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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 8

Section A : Heat Transfer + IC Engines
Section B : Fluid Mechanics and Turbo Machinery-1
Section C : Production Engineering & Material Science-2

ANSWER KEY

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

Section A : Heat Transfer + IC Engines

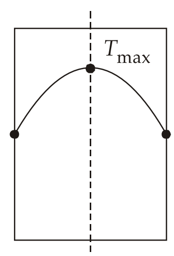
1. (d)

Heisler Charts are used for transient heat conduction in solids with the following assumptions, uniform initial temperature, one-dimensional heat conduction, negligible internal heat generation, and biot number (Bi ≤ 0.1).

2. (a)

Energy balance:

$$Q_{gen} = Q_{conv}$$
$$q_g AL = 2h(A)(T_S - T_\infty)$$
$$1 \times 10^5 \times (0.02) = 2 \times 60 \times (T_S - 25)$$
$$T_S = 41.67°C$$



3. (c)

$$L = \frac{V}{A} = \frac{\frac{4}{3}\pi r^3}{4\pi r^2} = \frac{r}{3} = \frac{d}{6} = \frac{0.001}{6} = 1.67 \times 10^{-4}\,\text{m}$$

$$\text{Bi} = \frac{hL}{k} = \frac{200 \times 1.67 \times 10^{-4}}{30} = 1.11 \times 10^{-3} < 0.01$$

Since, Bi < 0.1, lumped system analysis can be used

$$\therefore \quad \frac{T(t) - T_\infty}{T_i - T_\infty} = e^{-\frac{hAt}{\rho Vc}} = 0.01$$

$$\frac{hAt}{\rho Vc} = \ln 100 = 4.605$$

$$\Rightarrow \quad t = \frac{4.605 \times 10^3 \times 300 \times 1.67 \times 10^{-4}}{200}$$

$$t = 1.15 \text{ sec}$$

4. (b)

$$Q = q_G \times V = q_G \times \frac{4}{3}\pi R^3$$

Also,

$$Q = hA\,(T_w - T_\infty)$$

$$10 \times 4\pi \times (1)^2 \times (T_w - 25) = 2 \times 10^3 \times \frac{4}{3}\pi \times (1)^3$$

$\therefore$ $$T_w = 25 + \frac{2 \times 10^3}{3 \times 10}$$

or, $$T_w = 91.66°C$$

5. (a)

Given:
$$r_1 = 3 \text{ cm} ; T_1 = 100°C$$
$$r_2 = 6 \text{ cm} ; T_2 = 50°C$$
$$k = \frac{1}{3}[1 + 0.1T]$$
$$k_{avg} = \frac{1}{3}\left[1 + 0.1\left(\frac{100+50}{2}\right)\right] = 2.833 \text{ W/mK}$$
$$Q = \frac{T_1 - T_2}{\frac{1}{2\pi k_{avg} L}\ln\left(\frac{r_2}{r_1}\right)}$$
$$= \frac{100 - 50}{\frac{1}{2\pi \times 2.833}\ln\left(\frac{6}{3}\right)} = 1283.36 \text{ W/m}$$
$$= 1.28336 \text{ kW/m}$$

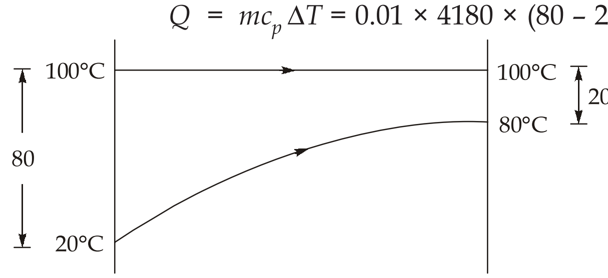
6. (a)

Water at mean bulk temperature $= \frac{20+80}{2} = 50°C$

$$Nu_d = 3.657 = \frac{hd}{k}$$
$$h = \frac{3.657 \times 0.638}{0.1}$$
$$h = 23.3316 \text{ W/m}^2\text{K}$$

7. (a)

$$Q = mc_p \Delta T = 0.01 \times 4180 \times (80 - 20) = 2508 \text{ W}$$



$$\text{LMTD} = \frac{80 - 20}{\ln\left(\frac{80}{20}\right)} = \frac{60}{\ln 4} = 43.28$$

