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Power Plant

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 17/07/2019

ANSWER KEY > Power Plant

1.	(c)	7.	(d)	13.	(a)	19.	(a)	25.	(c)
2.	(a)	8.	(b)	14.	(a)	20.	(c)	26.	(d)
3.	(a)	9.	(d)	15.	(a)	21.	(d)	27.	(c)
4.	(b)	10.	(a)	16.	(a)	22.	(c)	28.	(d)
5.	(d)	11.	(b)	17.	(b)	23.	(c)	29.	(a)
6.	(a)	12.	(d)	18.	(d)	24.	(a)	30.	(b)

DETAILED EXPLANATIONS

1. (c)

$$\text{Work ratio, } w_r = \frac{W_{Net}}{W_T} = 1 - \frac{T_{min}}{T_{max}}(r_p)^{\frac{\gamma-1}{\gamma}} = 1 - \frac{310}{1075} \times (6)^{\frac{0.4}{1.4}} = 0.52$$

3. (a)

$$\eta_{plant} = \eta_{boiler} \times \eta_{turbine} \times \eta_{electric\ generator} \times \eta_{cycle} \times \eta_{auxiliaries}$$

$$\Rightarrow \quad 0.25 = 0.96 \times 0.95 \times 0.92 \times 0.5 \times \eta_{auxiliaries}$$

$$\eta_{auxiliaries} = 0.6 = 60\%$$

4. (b)

$$\text{Internal power developed} = m \times \Delta h_{i\,sen} \times \eta_{gs} = 15 \times 450 \times 0.9 = 6075 \text{ kW}$$

5. (d)

Efficiency decreases with increase in pressure ratio.

7. (d)

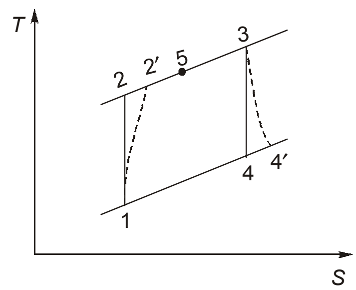
$$P_2 = \sqrt{P_1 P_3} = \sqrt{20 \times 1.1}$$

$$\Rightarrow \quad P_2 = 4.7 \text{ bar}$$

8. (b)

$$\text{Actual work input} = \frac{\text{Ideal work input}}{\eta} = \frac{W}{\eta} = \frac{v_f(\Delta P)}{\eta} = \frac{P_2 - P_1}{\rho\eta} = \frac{(3000-80)}{1000 \times 0.85} = 3.43 \text{ kJ/kg}$$

11. (b)



Given, $\eta_{Regeneration} = 0.8$; $\eta_T = 0.8 = \eta_C$; $P_1 = 1$ bar; $T_1 = 300$ K; $T_3 = 1200$

$$r_P = \frac{P_2}{P_1} = 6$$

$$\Rightarrow \quad P_2 = 6 \times 1 = 6 \text{ bar}$$

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = (6)^{\frac{0.4}{1.4}}$$

$$\Rightarrow \quad T_2 = 500.55 \text{ K}$$

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad T_4 = 1200 \times \left(\frac{1}{6}\right)^{\frac{0.4}{1.4}} = 719.2 \text{ k}$$

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

$$\Rightarrow \quad 0.8 = \frac{500.6 - 300}{T_2' - 300}$$

$$\Rightarrow \quad T_2' = 550.68 \text{ K}$$

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

$$\Rightarrow \quad 0.8 = \frac{T_4' - 1200}{719.2 - 1200}$$

$$\Rightarrow \quad T_4' = 815.36 \text{ K}$$

$$\eta_{reg.} = \frac{T_5 - T_2'}{T_4' - T_2'}$$

$$\Rightarrow \quad 0.8 = \frac{T_5 - 550.68}{815.36 - 550.68}$$

$$\Rightarrow \quad T_5 = 762.42 \text{ K}$$

$$\eta = \frac{W_T - W_C}{Q_S} = \frac{C_P(T_3 - T_4') - C_P(T_2' - T_1)}{C_P(T_3 - T_5)} = \frac{(1200 - 815.36) - (550.68 - 300)}{(1200 - 762.72)}$$

$$= 30.6\ \%$$

12. (d)

