DETAILED SOLUTIONS

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ESE 2020 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 8

Section A : Heat Transfer + IC Engines [All Topics]

Section B : Fluid Mechanics and Turbo Machinery-1 [Part Syllabus]

Section C : Production Engg. and Material Science-2 [Part Syllabus]

1.	(d)	16.	(b)	31.	(a)	46.	(d)	61.	(a)
2.	(a)	17.	(c)	32.	(a)	47.	(b)	62.	(d)
3.	(a)	18.	(b)	33.	(d)	48.	(a)	63.	(c)
4.	(a)	19.	(b)	34.	(c)	49.	(a)	64.	(c)
5.	(b)	20.	(a)	35.	(c)	50.	(b)	65.	(a)
6.	(c)	21.	(b)	36.	(c)	51.	(d)	66.	(c)
7.	(b)	22.	(b)	37.	(d)	52.	(b)	67.	(b)
8.	(c)	23.	(c)	38.	(d)	53.	(b)	68.	(a)
9.	(b)	24.	(a)	39.	(b)	54.	(b)	69.	(a)
10.	(c)	25.	(d)	40.	(c)	55.	(a)	70.	(b)
11.	(a)	26.	(b)	41.	(b)	56.	(c)	71.	(a)
12.	(d)	27.	(c)	42.	(d)	57.	(c)	72.	(a)
13.	(a)	28.	(a)	43.	(b)	58.	(c)	73.	(c)
14.	(d)	29.	(a)	44.	(d)	59.	(a)	74.	(a)
15.	(a)	30.	(a)	45.	(d)	60.	(b)	75.	(c)

DETAILED EXPLANATIONS :

1. (d)

Given: $T(0) = T_2 = 300$ K, $T(L) = T_1 = 400$ K

By Fourier's law of conduction,

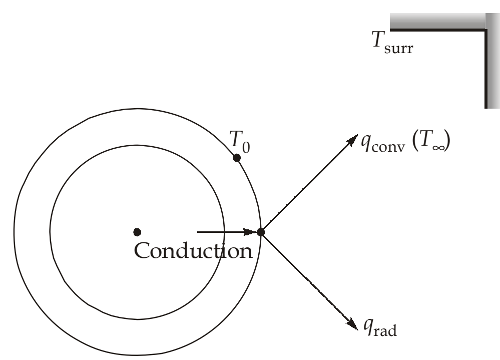
$$\text{Heat flux, } q'' = -k\frac{dT}{dx}$$

where,
$$\frac{dT}{dx} = \frac{T(L)-T(0)}{L}$$

Now,
$$\frac{dT}{dx} = \frac{T_1 - T_2}{L} = \frac{400-300}{0.5} = \frac{100}{0.5} = 200 \text{ K/m}$$

$$q'' = -25 \times 200 = -5000 \text{ W/m}^2$$

2. (a)



$$(q_{cond})_{\text{at surface}} = q_{conv.} + q_{rad.}$$

$$-k\left.\frac{dT}{dr}\right|_{r=R} = h(T_o - T_\infty) + \in\sigma\left(T_o^4 - T_{surr}^4\right)$$

3. (a)

$$h_1 = \frac{h_2}{2}$$

$\therefore$ $$h_1 < h_2$$

$$\text{Effectiveness, } \varepsilon_f = \left(\frac{kP}{hA}\right)^{1/2}$$

$$\text{Efficiency, } \eta_f = \frac{1}{mL} = \frac{1}{\left(\frac{hP}{kA}\right)^{1/2} \times L}$$

$\therefore$ Both $\in_f$ and η_f is inversely proportional to $h^{1/2}$.

$\therefore$ $(\in_{f1} > \in_{f2})$ and $(\eta_{f1} > \eta_{f2})$

4. (a)

Given: $\rho = 1.2\ \text{kg/m}^3$, $c_p = 1.005\ \text{kJ/kgK}$

From modified Reynolds analogy

$$\frac{\bar{C}_f}{2} = \overline{St} \times \text{Pr}^{2/3}$$

$$\overline{St} = \frac{\bar{C}_f}{2\text{Pr}^{2/3}}$$

$$\frac{\bar{h}}{\rho V c_p} = \frac{\bar{C}_f}{2\text{Pr}^{2/3}}$$

$$\bar{h} = \frac{\bar{C}_f}{2} \times \frac{\rho V c_p}{\text{Pr}^{2/3}} = \frac{0.0025 \times 1.2 \times 7 \times 1.005 \times 10^3}{2 \times (0.729)^{2/3}}$$

$$= \frac{0.01055 \times 10^3}{(0.9)^{3\times 2/3}} = \frac{0.01055 \times 10^3}{0.81}$$

$$\bar{h} = 13.027\ \text{W/m}^2\text{K}$$

5. (b)

$$\text{Heat transfer, } Q = \frac{\Delta T}{\frac{L_A}{k_A A} + \frac{L_B}{k_B A} + \frac{L_C}{k_C A}}$$

$\therefore$ $$\text{Heat flux, } q = \frac{Q}{A} = \frac{\Delta T}{\frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{L_C}{k_C}} = \frac{21}{\frac{0.08}{1.2} + \frac{0.05}{0.2} + \frac{0.019}{0.1}}$$

$$= \frac{21}{0.0667 + 0.25 + 0.19} = \frac{21}{0.5067}$$

$$q = 41.44\ \text{W/m}^2$$

7. (b)

