ANSWERS

1	A	7	B	13	C	19	B	25	C	31	C
2	B	8	A	14	C	20	C	26	A	32	B
3	D	9	D	15	C	21	B	27	D	33	A
4	B	10	A	16	C	22	B	28	B	34	D
5	D	11	B	17	B	23	A	29	A		
6	B	12	B	18	D	24	D	30	B		

SOLUTIONS

SOL. - 1.

Efficiency based on temperature:

$$\eta = 1-\frac{T_2}{T_1} = 1-\frac{773}{1873} = 58.73\%$$

Let x kg of petrol is consumed on testing per second.

Heat supplied = $x \times 42000 \text{kJ/s}$

Work done = 5.25 kW

Since design is justified

$$\eta = \frac{\text{work done}}{\text{heat supplied}} = \frac{5.25}{x \times 42000}$$

$$x = \frac{5.25}{0.5873 \times 42000} = 2.13 \times 10^{-4} \text{kg/sec.}$$

$$x = 0.766 \text{kg/hr}$$

SOL. - 2. And 3.

$$\eta_i = \frac{I.P \times 3600}{m_f \times c} \Rightarrow I.P = 14.30 \text{kW}$$

$$I.P = \frac{P_m \times L \times A \times n}{60} \quad LA = V_s = \text{stroke volume, } n = N$$

$$V_s = 8.8 \times 10^{-3} \text{ m}^3 = 8.8 \text{ liters}$$

$$r = 1+\frac{V_s}{V_c} = 1+\frac{8.8}{3} = 3.93$$

$$\eta = 1-\frac{1}{r^{\gamma-1}} = 1-\frac{1}{(3.93)^{1.4-1}} = 43\%$$

$$V_s = A \times L = \frac{\pi}{4} \times (D^2) \times 2 = \frac{\pi}{4} \times D^2 \times 1.5 \times D$$

$$\therefore D = 1.95$$

$$\text{Force} = P_m \times A = 19.42 \text{ KN}$$

SOL. - 4. And 5.

v_1 = Volume of charge admitted at N.T.P

$$= \frac{m \times R \times T}{P} = \frac{0.0002 \times 287 \times 273}{1.013 \times 10^5} = 0.155 \times 10^{-3} \text{m}^3$$

$$\eta_v = \frac{V_a}{V_s} \Rightarrow \text{ swept volume } V_s = \frac{V_a}{\eta} = \frac{0.155 \times 10^{-3}}{0.55}$$

$$V_s = 0.281 \times 10^{-3}$$

$$I.P = \frac{P_m \times V_s \times N/2}{60}$$

$$I.P = 0.64 \text{kW}$$

Indicated thermal efficiency

$$\eta_i = \frac{I.P \times 3600}{mf \times c} = 25.6\%$$

r_c = Compressor ratio $= 1+\frac{V_s}{V_c} = 16.61$

Air standard efficiency $= 1-\frac{1}{(r_c)^{\gamma-1}} = 68.40\%$

Relative efficiency = $\frac{51.2}{68.40} = 0.748$

SOL. - 6.

$$P_m = \text{Mean effective pressure} = \frac{A \times s}{\ell} = \frac{450 \times 1.5}{75} = 9 \text{bar}$$

$$I.P. = \frac{P_m \times L \times A \times n}{60}$$

$$\Rightarrow \quad 5000 = \frac{9 \times 10^5 \times (0.075) \times 450 \times 10^{-6} \times n}{2 \times 60}$$

$$\therefore \quad n = 9876.54 \text{ rpm}$$

$n = \frac{N}{2}$ for four stroke engine

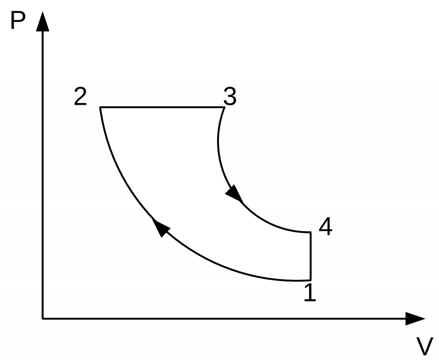
N=19753.08 rpm

Average speed of piston

$$= r \times w = \frac{0.125}{2} \frac{2\pi(19758.08)}{60} = 129.28 \text{ m/sec}$$

SOL. - 7.

Given data



$n = 4$

$N = 100$ rpm

$D = 100$ mm

$L = 160 \text{ mm}$

$V_c = 84CC = 84 \text{ cm}^3$

cut - off = 6.67% of the stroke.