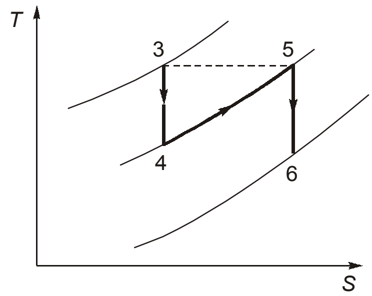
$$Q_s = (h_3 - h_{f_1}) + (h_5 - h_4) = (3450 - 191.8) + (3560 - 3050)$$

$$= 3768.2 \text{ kJ/kg}$$

$$W = (h_3 - h_4) + (h_5 - h_6)$$

$$= (3450 - 3050) + (3560 - 2300)$$

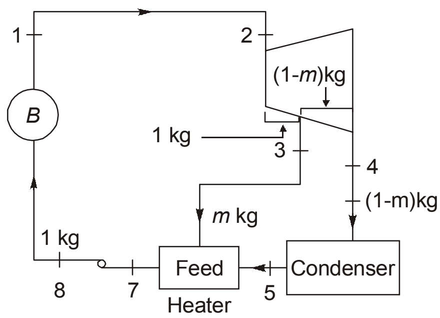
$$= 1660 \text{ kJ/kg}$$



$$\eta_{cycle} = \frac{W}{Q_s} = \frac{1660}{3768.2} = 44.05\%$$

$$\text{Steam rate} = \frac{3600}{W} = \frac{3600}{1660} = 2.17 \text{ kg/kWh}$$

13. (a)



Given,

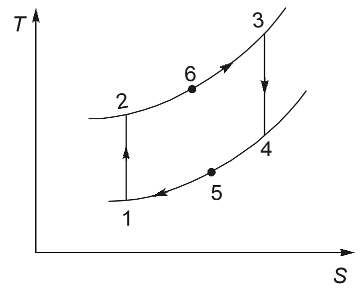
$$h_3 = 2622.22$$
$$h_5 = 188.39$$
$$h_7 = 640.23$$
$$h_7 = mh_3 + (1 - m)h_5$$

$$\Rightarrow \quad 1 \times 640.23 = \text{m} \times 2622.22 + (1 - m) \times 188.39$$

$$\Rightarrow \quad m = \frac{h_7 - h_5}{h_3 - h_5}$$

$$= \frac{640.23 - 188.44}{2622.22 - 188.44} = 0.18856 \text{ kg/s}$$

14. (a)



Given, P_1 = 1 bar = P_4; P_2 = 4 bar = P_3; T_1 = 300 K;
T_2 = 450 K; T_6 = 750 K; T_3 = 1200 K

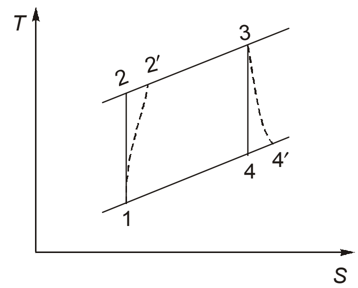
$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad \frac{1200}{T_4} = \left(\frac{4}{1}\right)^{\frac{0.3}{1.3}}$$

$$\Rightarrow \quad T_4 = 871.45$$

$$\varepsilon = \frac{T_6 - T_2}{T_4 - T_2} = \frac{750-450}{871.45-450} = 0.71$$

15. (a)



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

$$= 300 \times (5)^{\frac{0.4}{1.4}} = 475.15\text{K}$$

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

$$\Rightarrow \quad 0.8 = \frac{475.15-300}{T_2' - 300}$$

$$\Rightarrow \quad T_2' = 519 \text{ K}$$

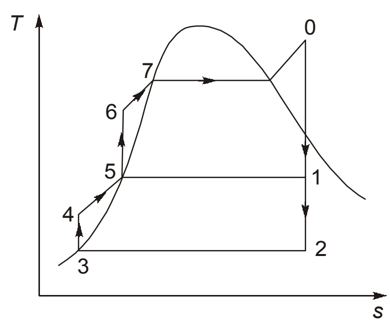
Heat supplied, $Q_s = C_p(T_3 - T'_2)$ = 1.005 (1100 – 519) = 584 kJ/kg of air

As 10% of heating value is lost i.e. efficiency of heat is 90%. So, each kg of fuel contributes

$$0.9 \times 41800 = 37620 \text{ kJ}$$

$$\therefore \quad \text{Air fuel ratio} = \frac{37620}{584} = 64.4$$

16. (a)



m is the amount of steam extracted per kg of steam.