We know that, $$\text{Effectiveness, } \varepsilon_f = \frac{q_f}{hA_{c,b}\theta_b}$$

$$\text{Efficiency, } \eta_f = \frac{q_f}{hA_f\theta_b}$$

where, $A_{c,b}$ = Cross sectional area of fin

A_f = Total area of fin

$$\frac{\varepsilon_f}{\eta_f} = \frac{A_f}{A_{c,b}} = \frac{4 \times (2 \times 30)}{2 \times 2}$$

[Neglecting end cross-section area in A_f]

$$\frac{\varepsilon_f}{0.71} = 60$$

$$\varepsilon_f = 42.6$$

8. (c)

$$\text{Nusselt number, Nu} = \frac{\dot{q}_{\text{conv}}}{\dot{q}_{\text{cond}}} = \frac{\dot{q}_{\text{cond}} + \dot{q}_{\text{advection}}}{\dot{q}_{\text{cond}}}$$

$$= 1 + \frac{\dot{q}_{\text{advection}}}{\dot{q}_{\text{cond}}}$$

$\therefore$ $$\text{Nu} \geq 1$$

9. (b)

Grashof number is a measure of the ratio of the buoyancy forces to the viscous forces acting on the fluid.

10. (c)

As per lumped heat analysis,

$$\frac{T - T_i}{T_o - T_i} = e^{-b \times t}$$

Where, $$b = \frac{hA_s}{\rho V c_p}$$

11. (a)

For three-sided enclosure, $$F_{i\text{-}j} = \frac{l_i + l_j - l_k}{2l_i}$$

$$F_{23} = \frac{l_2 + l_3 - l_1}{2l_2} = \frac{7 + 3 - 5}{2 \times 7} = \frac{5}{14}$$

$$F_{23} = 0.357$$

12. (d)

$$\dot{q}_{12} = \frac{\dot{Q}_{12,\text{with shield}}}{A} = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right) + \left(\frac{1}{\varepsilon_{3,1}} + \frac{1}{\varepsilon_{3,2}} - 1\right)}$$

where, $\varepsilon_1 = \varepsilon_2 = 0.2$ (Emissivity of plate)

$\varepsilon_{3,1} = \varepsilon_{3,2} = 0.1$ (Emissivity of shield)

$\therefore$ $$\dot{q}_{12} = \frac{5.67 \times 10^{-8}\left(800^4 - 500^4\right)}{\left(\frac{1}{0.2} + \frac{1}{0.2} - 1\right) + \left(\frac{1}{0.1} + \frac{1}{0.1} - 1\right)} = \frac{5.67 \times \left(8^4 - 5^4\right)}{9 + 19}$$

$$= \frac{5.67(4096 - 625)}{28} = 702.87 \text{ W/m}^2$$

13. (a)

We can take absorptivity of surface to be equal to its emissivity at room temperature, $\alpha = \varepsilon$. As the effective temperature of sky does not deviate much from room temperature.

$$\dot{q}_{\text{net,rad}} = \Sigma E_{\text{absorbed}} - \Sigma E_{\text{emitted}}$$

$$= E_{\text{solar, absorbed}} + E_{\text{sky, absorbed}} - E_{\text{emitted}}$$

$$= \alpha_s G_{\text{solar}} + \varepsilon\sigma T_{sky}^4 - \varepsilon\sigma T_s^4$$

$$= \alpha_s G_{\text{solar}} + \varepsilon\sigma\left(T_{sky}^4 - T_s^4\right)$$

14. (d)

Heat transfer rate, $q = C_h (T_{hi} - T_{he}) = C_c(T_{ce} - T_{ci})$

$$= C_h(250 - 150) = C_c(140 - 40)$$

$$C_h = C_c$$

$\therefore$ $$\frac{C_{\min}}{C_{\max}} = 1$$

$$\varepsilon = \frac{C_h(T_{hi} - T_{he})}{C_{\min}(T_{hi} - T_{ci})} = \frac{250 - 150}{250 - 40} = \frac{100}{210} = \frac{10}{21}$$

when, $$\frac{C_{\min}}{C_{\max}} = 1$$

For counter flow heat exchanger, $\varepsilon = \dfrac{\text{NTU}}{1 + \text{NTU}} = \dfrac{10}{21}$

$$21\ (\text{NTU}) = 10 + 10(\text{NTU})$$

$$\text{NTU} = \frac{10}{11} = 0.909 \simeq 0.91$$

15. (a)

$$\frac{1}{U_{\text{dirty}}} = \frac{1}{U_{\text{clean}}} + \frac{1}{1/R_f} = \frac{1}{U_{\text{clean}}} + R_f$$

$$R_f = \frac{1}{U_{\text{dirty}}} - \frac{1}{U_{\text{clean}}}$$

$$= \frac{1}{65} - \frac{1}{70} = \frac{5}{70 \times 65} = \frac{1}{910} = 0.00109\ \text{m}^2\text{K/ W}$$

16. (b)

Heat transfer coefficient, $h_x = \dfrac{k_l}{\delta}$

17. (c)

We know that,

$$\eta_m = \frac{\eta_{bth}}{\eta_{ith}} = \frac{\text{Brake thermal efficiency}}{\text{Indicated thermal efficiency}}$$

$$\eta_{bth} = 0.85 \times 0.6 = 0.51$$

and

$$\eta_{bth} = \frac{BP}{\dot{m}_f \times C.V.} \text{ or } \eta_{bth} = \frac{1}{SFC \times C.V.}$$

$$SFC = \frac{1}{\eta_{bth} \times C.V.} = \frac{1}{0.51 \times 40} = 0.049 \approx 0.05$$