$P_1 = 1\text{bar}$

$T_1 = 20^0C$

$\eta_m = 0.75$

$\therefore$ stroke volume = $\frac{\pi}{4}D^2L$

$\therefore V_s = \frac{\pi}{4}(100)^2 \times 160$

$= 1256637.061 \text{ mm}^3 = 1256.63 \text{ cm}^3$

$\therefore r_c = \frac{V_s + V_c}{V_c} = 15.95 \approx 16$

cut off = 6.67% of stroke volume

$\Rightarrow V_3 - V_2 = \frac{6.67}{100}(V_1 - V_2)$

$\Rightarrow \left(\frac{V_3}{V_2} - 1\right) = \frac{6.67}{100}\left(\frac{V_1}{V_2} - 1\right)$

$\Rightarrow \frac{V_3}{V_2} - 1 = \frac{6.67}{100} \times (16 - 1)$

$\Rightarrow \frac{V_3}{V_2} = \frac{6.67}{100} \times 15 + 1$

$\frac{V_3}{V_2} = \rho = 2$

$\therefore \eta = 1 - \frac{1}{\gamma}\left[\frac{\rho^\gamma - 1}{r_c^{\gamma-1}(\rho - 1)}\right] = 0.6138 = 61.4\%$

SOL. - 8.

$V_s = \frac{®}{4} \times 10^2 \times 10 \times 10^{-6} \times 4 = 0.00314 m^3$,

Volume sucked = $¦_V \times V_s \times ¦ = 0.047 \text{ m}^3 / s$

$m_a = 0.054 \text{ kg/s}$, $m_a = C_d A_2 \sqrt{2°_a \Delta P_a}$,

$\Delta P_a = \left(\frac{m_c}{C_d A_2}\right)^2 \frac{1}{2°_a} = 0.045 \text{ bar}$

SOL. - 9.

BP for 1 cylinders = $\frac{2®NT}{60000} = 13.82kW$,

IP with 1 cylinder = 20 – 13.82 = 6.18 kW

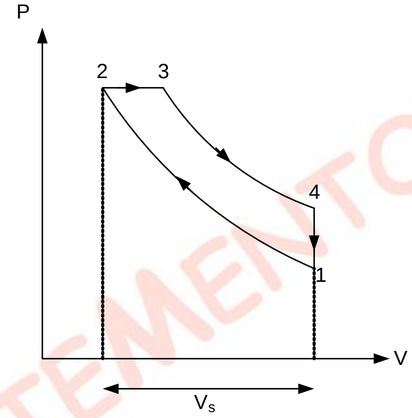
Total IP = 4 × 6.18 = 24.72 kW,

ISFC = $bSfc \times \frac{bP}{IP} = 291.26 \text{ g/KWh}$

Fuel consumption

$= \frac{ISfC \times iP}{3600 \times 1000} = 2 \times 10^{-3} \text{ kg/s}$

SOL. - 10.



Compression ratio, $r_k = \frac{V_1}{V_2} = 15$

Given that, $V_3 - V_2 = \frac{6.5}{100}[V_1 - V_2]$

$= 0.065[15V_2 - V_2]$

$V_3 = V_2 + [0.065 \times 14V_2]$

$= 1.91V_2$

$\frac{V_3}{V_2} = 1.91$

$¦_{th} = 1 - \frac{1}{¥ - r_k^{r-1}}\left[\frac{r_c^{¥} - 1}{r_c - 1}\right]$

$= 1 - \frac{1}{1.4 \times 15^{0.4}}\left[\frac{1.91^{1.4} - 1}{1.91 - 1}\right]$

$= 0.61$

SOL. - 11.

$¥ = \frac{C_p}{C_V} = 1.41$

$R = C_p - C_V = 0.293kJ / kgK$

r = expansion ratio = 2

Efficiency of Joule's cycle

$$= 1 - \frac{1}{(r)^{\gamma - 1}} = 0.247 ......(1)$$

Efficiency of Stirling cycle with regenerator

$$= \frac{2.3R\log r\,(T_1 - T_2)}{2.3RT_1\log r + C_V(T_1 - T_2)(1 - \eta_R)} ......(2)$$

η_R is efficiency of regenerator

Given (1) = (2)

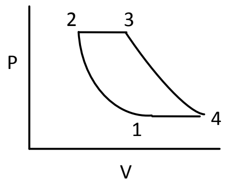
$\eta_R \simeq 35\%$

SOL. – 12 and 13

For maximum work output

$$r_p = \left(\frac{T_{max}}{T_{min}}\right)^{\frac{\gamma}{2(\gamma-1)}} = \left(\frac{1100}{300}\right)^{\frac{1.4}{2(1.4-1)}} = 9.71$$

$T_{max} = T_3, T_{min} = T_1$



$$\frac{T_2}{T_1} = (r_p)^{\frac{\gamma - 1}{\gamma}}, T_2 = 300 \times 1.914 = 574.4$$

Heat addition in Brayton cycle= $c_p(T_3 - T_2)$

= 1.005 (1100 – 594.4) = 523.3 kJ/kg.