h_o = 3000 kJ/kg

h_1 = 2600 kJ/kg

h_2 = 2115 kJ/kg

h_3 = h_{f2} = 140 kJ/kg

h_5 = h_{f1} = 505 kJ/kg

Heat added = $h_o - h_{f1}$ = 3000 – 505 = 2495 kJ/kg

Efficiency = η = 34% = 0.34

$\Rightarrow$ WD = η × Heat added = 848.3 kJ/kg

$(h_o - h_1) + (1 - m)(h_1 - h_2)$ = 848.3

$\Rightarrow$ (3000 – 2600) + (1 – m)(2600 – 2115) = 848.3

$$\Rightarrow \quad 1 - m = 0.924$$

$$\text{Specific steam consumption} = \frac{3600}{WD/\text{kg}} = 4.24 \text{ kg/kWh}$$

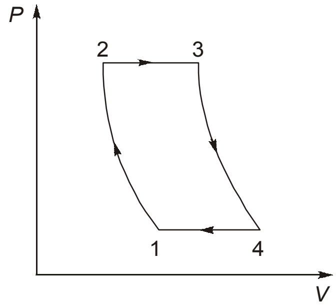
Condensor duty (steam condensed in the condenser per unit work done)

$$= (1 - m) \times 4.24 = 0.924 \times 4.24 = 3.92 \text{ kg/kWh}$$

17. (b)

Work developed in the turbine $= (h_5 - h_4) + (h_3 - h_2) + (1 - m)(h_2 - h_1)$

18. (d)



$$T_1 = 300 \text{ K}, P_1 = 20 \text{ bar}$$

$$P_2 = 60 \text{ bar}, T_3 = 1273 \text{ K}$$

$$\frac{T_2}{T_1} = (3)^{0.667/1.667}$$

$$\Rightarrow \quad T_2 = 465.6 \text{ K}$$

$$\frac{T_3}{T_4} = (3)^{0.667/1.667}$$

$$\Rightarrow \quad T_4 = 820.2 \text{ K}$$

$$w_{net} = Q_s - Q_R = C_p(T_3 - T_2) - C_p(T_4 - T_1)$$

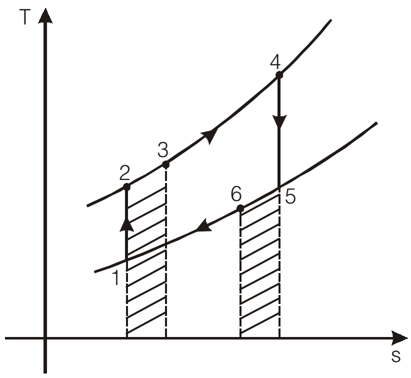
$$= 5.1926[(1273 - 465.6) - (820.2 - 300)] = 1491.3 \text{ kJ/kg}$$

20. (c)

$$\eta_{cycle} = 1 - \sqrt{\frac{T_{min}}{T_{max}}} = 1 - \sqrt{\frac{300}{1073}} = 47.12\%$$

$$W_{max} = C_p\left[\sqrt{T_{max}} - \sqrt{T_{min}}\right]^2 = 1.005\left[\sqrt{1073} - \sqrt{300}\right]^2 = 239.47 \text{ kJ/kg}$$

22. (c)



$$T_1 = 20°\text{C}$$

$$T_4 = 900°\text{C}$$

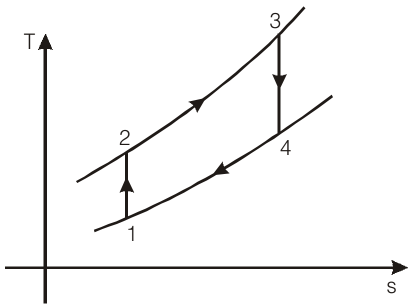
$$r = 1.3$$

$$r_p = 6$$

$$\eta = 1 - \frac{T_1}{T_4}(r_p)^{\frac{\gamma-1}{\gamma}} = 1 - \frac{293}{1173}(6)^{\frac{0.3}{1.3}}$$

$$= 0.6223 = 62.23\%$$

23. (c)



$$P_3 = P_2 = 1200 \text{ kPa}$$

$$P_1 = 100 \text{ kPa}$$

$$T_3 = 1273 \text{ K}$$

$$T_1 = 293 \text{ K}$$

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

$$\frac{T_2}{293} = \left(\frac{1200}{100}\right)^{\frac{0.667}{1.667}}$$

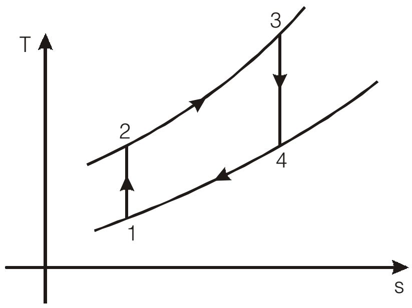
$$T_2 = 791.898\text{ k}$$

$$\eta = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}} = \frac{W_{net}}{Q_s} = \frac{W_{net}}{C_p(T_3 - T_2)}$$