Taking log-mean temperature difference

$$Q = hA\,(\text{LMTD})$$
$$= h \times \pi DL\ (\text{LMTD})$$
$$= 23.3316 \times \pi \times 0.1 \times L \times 43.28$$

or $$317.074L = 2508$$
$$L = 7.9 \text{ m} \simeq 8 \text{ m}$$

8. (b)

Reynold number at other side of the plate,

$$Re = \frac{\rho VL}{\mu} = \frac{0.1\times 4}{0.65\times 10^{-4}} = 6154$$

Since Reynold's number is less than 5×10^5, hence flow is laminar in nature.

$$\delta = \frac{5x}{\sqrt{\text{Re}}} = \frac{5\times 4}{\sqrt{6154}} = 0.2549 \text{ m}$$
$$\frac{\delta}{\delta_{th}} = (\text{Pr})^{1/3}$$
$$= \frac{0.2549}{(903)^{1/3}} = 0.02637$$
$$= 26.37 \text{ mm} \simeq 26 \text{ mm}$$

9. (c)

We know, $$h = \frac{-k\left.\dfrac{dT}{dy}\right|_{y=0}}{(T_s - T_\infty)}$$

$$\left.\frac{dT}{dy}\right|_{y=0} = (T_\infty - T_s)\cos\left(\frac{\pi y}{6}\right)\cdot\frac{\pi}{6}$$

$$\left.\frac{dT}{dy}\right|_{y=0} = (T_\infty - T_s)\cdot\frac{\pi}{6}$$

Now, $$h = \frac{-k(T_\infty - T_s)\cdot\frac{\pi}{6}}{(T_s - T_\infty)}$$

$$h = k\cdot\frac{\pi}{6} = 18\cdot\frac{\pi}{6} = 3\pi$$

10. (c)

In case of turbulent tube flow,

$$\overline{Nu} = \frac{\bar{h}D}{k} = 0.023\times(\text{Re})^{0.8}(\text{Pr})^{0.33}$$

$$\bar{h} = \frac{k}{D}\times 0.023(\text{Re})^{0.8}(\text{Pr})^{0.33}$$

When the flow velocity and the fluid properties remain unchanged

$$\bar{h} \propto \frac{1}{D^{0.2}}$$

$$\frac{\bar{h}_2}{\bar{h}_1} = \left(\frac{D_1}{D_2}\right)^{0.2} = \left(\frac{1}{2}\right)^{0.2}$$

11. (a)

The heat loss is given by both sides of the plate,

$$Q = \bar{h}(2A)\Delta T$$

$$Q = 2 \times (4.85 \times (1 \times 0.5) \times (130 - 20))$$

$$Q_{total} = 533.5 \text{ W}$$

12. (b)

The instantaneous heat lost by the plate is

$$2 \times h \times A \times (t - t_\infty) = -mc_p \frac{dt}{d\tau}$$

$$= -\frac{mc_p}{2hA}\int_{t_1}^{t_2} \frac{dt}{(t - t_\infty)} = \int_o^\tau d\tau = -\frac{mc_p}{2hA}\ln\left(\frac{t_2 - t_\infty}{t_1 - t_\infty}\right) = \tau$$

$$\tau = -\frac{20 \times 400}{2 \times 5 \times 1}\ln\left(\frac{80 - 30}{180 - 30}\right) = 800\ln(3)$$

$$\tau = 878.89 \text{ sec}$$

13. (b)

$$\frac{E_A}{E_B} = \frac{\sigma A_A T_A^4}{\sigma A_B T_B^4} = \frac{4\pi R_A^2 T_A^4}{4\pi R_B^2 T_B^4}$$

$$10^4 = (400)^2\left(\frac{T_A}{T_B}\right)^4$$

$$\frac{T_A}{T_B} = \left(\frac{10^4}{(400)^2}\right)^{0.25}$$

Wein's displacement law, $\lambda_A T_A = \lambda_B T_B$

$$\therefore \quad \frac{\lambda_A}{\lambda_B} = \frac{T_B}{T_A} = 2$$

14. (c)

For balanced counterflow heat exchanger, $c = 1$

$$\in = \frac{NTU}{1 + NTU} = \frac{5}{1+5} = \frac{5}{6} = 83.33\%$$

15. (a)

$$q = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\frac{1}{\in_1} + \frac{1}{\in_2} - 1} = \frac{5.67 \times 10^{-8} \times \left(1500^4 - 1200^4\right)}{\frac{1}{0.4} + \frac{1}{1} - 1}$$

$$= 67.78 \text{ kW}$$

16. **(a)**

The heat radiated without shield, $q_1 = \sigma(T_1^4 - T_2^4)$ ($\because \in = 1$, black body)

