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GATE 2016

Detailed Solutions For
Mechanical Engineering

Date: 31-01-2016
Forenoon Session

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Q.1- Q.5 carry one mark each

01. Based on the given statements, select the appropriate option with respect to grammar and usage.
Statements
(i) The height of Mr. X is 6 feet.
(ii) The height of Mr. Y is 5 feet.

(A) Mr. X is longer than Mr. Y
(B) Mr. X is more elongated than Mr. Y
(C) Mr. X is taller than Mr. Y
(D) Mr. X is lengthier than Mr. Y

01. Ans: (C)

Sol: In degrees of comparison Mr. X is taller than Mr. Y is apt.

Positive degree	–	tall
Comparative degree	–	taller
Superlative degree	–	tallest

02. The students _____ the teacher on teacher's day for twenty years of dedicated teaching.
(A) facilitated
(B) felicitated
(C) fantasized
(D) facillitated

02. Ans: (B)

Sol: Felicitate means honour.

03. After India's cricket world cup victory in 1985, Shrotria who was playing both tennis and cricket till then, decided to concentrate only on cricket. And the rest is history.
What does the underlined phrase mean in this context?
(A) history will rest in peace
(B) rest is recorded in history books
(C) rest is well known
(D) rest is archaic

03. Ans: (C)

Sol: 'rest is history' is an idiomatic expression which means 'rest is well known.'

04. Given $(9 \text{ inches})^{1/2} = (0.25 \text{ yards})^{1/2}$, which one of the following statements is **TRUE**?

(A) 3 inches = 0.5 yards (B) 9 inches = 1.5 yards

(C) 9 inches = 0.25 yards (D) 81 inches = 0.0625 yards

04. Ans: (C)

Sol: Given $(9 \text{ inches})^{1/2} = (0.25 \text{ yards})^{1/2}$

9 inches = 0.25 yards

05. S, M, E and F are working in shifts in a team to finish a project. M works with twice the efficiency of others but for half as many days as E worked. S and M have 6 hour shifts a day ,whereas E and F have 12 hours shifts. What is the ratio of contribution of M to contribution of E in the project?

(A) 1 : 1 (B) 1 : 2

(C) 1 : 4 (D) 2 : 1

05. Ans: (B)

Sol M efficiency = 2 [efficiency of S,E, and F]

Contribution of M in the project = x days × 6 hrs ×2

Contribution of E in the project = 2x days × 12 hrs ×1

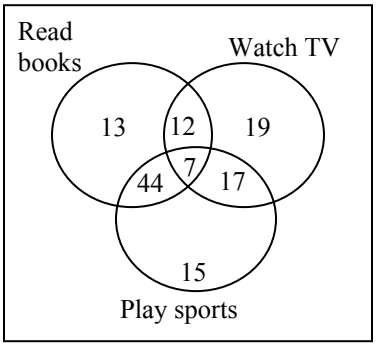
Contribution of M : Contribution of E

$x \times 6 \times 2 : 2x \times 12 \times 1$

1 : 2

Q.6 - Q.10 carry two marks each.

06. The Venn diagram shows the preference of the student population for leisure activities.



From the data given, the number of students who like to read books or play sports is _____.

(A) 44 (B) 51

(C) 79 (D) 108

06. Ans: (D)

Sol: Read books = n(R) = 12 + 44 + 7 + 13 = 76

Play sports = n(s) = 44 + 7 + 17 +15 = 83

$n(R \cap S) = 44 + 7 = 51$

$n(R \cup S) = n(R) + n(S) - n(R \cap S)$

$= 76 + 83 - 51$

$= 108$

07. Social science disciplines were in existence in an amorphous form until the colonial period when they were institutionalized. In varying degrees, they were intended to further the colonial interest. In the time of globalization and the economic rise of postcolonial countries like India, conventional ways of knowledge production have become obsolete.

Which of the following can be logically inferred from the above statements?

(i) Social science disciplines have become obsolete.

(ii) Social science disciplines had a pre-colonial origin.

(iii) Social science disciplines always promote colonialism.

(iv) Social science disciplines maintain disciplinary boundaries.

(A) (ii) only (B) (i) and (iii) only

(C) (ii) and (iv) only (D) (iii) and (iv) only

07. Ans: (A)

Sol: Until the colonial period means pre-colonial origin. Other options can't be inferred.

08. Two and a quarter hours back, when seen in a mirror, the reflection of a wall clock without number markings seemed to show 1:30. What is he actual current time shown by the clock?

(A) 8:15 (B) 11:15

(C) 12:15 (D) 12:45

08. Ans: (D)

Sol: Time back = $2\frac{1}{4}$ = 2 hrs 15 min

Clock time (C.T) + Mirror Time (M.T) = 12

$\downarrow$

1.30

$\therefore$ C.T = $\begin{array}{r} {}^{\swarrow 60}12.00 \\ 1.30 \\ \hline 10.30 \end{array}$

$\therefore$ The actual time shown by the clock = 10.30 + 2.15 = 12.45

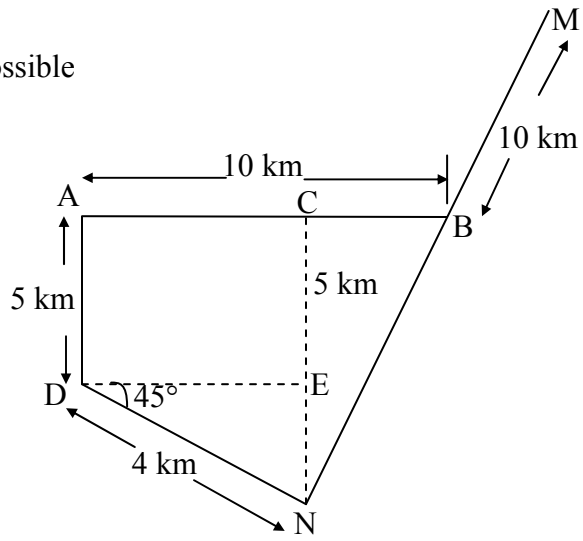
09. M and N start from the same location. M travels 10 km East and then 10 km North-East. N travels 5 km South and then 4 km South-East. What is the shortest distance (in km) between M and N at the end of their travel?

(A) 18.60 (B) 22.50

(C) 20.61 (D) 25.00

09. Ans: (C)

Sol: From the given data, the following diagram is possible



$$\cos 45^o = \frac{DE}{4}$$

$DE = \cos 45^o \times 4$

$= 2.828$ km

$$\sin 45^o = \frac{EN}{4}$$

$EN = \sin 45^o \times 4 = 2.828$ km

$$\sin 45^o = \frac{EN}{4}$$

$EN = \sin 45^o \times 4 = 2.828$ km

$CN = NE + CE = 2.828 + 5$

$= 7.828$ km

$CB = AB - AC = 10 - 2.828$

$= 7.171$ km

$(NB)^2 = (NC)^2 + (BC)^2$

$= (7.828)^2 + (7.171)^2$

$\therefore NB = \sqrt{(7.828)^2 + (7.171)^2} = 10.616$ km

$\therefore NM = NB + BN = 10.616 + 10 = 20.61$ km

10. A wire of length 340 mm is to be cut into two parts. One of the parts is to be made into a square and the other into a rectangle where side are in the ratio of 1:2. What is the length of the side of the square (in mm) such that the combined area of the square and the rectangle is a **MINIMUM**?