9.1. Refrigeration capacity of plant

= .542TR

Total heat removed will be

= .542 x 210=113.82KJ/min

Heat removed from fruit in 10 hrs.

$= mC_F(T_2 - T_1) = m \times 1.45 \times (30 + 5) = 50.75 mKJ / Kg$

Latent heat of freezing

$= mhf_g = m \times 125 = 125m$ KJ

Total heat removed

$= 125 + 50.75 = 175.75 mKJ / Kg$

Heat removed in one min

$$= \frac{175.75 \times m}{10 \times 60} = 113.82 \Rightarrow m = 388.5Kg$$

SOL. - 14.

$$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{1}{4}\right)^{\frac{1.4-1}{1.4}} = .67$$

$T_3 = 685.41K$ Similarly $T_1 = 442.8K$

Work done by turbine

$W_T = mC_P(T_2 - T_3) = m(1023 - 685.41)$

$W_T = 337.6 mKJ / sec$

Work absorbed by compressor

$W_C = mC_P(T_1 - T_4) = 144.8 mKj / sec$

Net work = Power = $W_T - W_C = 192.8m$

$m = 7.078$ kg / s

SOL. - 15.

Heat supplied by heating chamber

$= mC_P(T_2 - T_1) \simeq 4514 KJ / sec$

SOL. – 16 and 17

$p\overline{V} = RT$

$\Rightarrow \frac{p}{\rho} = RT$ p

$\because \frac{P_1}{\rho_1} = RT_1$

$\Rightarrow \frac{2 \times 10^6}{\rho_1} = \frac{8314}{29} \times 300$

$\because Q_1 = \frac{\dot{m}}{\rho_1} = \frac{600}{3600 \times 17.44} = 9.556 \times 10^{-3}\ m^3/sec$

$\because Q_1 = A_1V_1$

$\Rightarrow 9.556 \times 10^{-3} = A_1 \times 300$

$\therefore A_1 = 3.1853 \times 10^{-5}\ m^2$

$\therefore D_1 = 6.368 \times 10^{-3}$ m

$D_1 = 6.37$ mm

$\frac{P_2}{\rho_2} = RT_2$

$\Rightarrow \frac{0.5 \times 10^6}{\rho_1} = \frac{8314}{29} \times 269$

$\therefore Q_2 = \frac{\dot{m}}{\rho_2} = \frac{600}{3600 \times 6.483}$

$Q_2 = 0.0257\ m^3/sec$

$\because Q_2 = A_2V_2$

$\Rightarrow 0.0257 = A_2 \times 594$

$\therefore A_2 = 4.327 \times 10^{-5}$

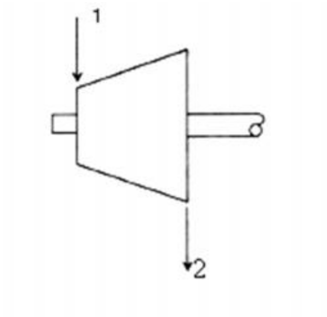
$D_2 = 829 \times 10^{-3}\ m$ $D_2 = 8.3$ mm

SOL. - 18.

$P_1 = 19\ bar$

$T_1 = 1490\ K$

$P_2 = 1 \text{ bar}$



$$\gamma = C_P / C_V = \frac{0.98}{0.75} = 1.3$$

For Adiabatic Process.

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad T_2 = \left(\frac{1}{19}\right)^{\frac{1.3-1}{1.3}} \times 1490 = 755.24K$$

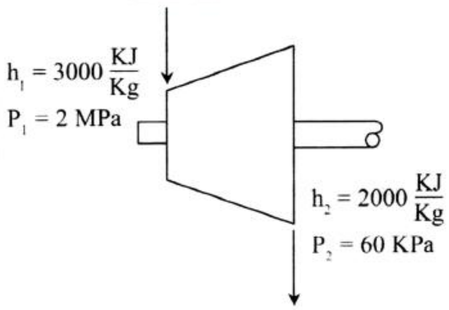
$$\eta = 0.94 = \frac{w_{net}}{Q_s} = \frac{w_{net}}{C_P(T_1 - T_2)}$$

$$\Rightarrow \quad 0.94 = \frac{w_{net}}{0.98(1490 - 755.24)}$$

$$w_{net} = 676.86 \text{ KJ/kg}$$

SOL. - 19.

$\dot{m} = 1000 \text{ kg/m}^3$



Specific work supplied to the pump

$$= \frac{P_1 - P_2}{\dot{m}} = \frac{200 - 60}{1000}$$

$$= 1.94 \text{ KJ/kg}$$

SOL. - 20.

$$\eta_B = 1 - \sqrt{\frac{T_{min}}{T_{max}}}$$

SOL. - 23.