$$0.63 = \frac{W_{net}}{0.5203(1273 - 791.893)}$$

$$W_{net} = 157.69\text{ kJ}$$

24. (a)



$$P_1 = 100\text{ kPa}$$
$$P_2 = P_3 = 1\text{ MPa}$$
$$T_1 = 298\text{ K}$$
$$T_3 = 1200\text{ K}$$
$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$$
$$\frac{1200}{T_4} = (10)^{0.4/1.4}$$
$$\Rightarrow \quad T_4 = 621.5\text{ K} = 348.5°\text{C}$$

25. (c)

$$h_1 = 3625.3\text{ kJ/kg}$$
$$s_1 = s_2$$
$$6.9029 = s_{f_2} + x_2 s_{fg_2}$$
$$6.9029 = 0.5725 + x_2(7.6845)$$
$$\Rightarrow \quad x_2 = 0.82378$$
$$\therefore \quad h_2 = h_{f2} + x_2\left(h_{fg_2}\right)$$
$$= 167.57 + 0.82378\,(2406.7)$$
$$= 2150.16\text{ kJ/kg}$$

Now, steam rate $(\dot{m}_s) = \dfrac{1}{(h_1 - h_2) - (h_4 - h_3)} = \dfrac{1}{3625.3 - 2150.16 - 10.06}$

$$= \frac{1}{1465.08} = 6.825 \times 10^{-4}\text{ kg/s/kW}$$

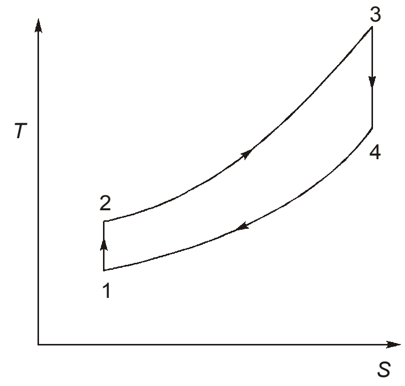
26. (d)

$$(W_{net})_{max} = ?$$
$$T_{max} = 800°\text{C} = 1073\text{ K}$$
$$T_{min} = 30°\text{C} = 303\text{ K}$$

Now, $(W_{net})_{max} = c_p\left(\sqrt{T_{max}} - \sqrt{T_{min}}\right)^2$

$$= 1.005\left(\sqrt{1073} - \sqrt{303}\right)^2 = 236.794\text{ kJ/kg}$$

27. (c)



$$\gamma = \frac{C_P}{C_V} = \frac{1}{0.717} = 1.3947$$

$$W_T = C_P(T_3 - T_4) = 336.5$$

$$T_3 - T_4 = 336.5$$

or $$T_3 - 700 = 336.5$$

or $$T_3 = 1036.5 \text{ K}$$

$$\frac{P_3}{P_4} = \left(\frac{T_3}{T_4}\right)^{\gamma/\gamma-1} = \left(\frac{1036.5}{700}\right)^{\frac{1.3947}{0.3947}} = 4$$

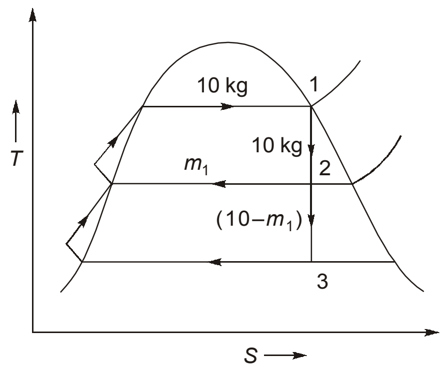
28. (d)

$$W_{max} = C_P\left[\sqrt{T_{max}} - \sqrt{T_{min}}\right]^2$$

$$W_{max} = C_P\left[\sqrt{1000} - \sqrt{400}\right]^2$$

$$W_{max} = C_P[11.6227]^2 = 135\ C_P$$

29. (a)



$W_T = 10(h_1 - h_2) + (10 - m_1)(h_2 - h_3)$

$W_T = 10(3200–2900) + 8.5(2900–2350)T$

$W_T = 7675 \times 10^3 \text{ W} = \dfrac{7675 \times 10^3}{10^6} = 7.675 \text{MW}$

30. (b)

$$\eta = \eta_1 + \eta_2 - \eta_1\eta_2 = 0.48 + 0.37 - 0.48 \times 0.37 = 0.6724$$

■■■■