(A) 30 (B) 40

(C) 120 (D) 180

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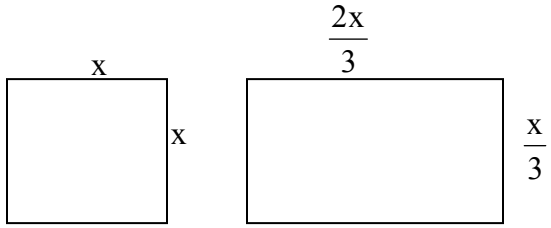
10. Ans: (B)

Sol: Length of the wire = 340 m



Perimeter of rectangle = $2\left[\frac{x}{3}+\frac{2x}{3}\right]$

$= 2x$

Perimeter of square = $340 - 2x$

Side of square $= \frac{340-2x}{4}$

Total area = Area of square + Area of rectangle

$$= \left[\frac{340-2x}{4}\right]^2 + \frac{x}{3}\times\frac{2x}{3}$$

$$= \left[\frac{340-2x}{4}\right]^2 + \frac{2x^2}{9}$$

Combined area of square + rectangle = minimum

$f'(x) = 0$

$$f(x) = \left[\frac{340-2x}{4}\right]^2 + \frac{2}{9}x^2$$

$$f'(x) = \frac{4}{9}x - \frac{340-2x}{4} = 0$$

$$\frac{4}{9}x = \frac{1}{4}[340-2x] \Rightarrow x = 90$$

Side of square = $\frac{340-2x}{4} = 40\,\text{mm}$

Q.1- Q. 25 carry one mark each.

01. A real square matrix A is called skew-symmetric if

(A) $A^T = A$ (B) $A^T = A^{-1}$

(C) $A^T = -A$ (D) $A^T = A + A^{-1}$

01. Ans: (C)

Sol: By using definition

A real square matrix A is said to be skew-symmetric matrix if

$A^T = -A$ (or) $a_{ij} = -a_{ji}\ \forall$ ij

02. $\lim\limits_{x\to 0} \dfrac{\log_e(1+4x)}{e^{3x}-1}$ is equal to

(A) 0 (B) $\dfrac{1}{12}$

(C) $\dfrac{4}{3}$ (D) 1

02. Ans: (C)

Sol: $\lim\limits_{x\to 0} \dfrac{\log(1+4x)}{e^{3x}-1} = \lim\limits_{x\to 0} \dfrac{\frac{1}{1+4x}(4)}{3e^{3x}} = \dfrac{4}{3}$

03. Solutions of Laplace's equation having continuous second-order partial derivatives are called

(A) biharmonic functions (B) harmonic functions

(C) conjugate harmonic functions (D) error functions

03. Ans: (B)

Sol: The solution of Laplace's equation having continuous 2nd order partial derivatives is called a harmonic function.

04. The area (in percentage) under standard normal distribution curve of variable Z within limits from –3 to + 3 is _____.

04. Ans: (99.73)

Sol: In the standard normal curve the area between –3 &3 is 0.9973

$\therefore$ Percentage of area is 99.73

05. The root of the function $f(x) = x^3 + x - 1$ obtained after first iteration on application of Newton-Raphson scheme using an initial guess of $x_0 = 1$ is

(A) 0.682 (B) 0.686

(C) 0.750 (D) 1.000

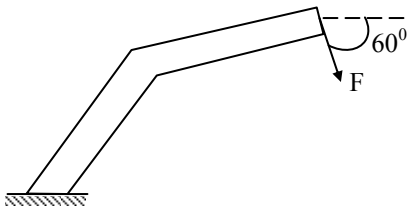
05. Ans: (C)

Sol: Let $f(x) = x^3 + x - 1$ & $x_0 = 1$

Then $f'(x) = 3x^2 + 1$

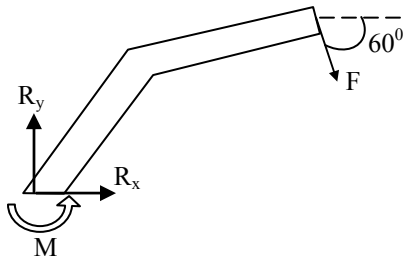
$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} = 1 - \frac{(1+1-1)}{(3+1)} = 0.75$$

06. A force F is acting on a bent bar which is clamped at one end as shown in the figure.

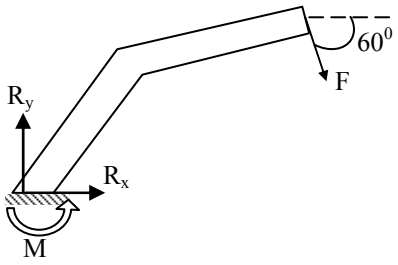


The CORRECT free body diagram is

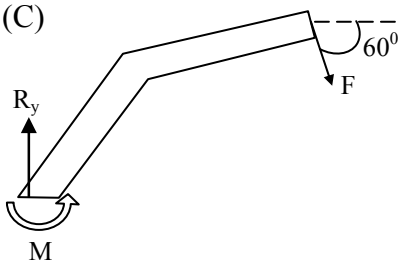
(A)



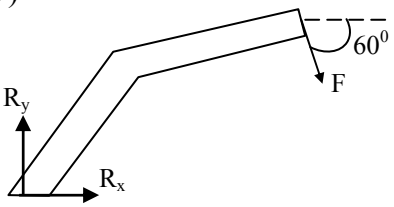
(B)



(C)

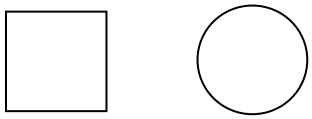


(D)



06. Ans: (A)

07. The cross-sections of two solid bars made of the same material are shown in the figure. The square cross-section has flexural (bending) rigidity I_1 while the circular cross-section has flexural rigidity I_2. Both sections have the same cross-sectional area. The ratio I_1/I_2 is



(A) $1/\pi$ (B) $2/\pi$ (C) $\pi/3$ (D) $\pi/6$

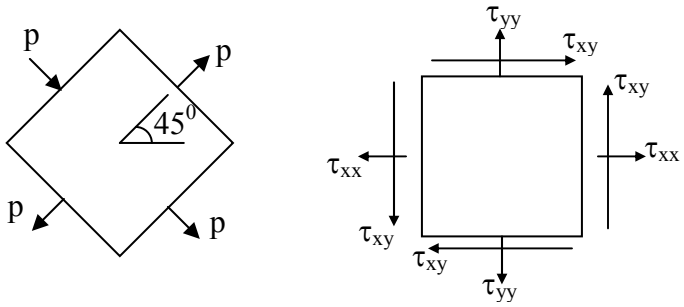
07. Ans: (C)

Sol: $a^2 = \pi r^2$

$a = r\sqrt{\pi}$

$$\frac{I_1}{I_2} = \frac{a^4}{\frac{12}{\frac{\pi d^4}{64}}} = \frac{\pi}{3}$$

08. The state of stress at a point on an element is shown in figure (a). The same state of stress is shown in another coordinate system in figure (b).