W_{net} is same for with regeneration and without regeneration gas power plant.

SOL. - 26.

$$WR = \frac{W_{net}}{W_T} = \frac{W_T - T_1}{W_T} = 1 - \frac{W_c}{W_T}$$

$$WR = 1 - \frac{T_2 - T_1}{T_3 - T_4}$$

$$= 1 - \frac{T_1}{T_3}\left[\frac{T_2 / T_1 - 1}{1 - T_4 / T_3}\right]$$

$$= 1 - \frac{T_1}{T_3}\left[\frac{r_p^{\frac{\gamma-1}{\gamma}} - 1}{1 - r_p^{\frac{\gamma-1}{\gamma}}}\right] r_p^{\frac{\gamma-1}{\gamma}}$$

$$= 1 - \left(\frac{T_{min}}{T_{max}}\right) r_p^{\frac{\gamma-1}{\gamma}}$$

SOL. - 27.

$$0.8 = \frac{T_{10} - T_4}{T_8 - T_4} = \frac{T_{10} - 350}{630 - 350}$$

$$T_{10} = 574K$$

$$W_{net} = \left[T_5 - T_6 + T_7 - T_8 - (T_4 - T_3) - (T_2 - T_1)\right] \times c_p$$

$$W_{net} = 250C_P$$

$$W_{net} = 251.25 \text{kJ/ kg}$$

$$Q_s = C_P(T_5 - T_{10}) + C_P(T_7 - T_6)$$

$$= 397.98 \text{kJ / kg}$$

$$\eta = \frac{W_{net}}{Q_s} \times 100$$

$$\eta = 63.2\%$$

SOL. - 28.

$$\eta_B = \quad \eta_o = 1 - \frac{T_1}{T_2}$$

$= 33.33\%$

SOL. - 29.

For otto cycle

$$0.33 = \frac{(W_{net})_O}{C_P(600-450)}$$

$$(W_{net})_0 = 49.5C_P \ \text{kJ/kg}$$

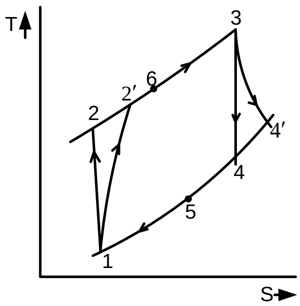
For brayton cycle

$$0.33 = \frac{(W_{net})_b}{C_P(550-450)}$$

$$(W_{net})_b = 33C_P \ \text{kJ/kg}$$

$$\therefore (W_{net})_0 > (W_{net})_{b.}$$

SOL. - 30.



$P_1 = 100\text{kPa} \quad T_1 = 303\text{k}$

$r_p = 6 \quad T_3 = 1173\text{k}$

$$T_2 = r_P^{\frac{\gamma-1}{\gamma}} \times T_1 = 505.56\text{k}$$

$$0.8 = \frac{T_2 - T_1}{T_2' - T_1}$$

$$T_2' = 556.2\text{K}$$

$$T_4 = r_p^{\frac{1-\gamma}{\gamma}} \times T_3 = 703.02\text{K}$$

$$0.8 = \frac{T_3 - T_4'}{T_3 - T_4}$$

$$T_4' = 797\text{K.}$$

$$W_{net} = C_P(T_3 - T_4') - C_P(T_2' - T_1)$$

$$= 123.41 \ \text{kJ/kg}$$

$$Q_S = C_p(T_3 - T_2') = 619.88 \ \text{kJ/kg}$$

$$\therefore \eta = \frac{W_{net}}{Q_s} = 20\%$$

SOL. - 31.

With regeneration

$$0.75 = \frac{T_6 - T_2'}{T_4' - T_2'}$$

$$T_6 = 736.8\text{K.}$$

$$\therefore \ Q_s = C_P(T_3 - T_6)$$

=438.4 kJ/kg

$$\therefore \eta' = \frac{123.41}{438.4} \times 100$$

$$\eta' = 28.15\%$$

% increase in cycle efficiency $= \dfrac{28.15-20}{20} \times 100$

= 40%

SOL. - 32.

No. of power strokes by one cylinder = $\dfrac{900}{60 \times 2} = 7.5$

$\therefore$ Number of power strokes by 9 cylinders = 7.5×9

= 67.5

SOL. - 33.

$$V_{swept} = 3 \times 10^{-3} \times \frac{3600}{60 \times 2} = 0.09\text{m}^3/\text{s}$$

$$\text{B.P.} = \frac{205 \times 2\pi \times 3600}{60 \times 746}$$

$$\text{B.P.} = 103.6\text{hp}$$

SOL. - 34.

$$\text{BMEP} = \frac{\text{B.P.}}{V_{swept}} = \frac{103.6 \times 746}{0.09}$$

$$\text{BMEP} = 8.6 \ \text{bar}$$