Example 1.1 Express the temperature of 63°F in the following units –

(a) Degrees centigrade

(b) Degress kelvin

(c) Degress Rankine

"[redacted] "Thermodynamics"

Example 1.2 Hydrogen is compressed under a constant pressure of 40 lbf/in² until its volume is reduced from 36 to 15 ft^3. Find the work done in compressing the gas.

Example 1.3 A volume of 10 ft^3 of air at a pressure of 150 lbf/in² is expanded in a cylinder until it occupies a volume of 35 ft^3. If the equation for the expansion is $pV^{1.4}$ = constant, find the final pressure of the air.

Example 1.4 Twenty-five cubic feet of nitrogen at a pressure of 15 lbf/in² are compressed until the final pressure is 300 lbf/in². If the compression follows the law $pV^{1.3}$ = constant, find the final volume of the nitrogen.

Example 1.5 Four pounds of gas at a temperature of 17°c are heated to a temperature of 89°c. The mean specific heats at constant pressure & constant volume are 0·2402 and 0·1718 respectively. Find the heat absorbed by the gas for each of the following two methods of heating: (a) at constant pressure, and (b) at constant volume. (c) Find also the value of the constant γ for this gas.

Example 1.6 A quantity of air has a volume of 20 ft^3 and a pressure of 100 lbf/in^2; it is expanded in a cylinder to a pressure of 15 lbf/in^2. Find the work done by the air exanding if the expansion is (a) hyperbolic (or isothermal), (b) reversible adiabatic, (c) follows a law $pV^{1\cdot2}$ = constant. The value of γ for air may be assumed to be 1·4.

Example 1.7 A gas engine has a cylinder diametee of 9 in. and a stroke of 15 in; the clearance volume is one-quarter of the swept volume. At the commencement of the working stroke the pressure of burnt gases is 230 lb/in^2. Find the work done during the working stroke if the xpansion follows the law – $pV^{1.3}$ = constant.

Example 1·8 A gas contain in cylinder is expand from a volume of $20 ft^3$ to a volume of $40 ft^3$ by the motion of a sliding piston. The equation for the pressure during the expansion is

$$p = \frac{2400}{V} - \frac{V}{8} \ lbf/in^2.$$

Calculate the work (w), done by the gas during the expansion.

"PROBLEMS"

(1) Express a temperature of 139°c in degree farantiet. and in degree Rankine.

(2) It was found that it required 200,000 ft-lbf of work to compress $20 ft^3$ of gas to a volume of $4 ft^3$. If compression was perform at constant pressure, find this pressure.

(3) The total volume of a gas engine cylinder is $1,350 in^3$. And the clearance volume is $270 in^3$. At the beginning of compression stroke the mixture of gas and air is at a pressure of $50 lbf/in^2$. Find its pressure at the

"Chapter No. 1"

"Examples & Problems"

Example 1.1 :-

Data:-

$T_F = 63°F$

$T(°C) = ?$

$T(K) = ?$

$T(°R) = ?$

Solution:-

As

$$°C = (°F - 32)\frac{5}{9}$$

$$T(°C) = (63 - 32)\frac{5}{9}$$

$$\boxed{T(°C) = 17.22}$$

Now

$$T(K) = °C + 273$$
$$= 17.22 + 273$$

$$\boxed{T(K) = 290.22}$$

Also,

$$°R = 1.8\ K$$

$$T(°R) = 1.8(290.22)$$

$$\boxed{T(°R) = 523}$$

Example # 1.2:-

Data:-

$P = 40\ lb/in^2 = 40 * 144\ lb/ft^2$

$V_2 = 36\ ft^3$

$V_1 = 15\ ft^3$

Work done = ?