When radiation shield is inserted, the effective heat transfer is

$$q_2 = \frac{q_1}{\left(\frac{1}{\in_1}+\frac{2}{\in_s}+\frac{1}{\in_2}-2\right)} = \frac{q_1}{2/0.6}$$

$$\frac{q_1}{q_2} = \frac{2\times 10}{6} = \frac{10}{3}$$

17. **(b)**

Nucleate boiling :

- The stirring and agitation caused by the entrainment of the liquid to the heater surface is primarily responsible for the increased heat transfer coefficient and heat flux.
- The condition of the heater surface greatly affects heat transfer.
- A lower viscosity allows bubbles to rise more freely, enhancing heat transfer.

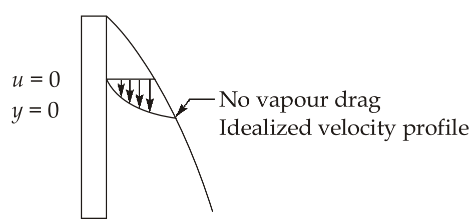
18. **(b)**

The Leidenfrost point is the temperature beyond which a stable vapour film forms, marking the transition from nucleate boiling to film boiling.

19. **(a)**

A fin made of high thermal conductivity material is more efficient as it maintains a more uniform temperature along it's length.

20. **(b)**



The velocity of the vapour is low so that it exerts no drag on the condensate, flow of the condensate is laminar, velocity of liquid remain uniform, hence gradient becomes zero.

21. **(a)**

$f_{11} = 0,$

$$f_{11} + f_{12} = 1$$

$$f_{12} = 1$$

$$f_{12}\,A_1 = f_{21}\,A_2$$

$$1\times\frac{\pi d^2}{4} = f_{21}\times 2\pi\left(\frac{d}{2}\right)^2$$

$$\frac{\pi d^2}{4} = f_{21}\times 2\pi\frac{d^2}{4}$$

$$f_{21} = \frac{1}{2}$$

$$f_{21} + f_{22} = 1$$

$$\therefore \quad f_{22} = \frac{1}{2}$$

22. (b)

$$\eta_m = \frac{bp}{ip} = 0.8$$

$$fp = ip - bp = 30$$

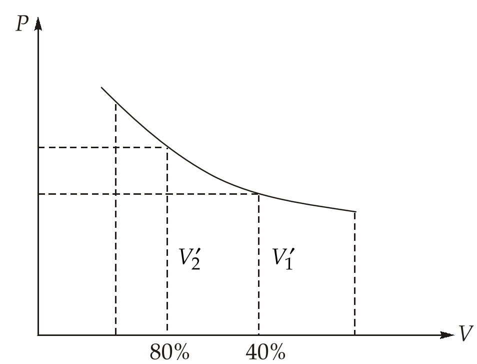
$$ip - 0.8\,ip = 30$$

$$0.2\,ip = 30$$

$$ip = 150 \text{ kW}$$

$$bp = 0.8 \times 150 = 120 \text{ kW}$$

23. (a)



Let

$$V_2 = 1$$

$$V_1' = 1 + 0.6(r - 1) = 0.6r + 0.4$$

$$V_2' = 1 + 0.2(r - 1) = 0.2r + 0.8$$

Now,

$$\frac{V_1'}{V_2'} = \left(\frac{P_2}{P_1}\right)^{1/n} = \left(\frac{3}{1.5}\right)^{1/1.5} \simeq 1.6$$

or,

$$\frac{0.6r + 0.4}{0.2r + 0.8} = 1.6$$

or,

$$r = 3.14$$

24. (d)

25. (b)

$$\text{Brake power, BP} = \frac{2\pi N T_b}{60} = \frac{2\pi \times 2000 \times 300}{60} = 62.83 \text{ kW}$$

$$\eta_m = \frac{BP}{IP}$$

$$IP = \frac{BP}{\eta_B} = \frac{62.83}{0.85} = 73.92 \text{ kW}$$

26. (a)

Centrifugal supercharger is only suitable for low speed. The required characteristics of a centrifugal type supercharger is poor and suitable for only low speeds. The root's supercharger is simple in construc-tion, requires only minimum maintenance and has longer life. The vane type supercharger has a special problem of wear of tips of the vanes with time.