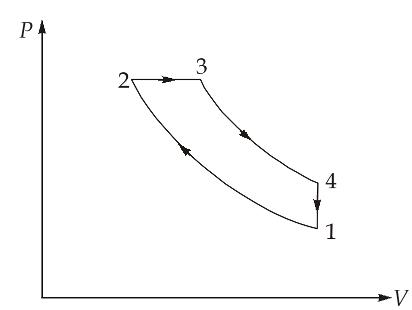
$$= 0.05 \text{ kg/MJ}$$

$$= \frac{0.05 \text{ kg/ s}}{10^3 \text{ kJ/ s}} = \frac{0.05 \times 3600 \text{ kg/ hr}}{10^3 \text{ kW}}$$

$$= 0.18 \text{ kg/kW-hr}$$

18. (b)

Given: P_1 = 1 bar, T_1 = 290 K, T_3 = 2000 K



$$\text{Cut off ratio, } \rho = \frac{V_3}{V_2} = 2.5$$

where 2-3 is a constant pressure process so,

$$\frac{T_3}{T_2} = \frac{V_3}{V_2} = 2.5$$

$$\frac{2000}{2.5} = T_2$$

$$T_2 = 800 \text{ K}$$

$$\text{Heat added} = c_p(T_3 - T_2) = 1.0\ (2000 - 800)$$

$$= 1200 \text{ kJ/kg}$$

$$\eta = \frac{\text{Heat added} - \text{Heat rejected}}{\text{Heat added}} = \frac{1200 - 537}{1200} = \frac{663}{1200} = 0.5525$$

$$= 55.25\%$$

19. (b)

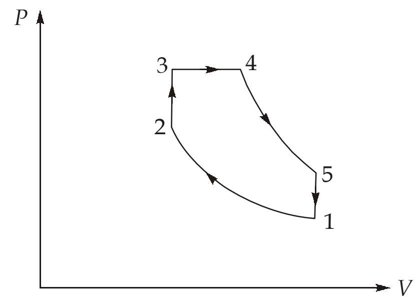
Heat added during constant pressure combustion

= 2 × Heat added during constant volume combustion

$$c_p(T_4 - T_3) = 2 \times c_v(T_3 - T_2)$$

$$\frac{c_p}{c_v}\left(\frac{T_4}{T_3} - 1\right) = 2 \times \left(1 - \frac{T_2}{T_3}\right)$$

$\because$ For constant pressure process, $\dfrac{V_4}{V_3} = \rho = \dfrac{T_4}{T_3}$ (Where ρ is cut-off ratio)



$$1.4 \times (1.5 - 1) = 2 \times \left(1 - \frac{T_2}{T_3}\right)$$

$$\frac{1.4 \times 0.5}{2} = 1 - \frac{T_2}{T_3}$$

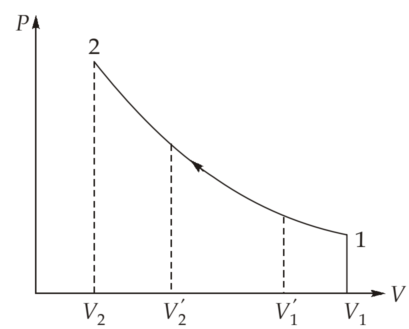
$$\frac{T_2}{T_3} = 1 - 0.35 = 0.65$$

$$T_3 = \frac{T_2}{0.65} = \frac{650}{0.65} = 1000 \text{ K}$$

$$\frac{T_4}{T_3} = 1.5$$

$$\Rightarrow \quad T_4 = 1.5 \times 1000 = 1500 \text{ K}$$

20. (a)



$$V_1' = V_2 + 0.7(V_1 - V_2)$$
$$= V_2\,[1 + 0.7(r - 1)]$$

where, r is the compression ratio $= \dfrac{V_1}{V_2}$

Similarly, $$V_2' = V_2 + 0.3(V_1 - V_2)$$
$$= V_2\,[1 + 0.3(r - 1)]$$

So, $$\frac{V_1'}{V_2'} = \frac{1 + 0.7(r-1)}{1 + 0.3(r-1)} = 1.7$$

$$1.7 = \frac{0.3 + 0.7r}{0.7 + 0.3r}$$

$$0.3 + 0.7r = 1.19 + 0.51r$$

$$r(0.7 - 0.51) = 1.19 - 0.3$$

$$r(0.19) = 0.89$$

$$r = 4.68$$

21. (b)

During dissociation of combustion products at high temperature the heat is absorbed, in IC engines mainly dissociation of CO_2 into CO and O_2 occurs, whereas there is very little dissociation of H_2O. The presence of CO and O_2 in the gases tends to prevent dissociation of CO_2; this is noticeable in a rich-fuel mixture, which by producing more CO, suppresses dissociation of CO_2. So for equivalence ratio greater than 1 i.e. at rich mixture, dissociation reduces. On the other hand, there is no dissociation in the burnt gases of a lean fuel-air mixture. This is mainly due to the fact that the temperature produced is too low for this phenomenon to occur. Hence the maximum extent of dissociation occurs in the burnt gases at the chemically correct fuel-air mixture.

22. (b)

The period of rapid combustion is also called the uncontrolled combustion period. In this period knocking phenomenon occurs.

