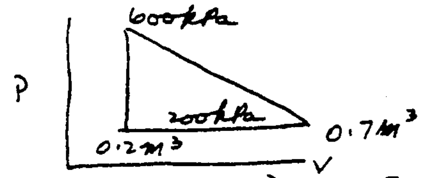
2.51 (a) $W = p\,\Delta V = 500\,(0.60 - 0.15) = 225\ \text{kJ}$

(b) $W = p_1 V_1 \ln \dfrac{V_2}{V_1} = 500\,(0.15) \ln 4 = 103.97\ \text{kJ}$

(c) $p_2 = \dfrac{p_1 V_1^{1.3}}{V_2^{1.3}} = \dfrac{500\,(0.15)^{1.3}}{(0.6)^{1.3}} = 82.47\ \text{kPa}$

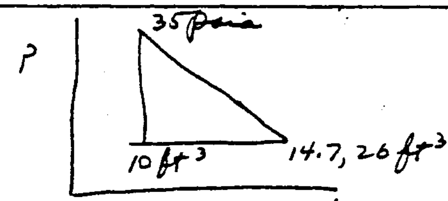
$$W = \frac{p_2 V_2 - p_1 V_1}{1-n} = \frac{82.47\,(0.6) - 500\,(0.15)}{-0.3} = 85.07\ \text{kJ}$$

2.52



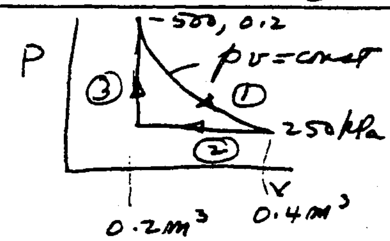
Work = net area $= \frac{1}{2}(0.7-0.2)(600-200) = 100\ kJ$

2.53



Work = net area $= \dfrac{(26-10)(35-14.7)}{2} \times 144 \dfrac{in^2}{ft^2} = 23,385.6\ ft\ lb_f$

2.54



$p_1 V_1 = p_2 V_2$

$V_2 = \frac{500}{250} \times 0.2 = 0.4\ m^3$

$p_1 V_1 \ln \frac{V_2}{V_1} = p_1 V_1 \ln \frac{p_1}{p_2}$

Work = Work ① − Work ②. Work ③ = 0

$= 500\ kPa \times 0.2\ m^3 \ln \frac{2}{1} - 250\ kPa\,(0.4-0.2)$

$= (69.31 - 50) = 19.31\ kJ$