General Aptitude

ONE MARK QUESTIONS (Q.01 – Q.05)

01. The cost of 7 pens, 8 pencils and 3 sharpeners is Rs 20. The cost of 3 pencils, 4 sharpeners and 5 erasers is Rs 21. The cost of 4 pens, 4 sharpeners and 6 erasers is Rs 25. The cost of 1 pen, 1 pencil, 1 sharpener and 1 eraser is ________ (Rs)

01. Ans: 6
Sol: Let the costs of pens, pencil, eraser and sharpeners be $p_n$, $p_p$, $e$ and $s$ respectively

Given

\[7p_n + 8p_p + 3s = 20\]
\[3p_p + 4s + 5e = 21\]
\[4p_n + 4s + 6e = 25\]

Adding all three equations,

\[11p_n + 11p_p + 11s + 11e = 66\]
\[\therefore 1p_n + 1p_p + 1s + 1e = 6\]

02. Sentence Completion:
Although some think the terms "bug" and "insect" are --------, the former term actually refers to -------- group of insects.

(A) parallel - an identical
(B) precise - an exact
(C) interchangeable - particular
(D) exclusive - a separate.

02. Ans: (C)
Sol: The word "although" indicates that while most people think the terms are "interchangeable," the term "bug" actually refers to a "particular" group of insects.

03. Sentence improvement:
Underestimating its value, breakfast is a meal many people skip.

(A) Underestimating its value, breakfast is a meal many people skip
(B) Breakfast is skipped by many people because of their underestimating its value
(C) Many people, underestimating the value of breakfast, and skipping it.
(D) Many people skip breakfast because they underestimate its value.

03. Ans: (D)
Sol: The problem with this sentence is that the opening phrase "underestimating its value" modifies "breakfast," not "people." The order of the words in the sentence in choice (D) does not have this problem of a misplaced modifying phrase. Choice (D) also clarifies the causal relationship between the two clauses in the sentence. None of the other choices convey the information presented in the sentence as effectively and directly as choice (D).

04. Spot the error, if any:
If I were her / I would accept / his offer

(A) If I were her,
(B) I would accept
(C) his offer
(D) No error
04. Ans: (A)
Sol: Rule we should use Subjective case of pronoun after BE forms...am, is, are was were., has been, have been, had been.
Her is an objective case ---
If I were she, is correct

05. Kishenkant walks 10 kilometres towards North. From there, he walks 6 kilometres towards south. Then, he walks 3 kilometres towards east. How far and in which direction is he with reference to his starting point?
(A) 5 kilometres, West Direction
(B) 5 kilometres, North-East Direction
(C) 7 kilometres, East Direction
(D) 7 kilometres, West Direction

05. Ans: (B)
Sol: The movements of Kishenkant are as shown in figure

A to B, B to C and C to D
AC = (AB – BC) = (10 – 6) km = 4 km
Clearly, D is to the North-East of A
∴ Kishenkant’s distance from starting point A
AD = \sqrt{AC^2 + CD^2}
= \sqrt{(4)^2 + (3)^2} = \sqrt{25} = 5 km
So, Kishenkant is 5 km to the North-East of his starting point

06. The infinite sum \(1 + \frac{4}{7} + \frac{9}{7^2} + \frac{16}{7^3} + \frac{25}{7^4} + \cdots - \) equals

06. Ans: 1.8 to 2
Sol: We have to find the sum of the series
\[1 + \frac{4}{7} + \frac{9}{7^2} + \frac{16}{7^3} + \frac{25}{7^4} + \cdots - \]
Putting \(x = \frac{1}{7}\) we get
\[1 + 2^2x + 3^2x^2 + 4^2x^3 + 5^2x^4 + \cdots - \]
\[s = 1 + 4x + 9x^2 + 16x^3 + 25x^4\]
\[s = x + 4x^2 + 9x^3 + 16x^4 + \cdots - \]
\[s = 1 + 3x + 5x^2 + 7x^3 + 9x^4 + \cdots - \]
\[x(s – sx) = x + 3x^2 + 5x^3 + 7x^4 + \cdots - \]
\[(s – sx) – x(s – sx) = 2 + 2x + 2x^2 + 2x^3 + \cdots - \]
\[\therefore (1 – x)s = 1 + \frac{2x}{1-x} \quad \text{since} \quad |x| < 1\]
\[s = \frac{1 + x}{(1-x)^3}\]
We may use it as direct formula for solving this type of problem
Substituting \(x = \frac{1}{7}\) we get
\[s = \frac{\left[ 1 + \frac{1}{7} \right]^3}{\left(1 - \frac{1}{7}\right)^3} = \frac{8 \times 343}{7 \times 216} = \frac{49}{27}\]

07. If \(\frac{x}{3a + 2b} = \frac{y}{3b + 2c} = \frac{z}{3c + 2a}\) and a, b and c are in continued proportion and b, c, a are in continued proportion, then \(\frac{x}{a} + \frac{y}{2b} + \frac{z}{3c}\) is ________ (∴ a, b and c are in continued proportion means \(b^2 = ac\))
(A) 55 \[\frac{1}{5}\]
(B) 25
(C) 4 \[\frac{1}{6}\]
(D) 45 \[\frac{5}{6}\]