23. (c)

The cycle pressure increases when the engine output is increased. With the increased throttle opening the cylinder gets filled to a higher density. This results in increase in flame speed.

A decrease in output of the SI engine decreases the temperature of the cylinder and the combustion chamber walls and also the pressure of the charge thereby, lowering mixture and end gas temperatures. This reduces the tendency to knock.

24. (a)

As by using supercharger the pressure of incoming air-mixture is higher and it pushes the piston, and do work on piston.

26. (b)

The heating value generally increases as the proportion of hydrogen atoms to carbon atoms in the molecule increases due to higher heating value of hydrogen than carbon. Thus paraffins have the highest heating value and the aromatics have the least.

27. (c)

Time available for combustion is given as:

$$t = \frac{\text{Ignition advance}(d)}{360 \times N}$$

where, N is the rotational speed in rpm

So, for same t, $d \propto N$

For 2000 rpm speed, ignition advance should be 30°.

29. (a)

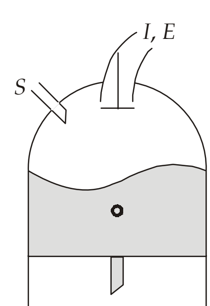
$$\text{Fuel consumed/hour} = 240 \times 10^{-3} \times 150 = 36 \text{ kg/h}$$

$$\text{Fuel consumed/cylinder} = \frac{36}{6} = 6 \text{ kg/ h}$$

$$\text{Fuel consumed/cycle} = \frac{6 \times 2}{60 \times 3000} = 6.66 \times 10^{-5} \text{ kg}$$

$$\text{Volume of fuel injected} = \frac{6.66 \times 10^{-5}}{0.80 \times 10^{3}} \times 10^{6} = 0.0833 \text{ cc/ cycle}$$

31. (a)



I-head type

I-head combustion chamber or overhead valve:

- Lower pumping losses and higher volumetric efficiency from better breathing of the engine from larger valves or valve lifts and more direct passage ways.
- Less distance for the flame to travel and therefore greater freedom from knock, or in other words, lower octane requirements.
- Less force on the head bolts and therefore less possibility of leakage.
- Lower surface to volume ratio and therefore, less heat loss and less air pollution.

32. (a)

$$\text{Brake power, BP} = \frac{2\pi NT}{60} = \frac{2\pi \times 2000 \times 300}{60} = 62.83 \times 10^3$$

$$= 62.83 \text{ kW}$$

$$\text{Indicated power, IP} = \frac{BP}{\eta_m} = \frac{62.83}{0.85} = 73.92 \text{ kW}$$

$$\text{Frictional power, FP} = \text{IP} - \text{BP}$$

$$= 73.92 - 62.83$$

$$= 11.09 \approx 11 \text{ kW}$$

33. (d)

Boiling and condensation heat transfer coefficients are generally much larger than those of convection heat transfer coefficients without phase change.

34. (c)

Temperature gradient always exist within the body, as to achieve zero temperature gradient we must have a material with infinite thermal conductivity and no such material is known to exist,

$$\text{Heat flux, } q_{\text{cond}} = -k\frac{dT}{dy}$$

k and $\frac{dT}{dy}$ are inversely proportional to each other for a given heat flux. Therefore the larger the thermal conductivity, the smaller the temperature gradient.

35. (c)

When $\frac{\text{Gr}}{\text{Re}^2} << 1$, then buoyancy forces are negligible and inertia forces are dominant therefore, forced convection must be considered.

36. (c)

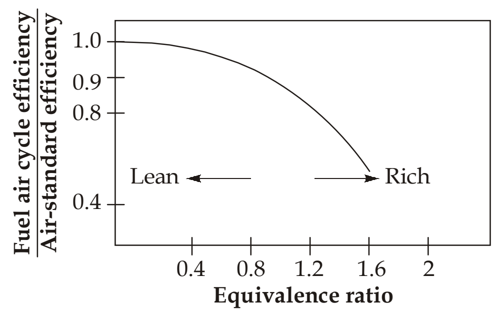
Vibration and unpleasant odour are the drawback of Diesel engines. Besides this drawback, Diesel engines are preferred in personal transportation due to high efficiency.

37. (d)

The naturally aspirated maximum *bmep* levels are higher for SI engine than CI engine because the maximum fuel-air ratio for SI engines is higher for the same size of engines.

38. (d)

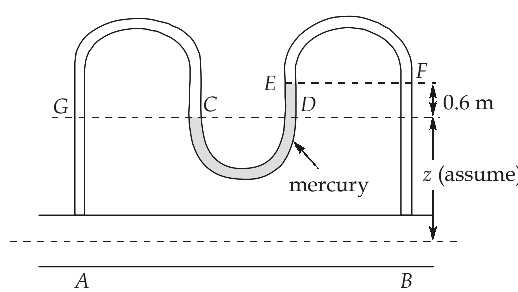
For lean air fuel mixture, the temperature rise is less, so it will lower the losses due to dissociation and variation in the specific heat. Therefore, losses will be less and efficiency will be high.



39. (b)

Surface tension is a binary property of liquid and gas or two liquids which are in contact with each other and bears an inverse relationship with temperature.