The components ($\tau_{xx}, \tau_{yy}, \tau_{xy}$) are given by

(A) $(P/\sqrt{2}, -P/\sqrt{2}, 0$

(B) (0,0, P)

(C) $\left(P, -P, -P/\sqrt{2}\right)$

(D) $\left(0, 0, P/\sqrt{2}\right)$

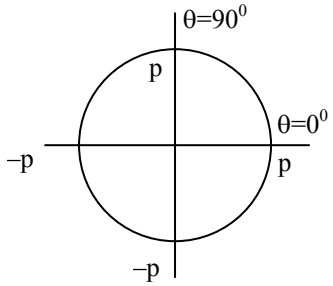
08. Ans: (B)

Sol: At the plane $\theta = 45^0$ (in Mohr circle $\theta = 90^0$)

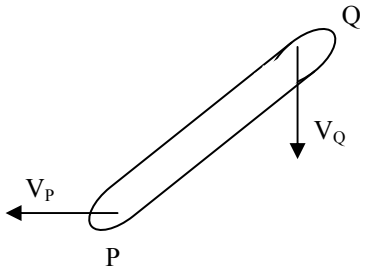
$\sigma_1 = \sigma_2 = 0$

$\tau_{xx} = \tau_{yy} = 0$

$\tau_{xy} = p$



09. A rigid link PQ is undergoing plane motion as shown in the figure (V_P and V_Q are non-zero). V_{QP} is the relative velocity of points Q with respect to point P.



Which one of the following is TRUE?

(A) V_{QP} has components along and perpendicular PQ

(B) V_{QP} has only one component directed from P to Q

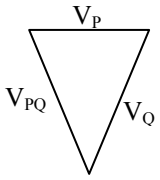
(C) V_{QP} has only one component directed from Q to P

(D) V_{QP} has only one component perpendicular to PQ

09. Ans: (D)

Sol:

$V_Q = V_P + V_{PQ}$



10. The number of degrees of freedom in a planner mechanism having n links and j simple hinge joints is

(A) 3(n – 3) – 2j (B) 3(n – 1) – 2j

(C) 3n – 2j (D) 2j – 3n + 4

10. Ans: (B)

Sol: "Grubler" s equation

11. The static deflection of a spring under gravity, when a mass of 1kg is suspended from it, is 1 mm. Assume the acceleration due to gravity g = 10 m/s^2. The natural frequency of this spring-mass system (in rad/s) is _____

11. Ans: (100)

Sol: $\omega_n = \sqrt{\frac{g}{\delta}}$

$= \sqrt{\frac{10}{1\times10^{-3}}} = 100 \text{ rad / sec}$

12. Which of the bearings given below SHOULD NOT be subjected to a thrust load?

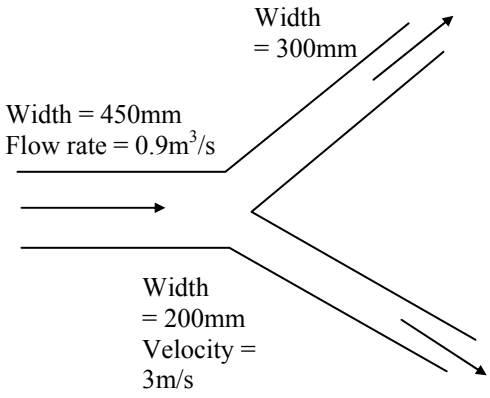
(A) Deep groove ball bearing (B) Angular contact ball bearing

(C) Cylindrical (straight) roller bearing (D) Single row tapered roller bearing

12. Ans: (C)

13. A channel of width 450 mm branches into sub-channels having width 300 mm and 200 mm as shown in figure. If the volumetric flow rate (taking unit depth) of an incompressible flow through the main channel is 0.9 m^3/s and the velocity in the sub-channel of width 200 mm is 3 m/s, the velocity in the sub-channel of width 300 mm is _____

Assume both inlet and outlet to be at the same elevation.



13. Ans: (1)

Sol: $A_1V_1 = A_2V_2 + A_3V_3$

$Q_1 = Q_2 + Q_3$

$0.9 = 3 \times 0.2 \times 1 + V \times 0.3 \times 1$

$V = 1$ m/sec

14. For a certain two-dimensional incompressible flow, velocity field is given by $2xy\hat{i} - y^2\hat{j}$. The streamlines for this flow are given by the family of curves

(A) x^2y^2 = constant (B) xy^2 = constant

(C) $2xy - y^2$ = constant (D) xy = constant

14. Ans: (B)

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

$\frac{dx}{2xy} = \frac{dy}{-y^2}$

$\ell n\sqrt{x} = -\ell ny + c$

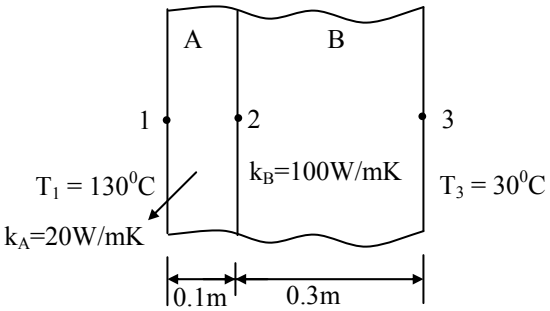
$\ell n\sqrt{x} \times y = c$

$\sqrt{x}\, y = c$

Squaring on both sides

$xy^2 = c$

15. Steady one-dimensional heat conduction takes place across the faces 1 and 3 of a composite slab consisting of slabs A and B in perfect as shown in the figure, where k_A , k_B denote the respective thermal conductivities. Using the data as given in the figure, the interface temperature T_2 (in °C) is _____.



15. Ans: (67.5)

Sol: $Q = \frac{130-30}{\frac{0.1}{20}+\frac{0.3}{100}} = 12500\,W/m^2$

$Q = \frac{130-T}{\frac{0.1}{20}} = 12500$

$\therefore T = 67.5$

16. Grashof number signifies the ratio of

(A) inertia force to viscous force

(B) buoyancy force to viscous force

(C) buoyancy force to inertia force

(D) inertial force to surface tension force

16. Ans: (B)

Sol: Grashof No. $= \dfrac{\text{Buoyancy force}}{\text{Viscous force}}$

17. The INCORRECT statement about the characteristics of critical point of a pure substance is that

(A) there is no constant temperature vaporization process

(B) it has point inflection with zero slope

(C) the ice directly converts from solid phase to vapor phase

(D) saturated liquid and saturated vapor states are identical

17. Ans: (C)

18. For a heat exchanger, ΔT_{max} is the maximum temperature difference and ΔT_{min} is the minimum temperature difference between the two fluids. LMTD is the log mean temperature difference. C_{min} and C_{max} are the minimum and the maximum heat capacity rates. The maximum possible heat transfer (Q_{max}) between the two fluids is

(A) C_{min}LMTD

(B) $C_{min}\Delta T_{max}$

(C) $C_{max}\Delta T_{max}$

(D) $C_{max}\Delta T_{min}$

18. Ans: (B)

Sol: The temperature difference is not for a given fluid but across the fluids and maximum heat transfer occurs for C_{min} and the temperature difference is equal to $\left(T_{h_i} - T_{c_i}\right)$.

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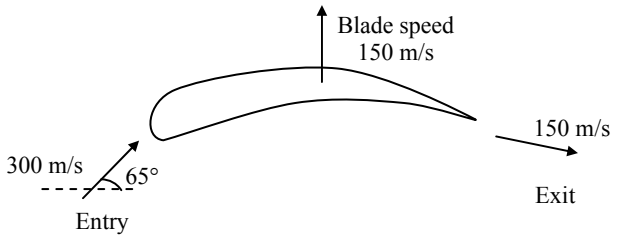
19. The blade and fluid velocities for an axial turbine are as shown in the figure.



The magnitude of absolute velocity at entry is 300 m/s at an angle of 65° to the axial direction, while the magnitude of the absolute velocity at exit is 150 m/s. The exit velocity vector has a component in the downward direction. Given that the axial (horizontal) velocity is the same at entry and exit, the specific work (in kJ/kg) is _____.