27. (b)

$$P = \frac{2\pi NT}{60000} = \frac{P_{bm}LAn}{60000}$$

$$P_{bm} = \frac{2\pi NT}{LAn} = \frac{2\pi NT}{L \times \frac{\pi}{4} \times D^2 \times \frac{N}{2}} = \frac{16T}{D^2 L}$$

$$= \frac{16 \times 20}{0.07^2 \times 0.1} = 6.5 \text{ bar}$$

28. (c)

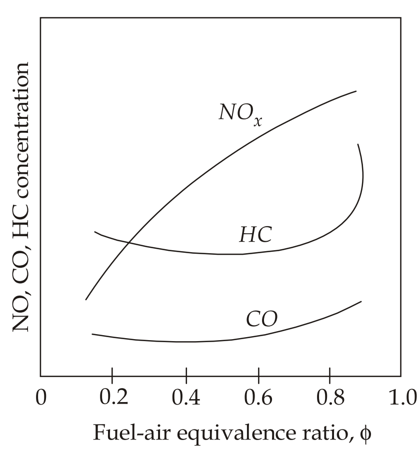
Particulates matter (PM) are mainly emitted from CI engine.

29. (c)

High HC emissions during engine startup occur due to incomplete combustion caused by a rich air-fuel mixture, cold cylinder walls, poor fuel atomization, and weak ignition. Additionally, the catalytic converter is inactive at low temperatures, failing to reduce emissions effectively. As the engine warms up, HC emissions decrease

30. (b)

31. (a)



Emissions as a function of equivalence ratio for a CI engine

32. (b)

We know,

$$\text{Mass flow of air} = \frac{\text{Mass flow of fuel}}{\text{Fuel-air ratio}}$$

$$= \frac{30}{0.05 \times 60} = 10 \text{ kJ/min}$$

$$\eta_{sc} = \frac{\text{Mass flow of air}}{\text{Theoretical mass flow rate}}$$

$$= \frac{10}{15} = 0.667$$

33. (d)

34. (b)

35. (a)

Blowby in an IC engine refers to leakage of combustion gases past the piston rings into crank case, and position of top ring and quenching of gases directly impact the sealing efficiency of combustion chamber and reduce gas leakage.

36. (a)

$$\text{bsfc} = \frac{\dot{m}_f}{bp} = \frac{6}{100} = 0.06 \text{ g/kWs}$$

$$= \frac{0.06}{1000} \times 3600 = 0.216 \text{ kg/kWh}$$

37. (a)

Section B : Fluid Mechanics and Turbo Machinery-1

38. (d)

39. (a)

- Even if the flow is unsteady (velocity changes with time), as long as ρ is constant, the equation remain valid.
- General form of the continuity equation for a fluid flow is

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \left(\rho \vec{V}\right) = 0$$

40. (b)

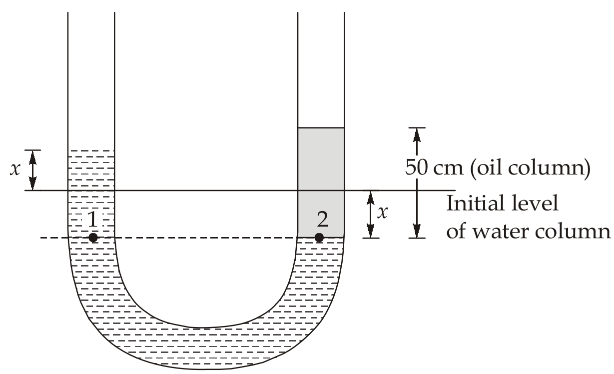
- At the wall ($y = 0$), the velocity u is zero due to the no-slip condition, but the velocity gradient $\frac{\partial u}{\partial y}$ is maximum.
- As y increases, the velocity u increases, the gradient $\frac{\partial u}{\partial y}$ decreases.

- For from the wall, in the freestream region, the velocity gradient approaches zero, as the velocity become constant at the freestream value, i.e. U_∞.
- The correct graph should show a high velocity gradient at the wall, and decreasing with distance from the wall.