40. (c)



$$P_C(\text{Pressure at C}) = P_D(\text{Pressure at } D) \quad \text{... (i)}$$

Again,

$$P_C = P_G(\text{Pressure at } G) = P_A - \rho_w g z \quad \text{... (ii)}$$

$$P_D = P_E(\text{Pressure at } E) + \text{Pressure of column ED of mercury}$$

$$= P_F(\text{Pressure at } F) + \rho_m g(0.6)$$

$$= P_B - \rho_w g(z + 0.6) + \rho_m g(0.6) \quad \text{... (iii)}$$

From (i), (ii) and (iii)

$$P_A - \rho_w g z = P_B - \rho_w g\,(z + 0.6) + 0.6\rho_m g$$

$$(P_A - P_B) - \rho_w g z = -\rho_w g z - (0.6)\rho_w g + 0.6\rho_m g$$

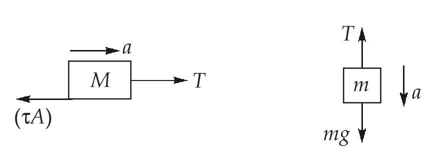
$$(P_A - P_B) = 0.6(\rho_m - \rho_w)g = 0.6 \times (13.57 - 1) \times 10^3 \times 9.81$$

$$= 0.6 \times 12.57 \times 9.81 \text{ kPa} = 74 \text{ kPa}$$

41. (b)

Assume, a = Acceleration of blocks and T = Tension in cord.

FBD →



$$T - \tau A = Ma$$

$$T = Ma + \tau A \quad \text{... (i)}$$

$$mg - T = ma$$

$$T = mg - ma \quad \text{... (ii)}$$

From (i) and (ii),

$$Ma + \tau A = mg - ma$$

$$a = \frac{mg - \tau A}{(M+m)}$$

From Newton's law of viscosity,

$$\tau = \mu \frac{V}{h}$$

$$\therefore \quad a = \left(\frac{m}{M+m}\right)g - \frac{\tau A}{(M+m)} = \left(\frac{m}{M+m}\right)g - \frac{\mu VA}{h(M+m)}$$

Putting given values, M = 4 kg, m = 1 kg, μ = 0.04 Pa.s, A = 25 cm^2, h = 0.5 mm, V = 5 m/s

$$a = \left(\frac{1}{4+1}\right)\times 10 - \frac{0.04\times 5\times 25\times 10^{-4}}{0.5\times 10^{-3}(4+1)}$$

$$= 2 - \frac{0.20\times 25\times 10^{-4}}{0.5\times 10^{-3}\times 5} = 2 - 0.2$$

$$a = 1.8 \text{ m/s}^2$$

42. (d)

Given: $u = 3x$ (Velocity along x-direction)

$v = -3y$ (Velocity along y-direction)

The equation of streamline in two-dimensional flow is:

$$\frac{dx}{u} = \frac{dy}{v}$$

$$\frac{dx}{3x} = \frac{dy}{-3y}$$

On integration,

$$\frac{1}{3}\ln x = -\frac{1}{3}\ln y + \frac{1}{3}\ln C$$

where C = Integration constant,

$$\ln(xy) = \ln C$$

$$xy = C$$

For streamline passing through (1, 1), $C = 1$

$$\therefore \quad xy = 1$$

43. (b)

Given: $\dot{Q} = 0.05\, l / \text{s}$, d_o = 0.5 cm, d_i = 1 cm, Δx = 10 cm

$$u_{\text{inlet}} = \frac{\dot{Q}}{\frac{\pi}{4}d_i^2} = \frac{0.05\times 10^{-3}}{\frac{\pi}{4}\times(0.01)^2} = \frac{5\times 10^{-5}\times 4}{\pi\times 1\times 10^{-4}} = \frac{2}{\pi}\text{ m/ s}$$

$$u_{\text{outlet}} = \frac{\dot{Q}}{\frac{\pi}{4}d_o^2} = \frac{0.05\times 10^{-3}}{\frac{\pi}{4}\times(0.005)^2} = \frac{8}{\pi}\text{ m/ s}$$

$$a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = u\frac{\partial u}{\partial x} = u_{avg}\frac{\Delta u}{\Delta x}$$

$$= \left(\frac{u_{\text{outlet}} + u_{\text{inlet}}}{2}\right)\left(\frac{u_{\text{outlet}} - u_{\text{inlet}}}{\Delta x}\right) = \frac{u^2_{\text{outlet}} - u^2_{\text{inlet}}}{2\Delta x}$$

$$a_x = \frac{\left(\frac{8}{\pi}\right)^2 - \left(\frac{2}{\pi}\right)^2}{2\times 0.1} = \frac{64-4}{\pi^2\times 0.2} = \frac{300}{\pi^2} = 30.39\ \text{m/s}^2$$

44. (d)

Given,

$$u = 0.5 + 0.8x$$
$$v = 1.5 - 0.8y$$
$$w = 0$$

$$\varepsilon_{xx} = \frac{\partial u}{\partial x} = 0.8\, s^{-1}$$

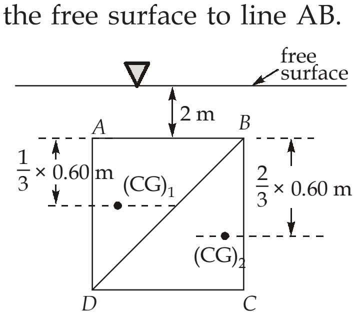
$$\varepsilon_{yy} = \frac{\partial u}{\partial y} = -0.8\, s^{-1}$$

$$\varepsilon_{xy} = \frac{1}{2}\left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right) = \frac{1}{2}(0+0) = 0$$

$$\text{Strain tensor} = \begin{pmatrix}\varepsilon_{xx} & \varepsilon_{xy}\\ \varepsilon_{yx} & \varepsilon_{yy}\end{pmatrix} = \begin{pmatrix}0.8 & 0\\ 0 & -0.8\end{pmatrix}\ \text{s}^{-1}$$