Solution:-

As in constant pressure process:

$$\text{Work done} = P(V_2 - V_1)$$

$$= 40 * 144\ (36 - 15)$$

$$\boxed{\text{Work done} = 120960\ ft\text{-}lb_f}$$

Example # 1.3:-

Data:-

$V_1 = 10 ft^3$

$V_2 = 35\ ft^3$

$P_1 = 150\ lb/in^2 = 150 * 144\ lb/ft^2$

$P V^{1.4} = \text{constant}$

$P_2 = ?$

Solution:-

As for the given process:

$$P_1 V_1^{1.4} = P_2 V_2^{1.4}$$

$$P_2 = \frac{P_1 V_1^{1.4}}{V_2^{1.4}}$$

$$= 150 * 144 * \frac{(10)^{1.4}}{(35)^{1.4}}$$

$$\boxed{P_2 = 3740\ lb/ft^2 = 25.96\ lb/in^2}$$

Example # 1.4:-

Data:-

$V_1 = 25\ ft^3$

$P_1 = 15\ lb/in^2$

$P_2 = 300\ lb/in^2$

$V_2 = ?$

$PV^{1.3} = const.$

Solution:-

As the given process follows the rule:

$$P_1 V_1^{1.3} = P_2 V_2^{1.3}$$

$$V_2^{1.3} = \frac{P_1 V_1^{1.3}}{P_2}$$

$$V_2 = \left(\frac{P_1 V_1^{1.3}}{P_2}\right)^{1/1.3}$$

$$= \left(\frac{15 * (25)^{1.3}}{300}\right)^{1/1.3}$$

$$V_2 = 25 \left(\frac{15}{300}\right)^{1/1.3}$$

$$\boxed{V_2 = 2.495\ ft^3}$$

Example # 1.5:-

Data:-

$T_1 = 17°C$

$T_2 = 89°C$

$C_p = 0.2404$

$C_v = 0.1718$

$w = 4\ lb$

(a) $Q_p = ?$

(b) $Q_v = ?$

(c) $\gamma = ?$

Solution:-

(a) As, at constant pressure:

$$Q_p = w\, C_p (T_2 - T_1)$$
$$= 4 * 0.2404 \, (89 - 17)$$

$$\boxed{Q_p = 69.23 \text{ Chu}}$$

(b)
$$Q_v = w\, C_v (T_2 - T_1)$$
$$= 4 * 0.1718 * (89 - 17)$$

$$\boxed{Q_v = 49.47 \text{ Chu}}$$

(c) Now

$$\gamma = \frac{C_p}{C_v}$$
$$= \frac{0.2404}{0.1718}$$

$$\boxed{\gamma = 1.399}$$

Example # 1.6 :-

Data:-

$V_1 = 20 ft^3$

$P_1 = 100\ lbf/in^2$

$P_2 = 15\ lbf/in^2$

Work done = ?

(a) hyperbolic

(b) Reversible adiabatic.

(c) $PV^{1.2} = const.$

$\gamma = 1.4$

Solution:-

(a) As in hyperbolic (isothermal) process:

$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2}$$

$$= \frac{100 * 20}{15}$$

$$V_2 = 133.33 \ ft^3$$

Now

$$\text{Work done} = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

$$= 100 * 20 \ln\left(\frac{133.33}{20}\right) * 144$$

$$\boxed{\text{Work done} = 546363.4 \ ft\text{-}lb_f}$$

(b) Now in adiabatic expansion:

$$P_1 V^\gamma = P_2 V_2^\gamma$$

$$V_2 = \left(\frac{P_1 V^\gamma}{P_2}\right)^{1/\gamma}$$

$$= V\left(\frac{P_1}{P_2}\right)^{1/\gamma}$$

$$= 20\left(\frac{100}{15}\right)^{1/1.4}$$

$$V_2 = 77.54 \ ft^3$$

Now work done in adeabatic process is:

$$\text{Work done} = \frac{P_1V_1 - P_2V_2}{\gamma - 1}$$

$$= \frac{(100*20 - 15*77.54)\,144}{1.4 - 1}$$

Work done = 301273.9 ft-lbf

(c) Now in the given process

$$P_1 V_1^{1.2} = P_2 V_2^{1.2}$$

$$V_2 = V_1 \left(\frac{P_1}{P_2}\right)^{1/1.2}$$

$$= 20 \left(\frac{100}{15}\right)^{1/1.2}$$

$$V_2 = 97.18 \text{ ft}^3$$

Now work done in this process:-

$$\text{Work done} = \frac{P_1V_1 - P_2V_2}{n-1}$$

$$= \frac{(100*20 - 15*97.18)\,144}{1.2 - 1}$$

Work done = 390350 ft-lbf

Example #1.7:-

Data:-

$d = 9$ in $= \frac{3}{4}$ ft

Stroke $= 15$ in $= \frac{5}{4}$ ft

Clearance volume $= \frac{1}{4}$ Swept Volume.