41. (d)

$$W = \sigma \times \text{Surface area} \times 2 \quad [\because \text{ Soap bubble has 2 free surfaces}]$$
$$W = 0.05 \times 4\pi(R)^2 \times 2$$
$$W = 0.05 \times 4\pi \times (0.075)^2 \times 2$$
$$= 7.068 \times 10^{-3} \text{ Nm}$$

42. (b)



$$P_1 = P_2$$
$$1 \times 2x = 0.8 \times 50$$
$$x = 20 \text{ cm}$$

43. (b)

Distance of center of area from free surface = $2.5 + \frac{D}{2} = D$

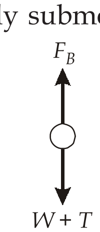
Distance between center of pressure and center of area

$$= \frac{I}{A\bar{x}} = \frac{\frac{\pi D^4}{64}}{\frac{\pi D^2}{4} \times D} = \frac{D}{16}$$

$$= \frac{5}{16} \times 1000 = 312.5 \text{ mm}$$

44. (b)

FBD of the spherical body when it is fully submerged.



$$T = 10 \times \frac{\pi}{6} \times 3^3 - 8$$
$$= 133.37 \text{ kN}$$

45. (a)

$$u = x^2 + y^2$$
$$u(1, 2) = 1^2 + 2^2 = 5 \text{ m/s}$$
$$v = 2xy$$
$$v(1, 2) = 2 \times 1 \times 2 = 4 \text{ m/s}$$
$$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = 5(2x) + 4(2y)$$
$$a_x(1, 2) = 10 \times 1 + 4 \times 2 \times 2 = 26 \text{ m/s}^2$$
$$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = 5(2y) + 4(2x)$$
$$a_y(1, 2) = 10 \times 2 + 8 \times 1 = 28 \text{ m/s}^2$$
$$\therefore \quad \vec{a}_{conv} = 26\hat{i} + 28\hat{j}$$

46. (d)

47. (b)

Equation for parabolic velocity profile can be represent as

$$u = a + by + cy^2$$

Boundary conditions are:

(i) at $y = 0$; $u = 0 \Rightarrow a = 0$

(ii) at $y = 20$ cm; $\frac{du}{dy} = 0 = b + 2cy$

$$\Rightarrow \quad -2c \times 20 = b$$
$$\Rightarrow \quad b = -40c \quad \text{...(i)}$$

(iii) at $y = 20$ cm; $u = 90$ cm/s

$$90 = -40c \times 20 + c(20)^2; \quad [b = -40c]$$
$$\Rightarrow \quad 90 = -800c + 400c$$
$$\Rightarrow \quad c = -\frac{90}{400} = -\frac{9}{40}$$
$$\Rightarrow \quad \left(\frac{du}{dy}\right)_{y=10\text{ cm}} = b + 2cy = -40c + 20c \quad \text{from equation (i)}$$
$$= -20c$$
$$= +20 \times \frac{9}{40}$$
$$\left(\frac{du}{dy}\right)_{y=10\text{ cm}} = 4.5 \text{ sec}^{-1}$$

48. (a)

$$F = \rho(v - u)^2 A$$
$$= 10^3(30 - 10)^2 \times 0.005$$
$$= 5 \times 400 = 2000 \text{ N} = 2 \text{ kN}$$

49. (d)

$$u \propto DN$$
$$u \propto \sqrt{H}$$
$$\frac{\sqrt{H}}{N} = \text{Const}$$
$$\frac{\sqrt{25}}{1000} = \frac{\sqrt{H_2}}{2000}$$
$$\sqrt{H_2} = 5 \times 2$$
$$H_2 = 100 \text{ m}$$

50. (c)

- NPSH is the difference between the absolute pressure at the pump suction and the vapour pressure of the liquid at operating temperature.
- Available NPSH is provided by the system and depends on factor like suction head, pipe friction and atmospheric pressure.
- Required NPSH is the minimum NPSH needed by the pump to avoid cavitation.
- For cavitation free operation, the available NPSH must be greater than the required NPSH. If the available NPSH is less, cavitation will occur, damaging the pump.

51. (b)

A draft-tube is a diverging passage fitted at the outlet of a reaction turbine to

1. Recover kinetic energy of the water exiting the turbine.
2. Reduce the velocity of discharged water, converting kinetic energy into pressure energy.
3. Establish a negative pressure head at the exit, improving the efficiency of the turbine.