45. (d)

Let H be the distance down from the free surface to line AB.



$$\text{Area of ABD} = \text{Area of BCD} = A = \frac{1}{2}\times 0.6^2$$

$$A = 0.18 \text{ m}^2$$

$$\Delta F = F_{BCD} - F_{ABD}$$

$$= \left[\left(P_{atm} + \rho g \bar{h}_{CG_2}\right)A_{BCD} - \left(P_{atm} + \rho g \bar{h}_{CG_1}\right)A_{ABD}\right]$$

$$= \rho g A\left[\left(\bar{h}_{CG_2} - \bar{h}_{CG_1}\right)\right]$$

$$= 1000 \times 10 \times 0.18\left[\left(H + \frac{2}{3} \times 0.60\right) - \left(H + \frac{1}{3} \times 0.60\right)\right]$$

$$= 100 \times 18 \,[0.40 - 0.20] = 1800 \times 0.20$$

$$\Delta F = 360 \text{ N}$$

47. (b)

$$\frac{F_S}{F_L} = \frac{F_{B,\text{sea}} - W_{\text{boat}}}{F_{B,\text{lake}} - W_{\text{boat}}} = \frac{\rho_{\text{sea}} g V - mg}{\rho_{\text{lake}} g V - mg}$$

$$= \frac{(1.03 \times 1000 \times 180 - 8560)g}{(1000 \times 180 - 8560)g} = \frac{176840}{171440}$$

$$\frac{F_S}{F_L} = \frac{17684}{17144} = 1.03$$

48. (a)

Assuming, $P_A = P_C = P_{\text{atm}}$

$V_A \approx 0$ and datum at C.

Applying Bernoulli's equation between A and C,

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A = \frac{P_C}{\rho g} + \frac{V_C^2}{2g} + Z_C$$

$$Z_A = \frac{V_C^2}{2g}$$

$$V_C = \sqrt{2g \times 0.80} = 4 \text{ m/s}$$

$$t_{\text{minimum}} = \frac{Q_{\text{req}}}{\dot{Q}_{\text{siphon}}} = \frac{4 \times 10^{-3}}{\frac{\pi}{4} \times (0.005)^2 \times 4} = 50.929 \text{ second}$$

49. (a)

Governing of Pelton Turbine:

- When a turbine drives an electrical generator or alternator, the primary requirement is that the rotational speed of the shaft and hence that of the turbine rotor has to be kept fixed. Otherwise the frequency of the electrical output will be altered. But when the electrical load is changed depending upon the demand, the speed of the turbine changes automatically.

- This is because the external resisting torque on the shaft is altered while the driving torques due to change of momentum in the flow of fluid through the turbine remains the same. For example, when the load is increased, the speed of the turbine decreases and vice versa.
- Constancy in speed is therefore maintained by adjusting the rate of energy input to the turbine accordingly. This is usually accomplished by changing the rate of fluid flow through the turbine, the flow is increased when the load is increased and the flow is decreased when the load is decreased.

This adjustment of flow with the load is known as the governing of turbines.

50. (b)

Centrifugal pump is a radially outward flow pump which is reverse of radially inward flow reaction turbine.

For minimum starting speed, $$H_m \leq \frac{u_2^2 - u_1^2}{2g} \quad \text{... (i)}$$

Equation (i) represent, the amount of pressure difference in the impeller is large enough to overcome gross or manometric head.

52. (b)

Change in momentun in y-direction.

$$F_y = [\rho Q_1 V\sin\theta - \rho Q_2 V\sin\theta] - 0$$
$$F_y = \rho V(Q_1 - Q_2)\sin\theta$$

53. (b)

State 1,

For turbine, Power, $P_1 = 1000$ kW

Head, $H_1 = 40$ m

State 2,

For turbine, Power, $P_2 = ?$

Head, $H_2 = 20$ m

As we know, from unit power relation

$$\left(\frac{P}{H^{3/2}}\right)_1 = \left(\frac{P}{H^{3/2}}\right)_2$$

$$\frac{1000}{(40)^{3/2}} = \frac{P_2}{(20)^{3/2}}$$

$$P_2 = 1000\left(\frac{20}{40}\right)^{3/2} = 1000\times\left[\left(\frac{1}{2}\right)^3\right]^{1/2}$$

$$= 1000\times\left(\frac{1}{8}\right)^{1/2} = \frac{1000}{2.82} = 353.55 \text{ kW}$$

55. (a)

Given: N = 900 rpm, H_m = 16 m, D_2 = 360 mm, B_2 = 40 mm, ϕ = 30°, η_{mano} = 0.80

$$\eta_{mano} = \frac{H_m}{\frac{V_{w2}u_2}{g}}$$

$$\frac{V_{w2}u_2}{g} = \frac{16}{0.8}$$

$$\frac{V_{w2} \times \pi \times D_2 \times N}{60 \times g} = \frac{16}{0.8}$$

$$V_{w2} = \frac{16 \times 60 \times 9.81}{0.8 \times \pi \times 0.36 \times 900} = \frac{20 \times 60 \times 9.81}{\pi \times 0.36 \times 900}$$