19. Ans: (52.807)

Sol: Given: $V_1 = 300$ m/sec

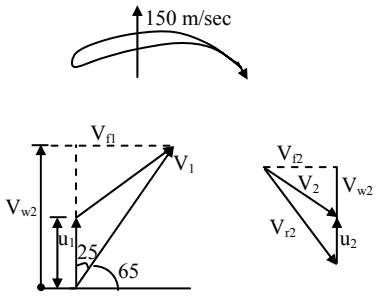
$u = 150$ m/sec

$V_{f1} = V_{f2}$

$(\alpha = 25°)$

$V_2 = 150$ m/sec

Specific work $= [V_{w1} + V_{w2}] \cdot u$



$V_{w1} = V_1 \cos 25$

$V_{w1} = 300 \cos 25 = 271.89$ m/s

$V_{f1} = V_{f2} = V_1 \sin 25$

$V_{f2} = 300 \sin 25 = 126.78$ m/s

$V_{w2} = \sqrt{V_2^2 - V_{f2}^2}$

$= \sqrt{150^2 - 126.78^2}$

$= \sqrt{6426.83}$

$V_{w2} = 80.16$ m/s

Specific work = $[V_{w1} + V_{w2}] \cdot u$

$= [271.89 + 80.76] \times 150$

$= 52807.5$ J/kg $= 52.81$ kJ/kg

20. Engineering strain of a mild steel sample is recorded as 0.100%. The true strain is

(A) 0.010% (B) 0.055%

(C) 0.099% (D) 0.101%

20. Ans: (C)

Sol: $\bar{\varepsilon} = ln\,(1+\varepsilon)$

where, ε = Engineering strain, $\bar{\varepsilon}$ = true strain

$\bar{\varepsilon} = ln\,(1 + 0.001) = 0.099\%$

21. Equal amounts of a liquid metal at the same temperature are poured into three moulds made of steel, copper and aluminum. The shape of the cavity is a cylinder with 15 mm diameter. The size of the moulds are such that the outside temperature of the moulds do not increase appreciably beyond the atmospheric temperature during solidification. The sequence of solidification in the mould from the fastest to slowest is

(Thermal conductivities of steel, copper and aluminum are 60.5, 401 and 237 W/m-K, respectively. Specific heats of steel, copper and aluminum are 434, 385 and 903 J/kg-K, respectively. Densities of steel, copper and aluminum are 7854, 8933 and 2700 kg/m^3, respectively.)

(A) Copper – Steel – Aluminum (B) Aluminum – Steel – Copper

(C) Copper – Aluminum – Steel (D) Steel – Copper – Aluminum

21. Ans: (C)

Sol: Solidification time is inversely proportional to diffusivity and based on the values diffusivity is highest for copper, next is aluminium and then steel. Hence the solidification time is lowest for copper, next aluminium and then steel.

22. In a wire-cut EDM process the necessary conditions that have to be met for making a successful cut are that

(A) wire and sample are electrically non-conducting

(B) wire and sample are electrically conducting

(C) wire is electrically conducting and sample electrically non-conducting

(D) sample is electrically conducting and wire is electrically non-conducting

22. Ans: (B)

Sol: In EDM or wirecut EDM, the work and tool must be electrically conductive otherwise the current passage will not takes place.

23. Internal gears are manufactured by

(A) hobbing

(B) shaping with pinion cutter

(C) shaping with rack cutter

(D) milling

23. Ans: (B)

Sol: Internal gears are manufactured by gear Broaching and shaping with pinion cutter only, whereas shaping with pinion cutter is used for both external and internal gears.

24. Match the following part programming codes with their respective functions

Part Programming Codes	Functions
P. G01	I. Spindle stop
Q. G03	II. Spindle rotation, clockwise
R. M03	III. Circular interpolation, anticlockwise
S. M05	IV. Linear interpolation

(A) P- II, Q - I, R - IV, S – III

(B) P - IV, Q - II, R - III, S - I

(C) P – IV, Q - III, R - II, S – I

(D) P - III, Q - IV, R - II, S - I

24. Ans: (C)

Sol: G01 is used for linear interpolation , G03 is used for circular interpolation counter clockwise, M03 for spindle rotation clockwise and M05 for spindle top.

25. In PERT chart, the activity time distribution is

(A) Normal (B) Binomial

(C) Poisson (D) Beta

25. Ans: (D)

Q.26 - Q.55 carry two marks each.

26. The number of linear independent eigenvectors of matrix $A = \begin{bmatrix} 2 & 1 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$ is _____

26. Ans: (2)

Sol: $A = \begin{bmatrix} 2 & 1 & 0 \\ 0 & 2 & 0 \\ 0 & 0 & 3 \end{bmatrix}$

$\Rightarrow \lambda = 2,2,3$

For $\lambda = 2, A - \lambda I$

$$= \begin{bmatrix} 2-\lambda & 1 & 0 \\ 0 & 2-\lambda & 0 \\ 0 & 0 & 3-\lambda \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \sim \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix}$$

$(A - \lambda I) = 2$, $n = 3$

$P = n - r = 3 - 2 = 1$

The no. of Linearly independent eigen vectors corresponding to an eigen value $\lambda = 2$ is one & corresponding to an eigen value $\lambda = 3$ is one

$\therefore$ The number of linearly independent eigen vectors of A is 2.

27. The value of the line integral $\oint_C \bar{F}.\bar{r}'ds$, where C is a circle of radius $\frac{4}{\sqrt{\pi}}$ units is _____

Here, $\bar{F}(x,y) = y\hat{i} + 2x\hat{j}$ and $\bar{r}'$ is the **UNIT** tangent vector on the curve C at an arc length s from a reference point on the curve. $\hat{i}$ and $\hat{j}$ are the basis vectors in the x-y Cartesian reference. In evaluating the line integral, the curve has to be traversed in the counter-clockwise direction.

27. Ans: (16)

28. $\lim_{x\to\infty} \sqrt{x^2+x-1} - x$ is

(A) 0 (B) ∞ (C) 1/2 (D) $-\infty$

28. Ans: (C)

Sol: It $\sqrt{x^2+x-1} - x = \underset{x\to\infty}{Lt}\left(\sqrt{x^2+x-1} - x\right)\times\frac{\left(\sqrt{x^2+x-1}+x\right)}{\left(\sqrt{x^2+x-1}+x\right)}$

$$= \underset{x\to\infty}{Lt}\frac{\left(x^2+x-1-x^2\right)}{\sqrt{x^2+x-1}+x}$$

$$= \underset{x\to\infty}{Lt}\frac{x\left(1-\frac{1}{x}\right)}{x\left(\sqrt{1+\frac{1}{x}-\frac{1}{x^2}}+1\right)} = \frac{1}{2}$$

29. Three cards were drawn from a pack of 52 cards. The probability that they are a king, a queen, and a jack is

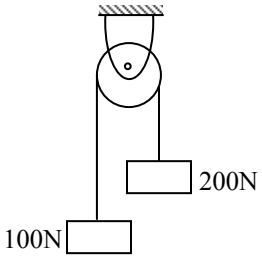
(A) $\frac{16}{5525}$ (B) $\frac{64}{2197}$

(C) $\frac{3}{13}$ (D) $\frac{8}{16575}$

29. Ans: (A)

Sol: Required probability = $\frac{4_{C_1} \times 4_{C_1} \times 4_{C_1}}{52_{C_3}} = \frac{16}{5525}$

30. An inextensible massless string goes over a frictionless pulley. Two weights of 100 N and 200 N are attached to the two ends of the string. The weights are released from rest, and start moving due to gravity. The tension in the string (in N) is _____.