$P_1 = 230$ lbf/in

$PV^{1.3} = $ Const

Work done = ?

Solution:-

As

Swept Volume $= \frac{\pi d^2}{4} \times$ Stroke

$= \frac{3.14}{4} \times \left(\frac{3}{4}\right)^2 \times \left(\frac{5}{4}\right)$

Swept Volume $= 0.552$ ft^3

Now

Clearance Volume $= \frac{1}{4}$ Swept Volume

$= \frac{1}{4} \times 0.552$

clearance Volume $= 0.138$ ft^3 $= V_1$

Now

Total Volume of cylinder $= 0.552 + 0.138$

$V_2 = 0.69$ ft^3

Now

$P_1 V_1^{1.3} = P_2 V_2^{1.3}$

$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{1.3}$

$= 230 \left(\frac{0.138}{0.69}\right)^{1.3}$

$P_2 = 28.3$ lbf/in^2

Now

$$\text{Work done} = \frac{P_1V_1 - P_2V_2}{n-1}$$

$$= \frac{(230 * 0.138 - 28.4 * 0.69)\,144}{1.3 - 1}$$

Work done = 5834.5 ft-lbf

Example # 1.8)

Data:-

$V_1 = 20\,ft^3$

$V_2 = 40\,ft^3$

$$P = \frac{2{,}400}{V} - \frac{V}{8}\ lbf/in^2 = \left(\frac{2400}{V} - \frac{V}{8}\right)144$$

Work done = ?

Solution:-

As in an isothermal process:

$$\int x = \frac{x^2}{2}$$

$$W = \int_{V_1}^{V_2} P\,dV$$

$$= \int_{V_1}^{V_2} 144\left(\frac{2400}{V} - \frac{V}{8}\right) dV$$

$$= 144\int_{V_1}^{V_2}\left(\frac{2400}{V} - \frac{V}{8}\right) dV$$

$$= 144\left[2400 \ln V\Big|_{V_1}^{V_2} - \frac{V^2}{16}\Big|_{V_1}^{V_2}\right]$$

$$W = 144\left[2400 \ln\left(\frac{V_2}{V_1}\right) - \frac{1}{16}(V_2^2 - V_1^2)\right]$$

$$W = 144\left[2400 \ln\left(\frac{40}{20}\right) - \frac{(40)^2 - (20)^2}{16}\right]$$

Work done = 228751.66 ft - lb

"Problems"

P-1.1)

Data:-

$T = 139°C$

$T(°F) = ?$

$T(°R) = ?$

Solution:-

As

$°F = 1.8°C + 32$

$T(°F) = 1.8(139) + 32$

$T(°F) = 282.2$

As;

$T(°R) = °F + 460$

$= 282.2 + 460$

$T(°R) = 742.2$

P-1.2)

Data:-

$V_1 = 20 ft^3$

$V_2 = 4 ft^3$

Work = 200,000 ft-lb

$P = ?$

Solution:-

As

Work done = $P(V_2 - V_1)$

$$P = \frac{\text{Work done}}{V_2 - V_1}$$

$$= \frac{200{,}000}{20-4}$$

$$P = 12500 \ lbf/ft^2 = 86.8 \ lbf/in^2$$

P-1.3)

Data:-

$V_1 = 1350 \ in^3$

$V_2 = 270 \ in^3$

$P_1 = 15 \ lbf/in^2$

$P_2 = ?$

$PV^{1.35} = const.$

Solution:-

As the process follows the rule:

$$P_1 V_1^{1.35} = P_2 V_2^{1.35}$$

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{1.35}$$

$$= 15 \left(\frac{1350}{270}\right)^{1.35}$$

$$P_2 = 131.73 \ lbf/in^2$$