52. (a)

Using 1st CR-equation,

$$\frac{\partial \phi}{\partial x} = \frac{\partial \psi}{\partial y}$$
$$2x + y = \frac{\partial \psi}{\partial y}$$
$$\psi = 2xy + \frac{y^2}{2} + f(x)$$

Using 2nd CR-equation to find $f(x)$

$$\frac{\partial \phi}{\partial y} = -\frac{\partial \psi}{\partial x}$$

$$x - 2y = -(2y + f'(x))$$
$$x = -f'(x)$$
$$f(x) = -\frac{x^2}{2} + c$$

So,
$$\psi = 2xy + \frac{y^2}{2} - \frac{x^2}{2} + c$$

53. (b)

$$u = k_u\sqrt{2gH} = 0.48\sqrt{2 \times 10 \times 1125}$$
$$= 0.48 \times 150 = 72 \text{ m/s}$$

54. (c)

55. (a)

56. (c)

Even if the fluid were non-viscous (ideal fluid), slip would still occur due to the following reasons:

1. **Non-Ideal Flow Patterns:** The flow in an impeller does not follow the exact theoretical streamline pattern assumed in ideal cases. Due to the finite number of blades, fluid particles do not move exactly along the blade curvature, leading to deviation from the ideal flow path.
2. **Finite Number of Blades (Blade Loading Effect):** In an ideal case (infinite blades), the fluid would perfectly follow the blade curvature, achieving the theoretical head. In real pumps with a finite number of blades, the flow deviates from the blade angle, causing a reduction in energy transfer.
3. **Secondary Flow and Circulation:** Even in inviscid flow, secondary circulations can develop within the impeller passages due to blade curvature and pressure variations. This alters the velocity triangle at the impeller exit, leading to slip and a reduction in head.

Final Conclusion: Slip is not solely dependent on viscosity; rather, it results from the complex flow field within the impeller, blade loading effects, and secondary flow patterns. Even in a non-viscous fluid, slip would still occur due to these fundamental hydrodynamic effects.

Section C : Production Engineering & Material Science-2

57. (b)

Graphene is a single layer of carbon atoms arranged in a hexagonal lattice. It has exceptional electrical, thermal and mechanical properties, making it a revolutionary material in various applications like electronics, composites and energy storage.

58. (a)

- The grain size determines the material removal rate and surface finish. Coarse grains remove material faster but produce a rougher finish, while fine grains provide a smoother finish.
- The structure of a grinding wheel refers to the spacing between abrasive grains, which influences chip clearance, heat dissipation and overall grinding performance.

- Vitrified bond grinding wheels are rigid and brittle, offering high precision but little flexibility. Resin bond grinding wheels are more flexible and impact-resistant, making them suitable for high speed grinding and heavy material removal.

59. (a)

- An eutectic alloy has an unique composition at which it solidifies at a single temperature, known as the eutectic temperature, transitioning directly from liquid to solid without forming a mushy zone (two-phase mixture).
- A peritectic reaction occurs when a liquid and a solid react at a specific composition and temperature to form a new solid phase. This is different from eutectic and eutectoid reactions at fixed compositions.

60. (c)

61. (c)

- Circularity (roundness) control the deviation of a circular profile from a perfect circle.
- Perpendicularity controls the 90 degree angular relationship between two surfaces or features.
- Flatness is a form tolerance that ensures a surface lies within two parallel planes without deviation.
- Concentricity ensures that multiple circular features share a common central axis.

62. (b)

- Brass is an alloy of copper and zinc known for its good electrical conductivity, corrosion resistance and machinability. However, it is not the best choice for marine applications, as it is susceptible to dezincification (corrosion in sea water) over time.
- Stainless steel, particularly marine-grade 316 stainless steel contains chromium, nickel and molybdenum, providing excellent corrosion resistance in sea water and harsh environments. Due to it's strength and durability it used in ship building, marine structures, underwater pipelines and chemical processing equipments.
- Duralumin is an alloy of aluminium, copper, manganese and magnesium known for its high strength to weight ratio. It is extensively used in the aerospace and automotive industries but lacks the corrosion resistance required for marine applications.
- Invar is an iron-nickel alloy with a very low coefficient of thermal expansion, making it ideal for precision instruments, measuring devices and optical equipment.

63. (a)

Both Statement (I) and Statement (II) are correct and Statement (II) directly explains why climb milling produces a better surface finish, the gradual chip reduction results in lower forces and smoother cutting action.