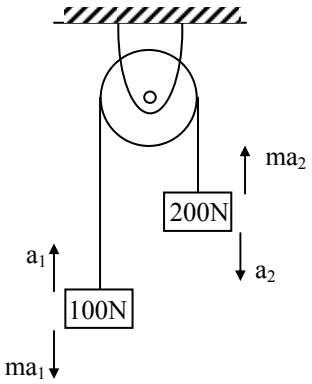
30. Ans: (133.33)

Sol: $m_1a_1 = T - 100$

$\frac{100}{g} a_1 = T - 100$ ------ (1)

$m_2a_2 = 200 - T$

$\frac{200}{g} a_2 = 200 - T$ ------ (2)



$\therefore T = 100\, a_1 + 100$ [$\because a_1 = a_2$]

$\frac{200}{g} a = 200 - \frac{100}{g} a - 100$

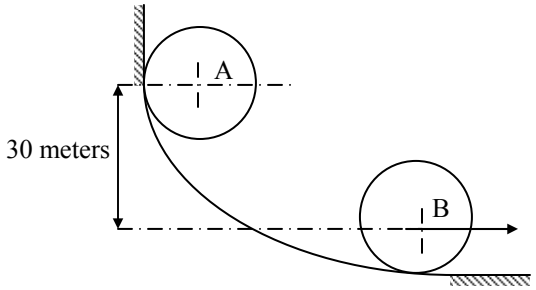
$300a = 100$

$\Rightarrow a = \frac{g}{3}$

$T = \frac{100}{g} \times \frac{g}{3} + 100 = 133.33$ N

31. A circular disc of radius 100 mm and mass 1 kg, initially at rest at position A, rolls without slipping down a curved path as shown in figure. The speed ν of the disc when it reaches position B is _____ m/s.

Acceleration due to gravity g = 10 m/s^2



31. Ans: (20)

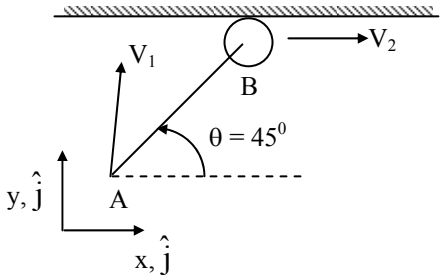
Sol: $\frac{1}{2}I\omega^2 - 0 = mgh$

$$\frac{1}{2}\times\frac{3}{2}mr^2\times\omega^2 = mgh$$

$$\frac{3}{4}mv^2 = mgh$$

$$v^2 = \frac{4}{3}gh \qquad v = \sqrt{\frac{4}{3}gh} = \sqrt{\frac{4}{3}\times 10\times 30} = 20 \text{ m/sec}$$

32. A rigid rod (AB) of length L = $\sqrt{2}$ m is undergoing translational as well as rotational motion in the x-y plane (see the figure). The point A has the velocity $V_1 = \hat{i} + 2\hat{j}\,m/s$. The end B is constrained to move only along the x direction.



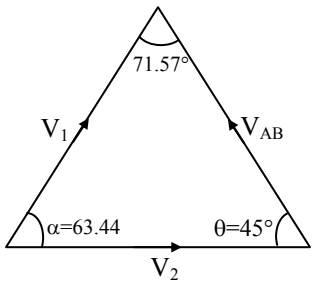
The magnitude of the velocity V_2 (in m/s) at the end B is _____

32. Ans: 3

Sol: $V_1 = i + 2j$

$|V_1| = \sqrt{2^2 + 1^2} = \sqrt{5}$

By drawing velocity diagram



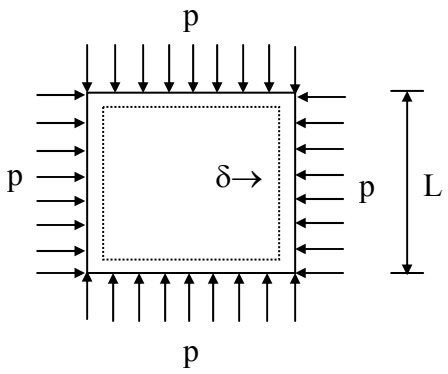
$\alpha = \tan^{-1}\left(\frac{2}{1}\right) = 63.44$

By applying sine rule

$$\frac{\sqrt{5}}{\sin 45} = \frac{V_2}{\sin 71.57}$$

$\therefore V_2 = 3$ m/sec

33. A square plate of dimension L × L is subjected to a uniform pressure load p = 250 MPa on its edges as shown in the figure. Assume plane stress conditions. The Young's modulus E = 200 GPa.



The deformed shape is a square of dimension L – 2 δ. If L = 2 m and δ = 0.001 m, the Poisson's ratio of the plate material is _____.

33. Ans: (0.2)

Sol: $\frac{\Delta V}{V} = \frac{\sigma}{E}(1-\nu)$

$\varepsilon_v = \varepsilon_x + \varepsilon_y + \varepsilon_z$

$$\varepsilon_v = \left(\frac{\sigma}{E} - \frac{\mu\sigma}{E}\right) + \left(\frac{\sigma}{E} - \frac{\mu\sigma}{E}\right) - \frac{\mu(\sigma+\sigma)}{E}$$

Due to plane stress condition $\varepsilon_z = 0$

$$\varepsilon_v = \frac{\sigma}{E} \times 2 \times (1-\mu)$$

$$\frac{(2-2\times 0.001)^2 - 2^2}{2^2} = -\frac{P}{E} \times 2(1-\mu)$$

$$-2\times 10^{-3} = -\frac{250}{200\times 10^3} \times 2(1-\mu)$$

$$\frac{200}{250} = 1-\mu$$

$0.8 = 1 - \mu$ $\quad\quad\quad\quad\quad\quad$ $\therefore\ \mu = 0.2$

34. Two circular shafts made of same material, one solid (S) and one hollow (H), have the same length and polar moment of inertia. Both are subjected to same torque. Here. θ_S is the twist and τ_S is the maximum shear stress in the solid shaft, whereas θ_H is the twist and τ_H is the maximum shear stress in the hollow shaft. Which one of the following TRUE?

(A) $\theta_S = \theta_H$ and $\tau_S = \tau_H$ (B) $\theta_S > \theta_H$ and $\tau_S > \tau_H$

(C) $\theta_S < \theta_H$ and $\tau_S < \tau_H$ (D) $\theta_S = \theta_H$ and $\tau_S < \tau_H$

34. Ans: (D)

Sol: $\theta_S = \dfrac{TL}{CJ}$ (solid)

$\theta_H = \dfrac{TL}{CJ}$ (hollow)

$\theta_S = \theta_H = \theta$

Since material length , polar moment of inertia and applied torque all are same.