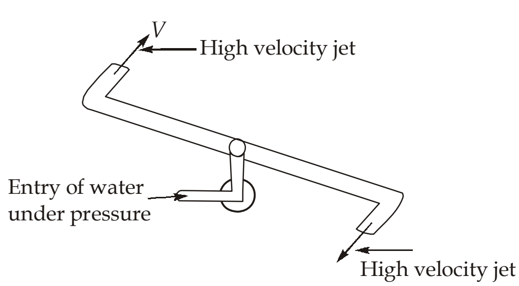
$$= \frac{40 \times 9.81}{\pi \times 30 \times 0.36} \approx 11.56 \text{ m/s}$$

56. (c)

- The parameter characterizing the proportion of changes in the dynamic and static head in the rotor of a fluid machine is known as degree of reaction.
- It is defined as the ratio of energy transfer by the change in static head to the total energy transfer in the rotor.

$$R = \frac{\frac{1}{2g}\left[\left(U_1^2 - U_2^2\right) + \left(V_{r2}^2 - V_{r1}^2\right)\right]}{H}$$

- A machine with any degree of reaction must have an enclosed rotor so that the fluid cannot expand freely in all direction.
- A simple example of a reaction machine can be shown by the familiar lawn sprinkler, in which water comes out at a high velocity from the rotor in tangential direction. The essential feature of the rotor is that water enters at high pressure and its high pressure energy is transformed into kinetic energy by a nozzle which is a part of the rotor itself.



57. (c)

- For fluid machine, geometrical similarity must apply to all significant parts of the system i.e. the rotor, the entrance and discharge passages and so on.
- Machines which are geometrically similar form a homologous series.
- Statements 2 and 3 are the major advantage of principle of similarity of machines.

58. (c)

For Pelton wheel,
$$\eta_h = 2[1+k\cos\phi]\left[1-\frac{u}{V_1}\right]\left[\frac{u}{V_1}\right]$$

$$\frac{d\eta_h}{d\left(\frac{u}{V_1}\right)} = 2[1+k\cos\phi]\left[1-2\frac{u}{V_1}\right] = 0$$

$$\frac{u}{V_1} = \frac{1}{2}$$

59. (a)

Maximum material condition of hole = Lower limit of hole = 50.00 mm

Maximum material condition of shaft = Upper limit of shaft

= 50 – 0.05 = 49.95 mm

Maximum clearance = Upper limit of hole – Lower limit of shaft

= 50.02 – (50 – 0.08)

= 0.1 mm

Minimum clearance = Lower limit of hole – Upper limit of shaft

= 50.00 – (50 – 0.05)

= 0.05 mm

Since the minimum clearance is positive it can be concluded that the given pair has a clearance fit.

60. (b)

$$\text{Frictional energy proportion} = \frac{\text{Frictional energy}}{\text{Total energy}} = \frac{FV_C}{F_C V} = \frac{F\times r}{F_C}$$

where, r = Chip thickness ratio = $\dfrac{\text{Chip velocity},(V_C)}{\text{Cutting velocity},(V)}$

F is friction force and F_C is the cutting force.

We know that, $F = F_C \sin\alpha + F_T \cos\alpha$

$F = 500 \sin 0° + 200 \cos 0° = 200$ N

$$r = \frac{\text{Uncut chip thickness}}{\text{Chip thickness}} = \frac{t}{t_C} = \frac{0.1}{0.25} = 0.4$$

$$\text{Frictional energy \%} = \left(\frac{F\times r}{F_C}\right)\times 100 = \left(\frac{200\times 0.4}{500}\right)\times 100 = 16\%$$

61. (a)

For oblique cutting, the effective rake angle is given by:

$$\alpha_e = \sin^{-1}[\sin^2(i) + \cos^2(i)\sin(\alpha_n)]$$

where α_e = Effective rake angle, i = Inclination angle, α_n = Normal rake angle.

So, if i increases, effective rake angle increases and thus chip becomes thinner and longer.

62. (d)

Bismuth: It is used in place of lead which lowers the shear stress in primary shear.

Sulphur: It forms manganese sulfide inclusion and these particles act as stress raiser in primary shear zone as a result chips produced is small and improves machinability.

Phosphorus: It improves machinability by virtue of the hardness of steel and produces less continuous chips.

64. (c)

The assumption for Merchant's model is that width of the tool is greater than width of the work.

65. (a)

We know that

$$\tan(\beta - \alpha) = \frac{F_T}{F_C} = \frac{1000}{1732} = 0.577 = \frac{1}{\sqrt{3}}$$

$$\beta - \alpha = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) = 30°$$

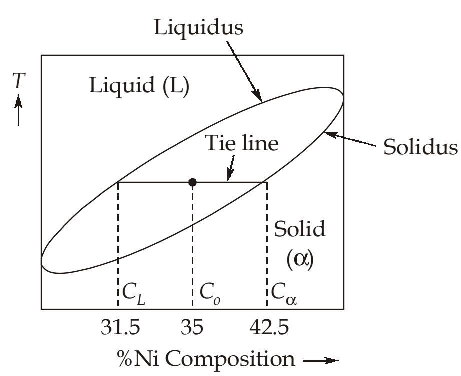
$$\beta = 30° + 10° = 40°$$

According to Merchant analysis,

$$\phi = \frac{\pi}{4} + \frac{\alpha}{2} - \frac{\beta}{2} = 45° + \frac{10°}{2} - \frac{40°}{2} = 30°$$

66. (c)

For the tie line shown below:



$$W_\alpha = \frac{C_o - C_L}{C_\alpha - C_L} = \frac{35 - 31.5}{42.5 - 31.5} = \frac{3.5}{11} = 0.318 \approx 32\%$$

$$W_\alpha = 32\%$$

$$W_L = \frac{C_\alpha - C_o}{C_\alpha - C_L} = \frac{42.5 - 35}{42.5 - 31.5} = \frac{7.5}{11} = 0.682 \approx 68\%$$

$$W_L \approx 68\%$$

67. (b)

Careful surface preparation of specimen like grinding and polishing may be necessary to ensure a well-defined indentation that may be accurately measured.