64. (a)

Statement II correctly explains the statement I because the overlapping tolerance zones are what cause the fit to sometimes have clearance and sometimes have interference.

65. (c)

- Some materials, like certain polymers, may have UTS less than yield strength due to strain hardening behaviour.

- Brittle materials have low elongation before fracture.
- Impact strength is the ability of a material to absorb energy during fracture. It is measured using Charpy and Izod impact tests.

66. (c)

- Ferrite (α-Fe) is a BCC phase and has very low carbon solubility, maximum solubility is 0.022% carbon at 727°C.
- Austenite (α-Fe) is an FCC phase, and has maximum solubility is 2.1% at 1147°C.
- Cementite is a hard, brittle intermetallic compound with 6.67% carbon.

67. (b)

- Brittle fracture : SCC often leads to sudden brittle failure, even in materials that are normally ductile due to localized crack propagation.
- Ductile failure of metals : In some cases, SCC can result in a ductile failure mode if the material undergoes significant plastic deformation before failure.
- Loss in elongation of metals : SCC reduces the material's ability to deform plastically, leading to a loss in ductility and elongation.

68. (c)

h = 0.1 mm, p = 15 mm

$$\text{Length of broach} = \left[\frac{\left(\frac{D_2 - D_1}{2}\right)}{h}\right] p$$

$$= \left[\frac{\left(\frac{32-20}{2}\right)}{0.1}\right] \times 15 = 900 \text{ mm}$$

$$\text{Machining time} = \frac{t + l_b}{V}$$

$$= \frac{40+900}{5\times 10^3} \times 60 = 11.28 \text{ sec}$$

69. (b)

$$\text{Time for one forward stroke} = \frac{l}{v_f} = \frac{300}{10\times 10^3} \text{min}$$

$$= \frac{3}{100} \text{min}$$

$$\text{Time for one return stroke} = \frac{3}{100} \times 0.6 = \frac{1.8}{100} \text{min}$$

$$\text{Time for one complete stroke} = \frac{3}{100} + \frac{1.8}{100} = \frac{4.8}{100} \text{min}$$

$$\text{Stoke per min} = \frac{100}{4.8}\text{spm}$$

$$\text{Machining time, } t_m = \frac{b}{fN} = \frac{100}{\frac{100}{4.8}\times 1} = 4.8 \text{ min}$$

70. (b)

$$\text{MRR} = \frac{\pi D^2}{4}\times\frac{fN}{60}$$

$$\text{Power} = \frac{MRR\times U}{\eta} = T\times\omega$$

$$\Rightarrow \quad \frac{\frac{\pi D^2}{4}\times\frac{fN}{60}\times U}{\eta} = T\times\frac{2\pi N}{60}$$

$$T = \frac{\frac{D^2}{4}\times f\times U}{2\eta} = \frac{\frac{25^2}{4}\times 0.3\times 3}{2\times 0.9} = 78.125 \text{ N-m}$$

71. (b)

Maximum MRR will be achieved, when cutter cover total width of workpiece.

$$\text{MRR} = (b\cdot d)\cdot(fZN)$$

$$= (40\times 5)\times 0.1\times 10\times\frac{31.4\times 10^3}{\pi\times 100}$$

$$= 19989 \text{ mm}^3/\text{min} \simeq 20 \text{ cc/min}$$

72. (c)

After electro-plating,

Minimum hole diameter = 50.020 – 0.030 × 2
= 49.960 mm

Maximum shaft diameter = 50.000 – 0.010
= 49.990 mm

Maximum interference = 49.990 – 49.960
= 0.030 mm or 30 μm

73. (a)

$$\text{BHN} = \frac{P}{\frac{\pi D}{2}\left[D-\sqrt{D^2-d^2}\right]}$$

$$= \frac{1600}{\frac{\pi\times 10}{2}\left[10-\sqrt{10^2-2^2}\right]} = 504.15$$

74. (c)

By lever rule,
$$m_\alpha = \frac{99-40}{99-11} = \frac{59}{88} = 67.04\% \simeq 67\%$$

75. (b)

Oxidation in copper follows parabolic law,

$$x = A_P\sqrt{t} = \frac{x}{\sqrt{t}} = \text{Const}$$

$$\frac{150}{\sqrt{16}} = \frac{x_2}{\sqrt{225}}$$

$$x_2 = 562.5\ \mu\text{m}$$

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