$\tau_S = \dfrac{T}{J} \times r_S$ (or) $\tau_S \propto r_S$

$\tau_H = \dfrac{T}{J} \times r_H$ (or) $\tau_H \propto r_H$

$\therefore J_H = J_S$

$\dfrac{\pi}{32}\left(D_H^4 - d_H^4\right) = \dfrac{\pi}{32} D_S^4$

$D_H^4 - d_S^4 = D_s^4$

$1 - \left(\dfrac{d_S}{D_H}\right) = \left(\dfrac{D_S}{D_H}\right)^4$

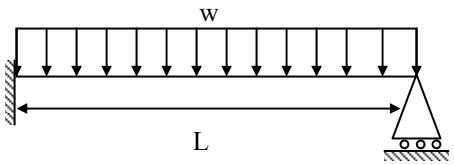
Since $\dfrac{d_S}{d_H} < 1$

$\therefore D_S < D_H$

$\therefore r_H > r_S$

$\therefore \tau_H > \tau_S$

35. A beam of length L is carrying a uniformly distributed load w per unit length. The flexural rigidity of the beam is EI. The reaction at the simple support at the right end is

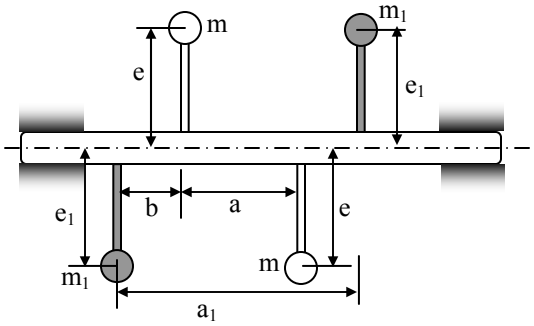


(A) $\frac{wL}{2}$ (B) $\frac{3wL}{8}$ (C) $\frac{wL}{4}$ (D) $\frac{wL}{8}$

35. Ans: (B)

Sol: $\frac{w\ell^4}{8EI} = \frac{R\ell^3}{3EI}$ $R = \frac{3w\ell}{8}$

36. Two masses m are attached to opposite sides of a rigid rotating shaft in the vertical plane. Another pair of equal masses m_1 is attached to the opposite sides of the shaft in the vertical plane as shown in figure. Consider m = 1 kg, e = 50 mm. e_1 = 20 mm, b = 3 m, a = 2 m and a_1 = 2.5 m. For the system to be dynamically balanced, m_1 should be _____ kg.



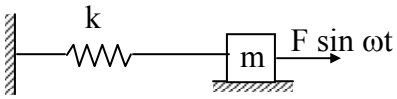
36. Ans: 2

Sol: By symmetric two system is in dynamic balance when

$mea = m_1e_1a_1$

$m_1 = m\frac{e}{e_1}.\frac{a}{a_1} = 1\times\frac{50}{20}\frac{2}{2.5} = 2kg$

37. A single degree of freedom spring-mass system is subjected to a harmonic force of constant amplitude. For an excitation frequency of $\sqrt{\frac{3k}{m}}$, the ratio of the amplitude of steady state response to the static deflection of the spring is _____

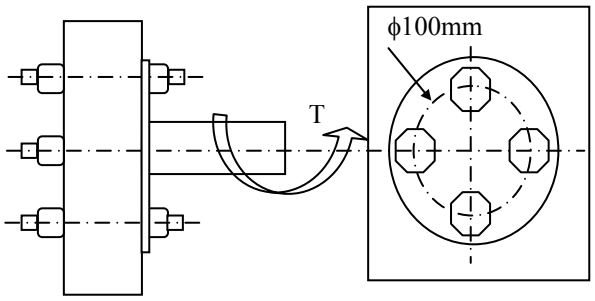


37. Ans: 0.5

Sol: $\frac{\omega}{\omega_n} = \frac{\sqrt{3k/m}}{\sqrt{\frac{k}{m}}} = \sqrt{3}$

$$M.F = \frac{1}{\sqrt{\left(1-\left(\frac{\omega}{\omega_N}\right)^2\right)^2}} = \sqrt{\frac{1}{(1-3)^2}} = \frac{1}{2} = 0.5$$

38. A bolted joint has four bolts arranged as shown in figure. The cross sectional area of each bolt is 25 mm^2. A torque T = 200 N-m is acting on the joint. Neglecting friction due to clamping force, maximum shear stress in a bolt is _____ MPa.



38. Ans: 160

Sol: $T = F \times \frac{D}{2}$

$200 = F \times \frac{0.1}{2}$

$F = 4000\ N$

$\tau = \frac{F}{A} = \frac{4000}{25} = 160\,MPa$

39. Consider a fully developed steady laminar flow of an incompressible fluid with viscosity μ through a circular pipe of radius R. Given that the velocity at a radial location of R/2 from the centerline of the pipe is U_1, the shear stress at the wall is $K\mu U_1/R$, where K is _____

39. Ans: (2.667)

Sol: $\tau_w = -\frac{\partial P}{\partial x}\left(\frac{r}{2}\right)$

$u = -\frac{R^2}{4\mu}\left(\frac{\partial p}{dx}\right)\left(1 - \frac{r^2}{R^2}\right)$

$$u_1 = -\frac{R^2}{4\mu}\left(\frac{\partial p}{dx}\right)\left(1-\frac{R^2}{4\times R^2}\right) = -\frac{R^2}{4\mu}\left(\frac{\partial p}{\partial x}\right)\times\frac{3}{4}$$

$$\left(-\frac{\partial p}{\partial x}\right) = \frac{16\mu u_1}{3R^2}$$

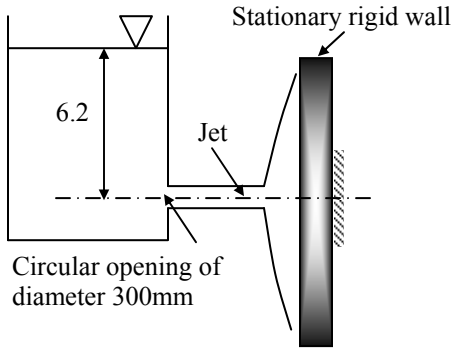
$$\tau_w = -\frac{\partial p}{\partial x}\times\frac{R}{2} = \frac{k\times\mu\times u_1}{R}$$

$$\frac{16\times\mu\times u_1}{3R^2}\times\frac{R}{2} = \frac{k\times\mu\times u_1}{R}$$

$$k = \frac{16\mu\times u_1}{3R^2}\times\frac{R}{2}\times\frac{R}{\mu u_1} = \frac{8}{3} = 2.66$$

40. The water jet exiting from a stationary tank through a circular opening of diameter 300 mm impinges on a rigid wall as shown in the figure. Neglect all minor losses and assume the water level in the tank to remain constant. The net horizontal force experienced by the wall is _____ kN. Density of water is 1000 kg/m^3.

Acceleration due to gravity g = 10 m/s^2.



40. Ans: 8.765

Sol: $F_x = \rho AV^2$

$$= 10^3\times\frac{\pi}{4}\times 0.3^2\times 2\times 10\times 6.2$$

$$= 8.765 \text{ kN}$$

41. For a two-dimensional flow, the velocity field is $\vec{u} = \frac{x}{x^2+y^2}\hat{i} + \frac{y}{x^2+y^2}\hat{j}$, where $\hat{i}$ and $\hat{j}$ are the basis vectors in the x-y Cartesian coordinate system. Identify the **CORRECT** statements from below.