68. (a)

Three basic factors contribute to a brittle-cleavage type of fracture. They are:

1. Triaxial state of stress,
2. A low temperature
3. A high strain rate or rapid rate of loading.

Triaxial state of stress, existing at a notch and low temperature are responsible for most service failures of brittle type. Since, these effects are accented at a high rate of loading, various types of notched bar impact tests have been used to determine the susceptibility of materials to brittle fracture.

Thus, notch in the specimen provides triaxiality of stress and the high hammer velocity insures a high strain rate.

69. (a)

$$\text{Offset, } S = L\frac{(D-d)}{2l}$$

where, L is the total length and l is length in which taper is done.

So, $$S = \frac{300(75-60)}{2\times 200} = 11.25 \text{ mm}$$

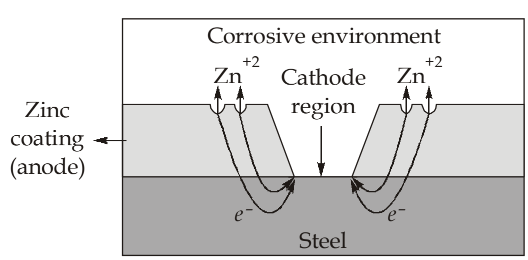
70. (b)

We know, that, $$t_c = RC\ln\frac{V_S}{(V_S-V_d)} = 40\times 20\times 10^{-6}\ln\left(\frac{220}{220-110}\right)$$

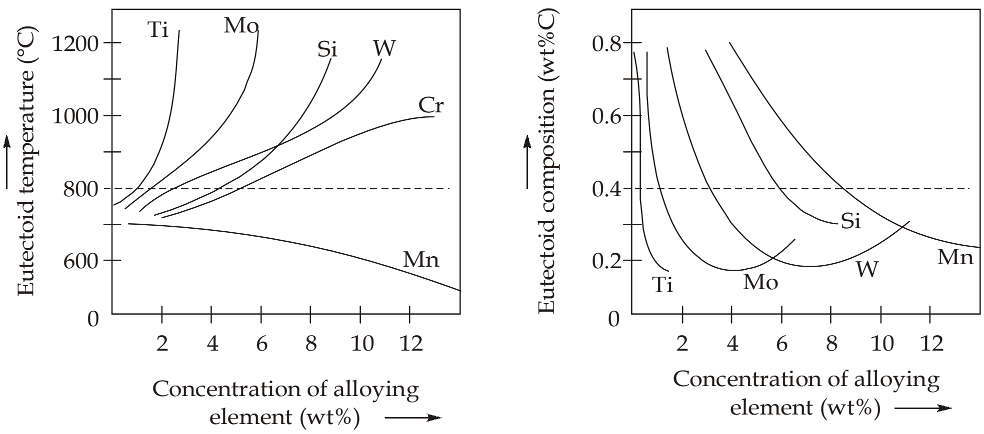
$$= 40 \times 20 \times 10^{-6} \times \ln(2)$$
$$= 8 \times 10^{-4} \times 0.6932$$
$$= 0.55 \times 10^{-3} \text{ s}$$
$$= 0.55 \text{ millisecond}$$

71. (a)

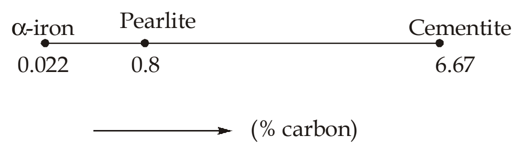
In the process of galvanizing a layer of zinc is applied to the surface of steel by hot dipping. In the atmosphere and most aqueous environments, zinc is anodic to and will thus cathodically protect the steel if there is any surface damage. Any corrosion of zinc coating will proceed at an extremely slow rate because the ratio of anode to cathode surface area is quite large. When anode area is large relative to cathode, then current density (current per unit area) will be low and thus galvanic corrosion rate decreases.



72. (a)



73. (c)



By Lever rule:

$$\% \text{ cementite} = \frac{0.8 - 0.022}{6.67 - 0.022} \times 100 = 11.70\% \approx 12\%$$

74. (a)

Shaft basis system is normally preferred where the hole dimensions is dependent on the shaft dimensions and is used in situations where the standard shaft determines the dimensions of the mating parts such as coupling, bearings, collars, gears and bushing.

75. (c)

A strong reducing agent promotes a fast reduction reaction and if the reaction is fast, generally small nanoparticles are formed.

A strong reducing agent generates an abrupt surge of the concentration of growth species resulting in a very high supersaturation. Consequently, a very large number of nuclei are formed initially. For a given concentration of metal precursor, the formation of a large number of nuclei results in small size of nanoparticles.

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