(1) The flow is incompressible

(2) The flow is unsteady

(3) y-component of acceleration, $a_y = \frac{-y}{(x^2+y^2)^2}$

(4) x-component of acceleration, $a_x = \frac{-(x+y)}{(x^2+y^2)^2}$

(A) (2) and (3) (B) (1) and (3)

(C) (1) and (2) (D) (3) and (4)

41. Ans: (B)

Sol: $a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}$

$$= \frac{x}{x^2+y^2}\left(\frac{x^2+y^2-x\times 2x}{(x^2+y^2)^2}\right) - \frac{y}{(x^2+y^2)}\times x\times\frac{1}{(x^2+y^2)^2}\times 2y$$

$$= \frac{x(x^2+y^2-2x^2)-2xy^2}{(x^2+y^2)(x^2+y^2)^2} = \frac{-x^3-xy^2}{(x^2+y^2)^3}$$

$\therefore a_x = -\frac{x}{(x^2+y^2)^2}$

$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}$

$$= \frac{x}{(x^2+y^2)}\times\frac{-y}{(x^2+y^2)^2}\times 2x + \frac{y}{(x^2+y^2)}\times\left(\frac{(x^2+y^2)-y\times 2y}{(x^2+y^2)^2}\right) = \frac{-2x^2y+yx^2-y^3}{(x^2+y^2)^3}$$

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

The velocity components are not functions of time, so flow is steady according to continuity equation,

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=\frac{-\left(x^2-y^2\right)}{\left(x^2+y^2\right)^2}+\frac{\left(x^2-y^2\right)}{\left(x^2+y^2\right)^2}=0$$

Since it satisfies the above continuity equation for 2D and incompressible flow.

$\therefore$ The flow is incompressible.

42. Two large parallel plates having a gap of 10 mm in between them are maintained at temperatures T_1 = 1000 K and T_2 = 400 K. Given emissivity values, $\varepsilon_1 = 0.5$, $\varepsilon_2 = 0.25$ and Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W/m^2-K, the heat transfer between the plates (in kW/m^2) is _____.

42. Ans: 11.0496

Sol: $$\dot{Q}=\frac{\sigma\left(T_1^4-T_2^4\right)}{\frac{1}{\in_1}+\frac{1}{\in_2}-1}=\frac{5.67\times10^{-8}\left(1000^4-400^4\right)}{\frac{1}{0.5}+\frac{1}{0.25}-1}=11.05\ \text{kW/m}^2$$

43. A cylindrical steel rod, 0.01 m in diameter and 0.2 m in length is first heated to 750°C and then immersed in a water both at 100°C. The heat transfer coefficient is 250 W/m^2-K. The density, specific heat and thermal conductivity of steel are ρ = 7801 kg/m^3, c = 473 J/kg-K, and k = 43 W/m-K, respectively. The time required for the rod to reach 300°C is _____ seconds.

43. Ans: (43.49)

Sol: d = 0.01 m, L = 0.2m , T_0 = 750°C , T_∞ = 100°C , h = 250 W/m^{2}K

ρ = 7801 kg/m^3, C = 473 J/kgK

$$\frac{T-T_\infty}{T_0-T_\infty}=e^{-\frac{hA\tau}{\rho VC}}$$

$$\frac{V}{A}=\frac{\pi D^2L}{4\times\pi DL}=\frac{D}{4}$$

$$\frac{300-100}{750-100} = e^{-\frac{250\times4\times\tau}{7801\times0.01\times473}}$$

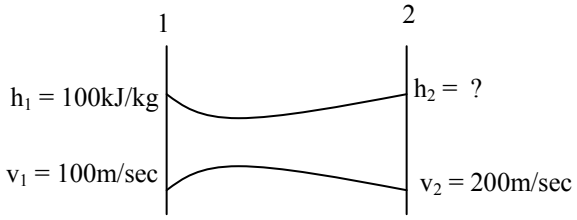
$$-1.178 = -\frac{250\times4\times\tau}{7801\times0.01\times473}$$

$\therefore \tau = 43.49$ sec

44. Steam at an initial enthalpy of 100 kJ/kg and inlet velocity of 100 m/s, enters and insulated horizontal nozzle. It leaves the nozzle at 200 m/s. The exit enthalpy (in kJ/kg) is _____

44. Ans: (85)

Sol: $h_1 + \frac{V_1^2}{2000} + \frac{\delta Q}{dm} = h_2 + \frac{V_2^2}{2000} + \frac{\delta W}{dm}$



$$h_2 = h_1 + \frac{V_1^2 - V_2^2}{2000}$$

$$= 100 + \left(\frac{100^2 - 200^2}{2000}\right)$$

$$= 100 - 15 = 85\,kJ/kg$$

45. In a mixture of dry air and water vapor at a total pressure of 750 mm of Hg, the partial pressure of water vapor is 20 mm of Hg. The humidity ratio of the air in grams of water vapor per kg of dry air (g_w/kg_{da}) is _____

45. Ans: (17.0410)

Sol: $w = 0.622\,\frac{P_v}{P_{atm} - P_V}$

$$= 0.622 \times \frac{20}{750 - 20}$$

$$= 0.01704 \frac{kg\ vapour}{kg\ dry\ air}$$

46. In a 3-stage air compressor, the inlet pressure is p_1, discharge is p_4 and the intermediate pressure are p_2 and p_3 and p_3 ($p_2 < p_3$). The total pressure of the compressor is 10 and the pressure ratios of the stages are equal. If $p_1 = 100$ kPa, the value of the pressure p_3 (in kPa) is _____

46. Ans: (464.151)

Sol: $\left(r_P\right)_{OPT} = \left(\frac{P_4}{P_1}\right)^{\frac{1}{3}} = (10)^{\frac{1}{3}} = 2.1544$

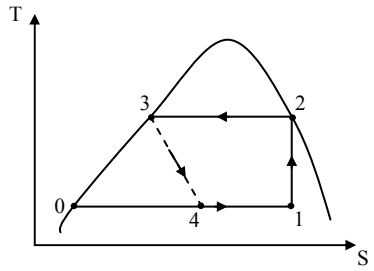
$$\frac{P_2}{P_1} = \frac{P_3}{P_2} = \frac{P_4}{P_3} = 2.1544$$

$$P_2 = 2.1544 \times 100 = 215.44$$

$$\frac{P_3}{P_2} = 2.1544$$

$$P_3 = 2.1544 \times 215.44 = 464.15 \text{ kPa}$$

47. In the vapour compression cycle shown in the figure the evaporating and condensing temperatures are 260 K and 310 K, respectively. The compressor takes in liquid-vapour mixture (state 1) and isentropically compresses it to a dry saturated vapour condition (state 2). The specific heat of the liquid refrigerant is 4.8 kJ/kg-K and may be treated as constant. The enthalpy of evaporation for the refrigerant at 310 K is 1054 kJ/kg.



The difference between the enthalpies at state points 1 and 0 (in kJ/kg) is _____

47. Ans: (1103.44)

Sol: $h_2 - h_3 = 1054$

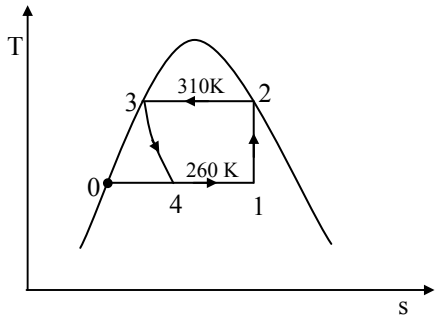
$h_2 - c_{pl}(T_3 - T_0) = 1054$

$h_2 - 4.8(310 - 273) = 1054$

$h_2 = 1231.6$ kJ/kg

reference temperature = 273 = T

at reference temperature entropy is zero.



$$s_3 = c_{pl}\,\ell n\left(\frac{T_3}{T}\right)$$

$$= 4.8\ell n\left(\frac{310}{273}\right) = 0.61\,\text{kJ/kgK}$$

$T_2(s_2 - s_3) = h_2 - h_3$

$310(s_2 - 0.61) = 1054$

$$s_2 = 0.61 + \frac{1054}{310} = 4.01\ \text{kJ/kgK}$$

$s_2 = s_1 = 4.01$ kJ/kgK

$$s_0 = c_{pl}\,\ell n\left(\frac{T_0}{T}\right)$$

$$= 4.8\ell n\left(\frac{260}{273}\right) = -0.23\,\text{kJ/kgK}$$

$$h_1 - h_0 = T_0\,(s_1 - s_0)$$

$$= 260\,(4.01 - (-0.23))$$

$$= 1103.44\ \text{kJ/kg}$$

48. Spot welding of two steel sheets each 2 mm thick carried out successfully by passing 4 kA of current for 0.2 seconds through the electrodes. The resulting weld nugget formed between the sheets is 5 mm in diameter. Assuming cylindrical shape for the nugget, the thickness of the nugget is _____ mm.

Latent heat of fusion for steel	1400 kJ/kg
Effective resistance of the weld joint	200 μΩ
Density of steel	8000 kg/m^3

48. Ans: (2.91)

Sol: $I^2R\tau$ = volume × ρ × H.R /kg

$4000^2 \times 200 \times 10^{-6} \times 0.2$ = volume × 8000 × 1400 × 10^3

Volume = 5.7×10^{-8} m^3 $= \frac{\pi}{4} \times 5^2 \times h \times 10^{-6}$

$\Rightarrow$ h = 2.91 mm

49. For an orthogonal cutting operation, tool material is HSS, rake angle is 22°, chip thickness is 0.8 mm, speed is 48 m/min and feed is 0.4 mm/rev. The shear plane angle (in degrees) is

(A) 19.24 (B) 29. 70

(C) 56.00 (D) 68.75

49. Ans: (B)

Sol: $\alpha = 22$, $t_2 = 0.8$, $V = 48$, $t_1 = 0.4$

$$r = \frac{t_1}{t_2} = 0.5$$

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = \tan^{-1}\left(\frac{0.5\cos 22}{1 - 0.5\sin 22}\right) = 29.7°$$

50. In a sheet metal of 2 mm thickness a hole of 10 mm diameter needs to be punched. The yield strength in tension of the sheet material is 100 MPa and its ultimate shear strength is 80 MPa. The force required to punch the hole (in kN) is _____.

50. Ans: (5.024)

Sol: Punching force = $F_{max} = \pi dt\tau_u$

$= \pi \times 10 \times 2 \times 80 = 5024 = 5.024$ kN

51. In a single point turning operation with cemented carbide tool and steel work piece, it is found that the Taylor's exponent is 0.25. If the cutting speed is reduced by 50% then the tool life changes by _____ times.

51. Ans: (16)

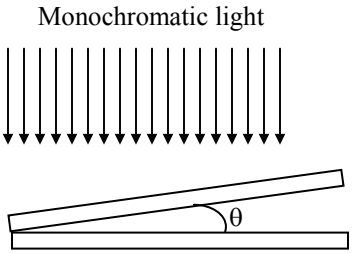
Sol: $V_2 = 0.5V_1$, $\frac{V_1}{V_2} = \frac{V_1}{0.5V_1} = \frac{1}{0.5} = 2$

$$V_1T_1^n = V_2T_2^n$$

$$\left(\frac{T_2}{T_1}\right)^n = \left(\frac{V_1}{V_2}\right)$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\frac{1}{n}} = \left(\frac{V_1}{V_2}\right)^{\frac{1}{0.25}} = \left(\frac{V_1}{V_2}\right)^4 = (2)^4 = 16$$

52. Two optically flat plates of glass are kept at a small angle θ as shown in the figure. Monochromatic light is incident vertically.



If the wavelength of light used to get a fringe spacing of 1 mm is 450 nm, the wavelength of light (in nm) to get a fringe spacing of 1.5 mm is _____

52. Ans: (675)

Sol: $1\text{mm} = n \times \frac{\lambda}{2}$

$$n = \frac{2}{\lambda} = \frac{2}{450}$$

$$1.5 = n \times \frac{\lambda_2}{2}$$

$$\lambda_2 = \frac{1.5 \times 2}{n}$$

$$= \frac{1.5 \times 2}{\frac{2}{450}} = 1.5 \times 450 = 675$$

53. A point P(1, 3, –5) is translated by $2\hat{i} + 3\hat{j} - 4\hat{k}$ and then rotated counter clockwise by 90° about the z-axis. The new position of the point is

(A) (–6, 3, –9) (B) (–6, –3, –9)

(C) (6, 3, –9) (D) (6, 3, 9)

53. Ans: (A)

Sol: "P" after translation = (1+2, 3+3, –5 –4)

= (3, 6, –9)

Rotation about z- axis means

$$\begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 & 0 \\ \sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 6 \\ -9 \\ 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0-6+0+0 \\ 3+0+0+0 \\ 0+0-9+0 \\ 0+0+0+1 \end{bmatrix} = \begin{bmatrix} -6 \\ 3 \\ -9 \\ 1 \end{bmatrix}$$

Final point = [–6, 3, –9]

54. The demand for a two-wheeler was 900 units and 1030 units in April 2015 and May 2015, respectively. The forecast for the month of April 2015 was 850 units. Considering a smoothing constant of 0.6, the forecast for the month of June 2015 is

(A) 850 units (B) 927 units

(C) 965 units (D) 970 units

54. Ans: (D)

Sol: $F_{MAY} = F_{APRIL} + 2\,(D_{APRIL} - F_{APRIL})$

$= 850 + 0.6\,(900 - 850)$

$= 850 + 30$

$= 880$ Units

$F_{JUNE} = F_{MAY} + 2(D_{MAY} - F_{MAY})$

$= 880 + 0.60\ (1030 - 880)$

$= 880 + 90$

$= 970$ Units

55. A firm uses a turning center, a milling center and a grinding machine to produce two parts. The table below provides the machining time required for each part and the maximum machining time available on each machine. The profit per unit on parts I and II are Rs.40 and Rs. 100, respectively. The maximum profit per week of the firm is Rs _____

Type of machine	Machining time required for the machine part (minutes)		Maximum machining time available per week(minutes)
	I	II	
Turning Center	12	6	6000
Milling Center	4	10	4000
Grinding Machine	2	3	1800

55. Ans: (40,000)

Sol:

	M/C I	M/C II	
T C	12	6	6000
M C	4	10	4000
G M	2	3	1800
Profit/unit	40	100	
	x	y	

$Z_{max} = 40\ x + 100\ y$

S.t

$12x + 6y \le 6000,\ \ 4\ x + 10y \le 4000$

$2x + 3y \le 1800 \quad x, y \ge 0$

$\frac{x}{500} + \frac{y}{1000} \le 1 \quad \frac{x}{1000} + \frac{y}{400} \le 1$

$$\frac{x}{900}+\frac{y}{600}\le 1$$

$$12x + 6y = 6000$$

$$4x + 10y = 4000$$

$$12x + 6y = 6000$$

$$\underline{12x + 30y = 12000}$$

$$-24y = -6000$$

$$y = \frac{6000}{24} = 250$$

$$4x + 10y = 4000$$

$$4x + 250 \times 10 = 4000$$

$$4x = 1500$$

$$x = \frac{1500}{4} = 375$$

$Z_{max} = 40x + 100y$

$= 40 \times 375 + 100 \times 250$

$= 15000 + 25000$

$Z_D = 40{,}000/-$

$Z_A = 0$

$Z_B = 40 \times 500 + 100 \times 0 = 20{,}000$

$Z_C = 40 \times 0 + 100 \times 400 = 40{,}000$

Optional at (D) & (C)