07. Ans: (D)
Sol: Given that a, b, c are in continued proportion
\(\Rightarrow b^2 = ac \quad \text{(1)}\)
Also b, c, a are in continued proportion
\(\Rightarrow c^2 = ab \quad \text{(2)}\)
From (1) and (2)
\(b^2c^2 = a^2bc \Rightarrow a^2 = bc \quad \text{(3)}\)
Conditions (1), (2) and (3) can only be satisfied when a = b = c = k (say)
08. Rasputin was born in 3233 B.C. The year of birth of Nicholas when successively divided by 25, 21 and 23 leaves remainder of 2, 3 and 6 respectively. If the ages of Nicholas, Vladimir and Rasputin are in arithmetic progression, when was Vladimir born?
(A) 3227 B.C
(B) 3229 B.C
(C) 3230 B.C
(D) 3231 B.C

08. Ans: (C)
Solution: The year of birth of Nicholas
\[ \frac{25}{2} \quad \frac{21}{3} \quad \frac{23}{3} \]
\[ \downarrow \quad \downarrow \quad \downarrow \]
23 7 36 \Rightarrow 3227

The ages of Nicholas, Vladimir and Rasputin are in A.P.
The ages of Nicholas Vladimir Rasputin
3227 ?? 3233

\[ \therefore \text{Vladimir age} = \frac{\text{Nicholas} + \text{Rasputin}}{2} \]
\[ = \frac{3227 + 3233}{2} = 3230 \text{ B.C} \]

09. Recent studies have highlighted the harmful effects of additives in food (colors, preservatives, flavor enhancers etc.). There are no synthetic substances in the foods we produce at Munchon Foods - we use only natural ingredients. Hence you can be sure you are safeguarding your family’s health when you buy our products, says Munchon Foods. Which of the following, if true, would most weaken the contention of Munchon Foods?
(A) Some synthetic substances are not harmful
(B) Some natural substances found in foods can be harmful
(C) Food without additives is unlikely to taste good
(D) Munchon Foods produces only breakfast cereals

09. Ans: (B)
Sol: Munchon’s contention is that buying their products safeguards health. To weaken that argument we can show that, for some reason, their foods might not be healthy. So think about an alternative cause

10. To open a lock, a key is taken out of a collection of n keys at random. If the lock is not opened with this key, it is put back into the collection and another key is tried. The process is repeated again and again. It is given that with only one key in the collection, the lock can be opened. The probability that the lock will open in ‘n’th trail is_____
(A) \( \left( \frac{1}{n} \right)^n \)
(B) \( \left( \frac{n-1}{n} \right)^n \)
(C) \( 1 - \left( \frac{n-1}{n} \right)^n \)
(D) \( 1 - \left( \frac{1}{n} \right)^n \)

10. Ans: (C)
Sol: Probability that the lock is opened in a trail is \( \frac{1}{n} \) (since there is exactly one key, which opens the lock)

\[ \therefore \text{The chance that the lock is not opened in a particular trail} = 1 - \frac{1}{n} \]

\[ P(\text{lock is opened in n}^{th} \text{ trial}) = 1 - P(\text{lock is not opened in n trials}) \]
\[ = 1 - \left[ 1 - \frac{1}{n} \right]^n = 1 - \left[ \frac{n-1}{n} \right]^n \]
Mechanical Engineering

ONE MARK QUESTIONS (Q.11 – Q.35)

11. \[ \int_{-2}^{2} (1 - x^4) \, dx = \text{________} \]

11. Ans: 12

Sol: \[ \int_{-2}^{2} (1 - x^4) \, dx = 2 \int_{0}^{2} (1 - x^4) \, dx \]
\( \because |1 - x^4| \text{ is even function} \)
\[ = 2 \left\{ \int_{0}^{1} (1 - x^4) \, dx - \int_{1}^{2} (1 - x^4) \, dx \right\} \]
\[ = 12 \]

12. A fair coin is tossed until one of the two sides occurs twice in a row. The probability that the number of tosses required is even is \[\text{________} \].

12. Ans: 0.66 (range 0.6 to 0.7)

Sol: A = {HH, HTHH, HTHTHH, ...........} B = {TT, THTT, THHTTT, ............}
\[ P(A) = \frac{1}{3} \quad \text{&} \quad P(B) = \frac{1}{3} \]
\[ P(A \text{ or } B) = \frac{2}{3} = 0.667 \]

13. If \( \delta_1 \) and \( \delta_2 \) are boundary layer thicknesses at a point \( x \) from the leading edge on a flat plate when the Reynolds numbers are 225 and 400 respectively, then the ratio of \( \delta_1 \) to \( \delta_2 \) is \[\text{________} \].

13. Ans: 1.33 (range 1.3 to 1.4)

Sol: \[ \delta \propto \frac{1}{\sqrt{R_e}} \quad \text{(At given distance } \text{‘}x\text{’)} \]
\[ \frac{\delta_1}{\delta_2} = \sqrt{\frac{R_{e_2}}{R_{e_1}}} \]
\[ \frac{\delta_1}{\delta_2} = \sqrt{\frac{400}{225}} = \frac{20}{15} = 1.33 \]

14. Two reservoirs are connected by two pipes ‘A’ and ‘B’ of identical diameter and length in parallel. If the friction factor of ‘A’ is 2 times that of ‘B’ the ratio of the discharge in ‘A’ to that of in ‘B’ is \[\text{________} \].

14. Ans: 0.707 (range 0.70 to 0.71)

Sol: In parallel pipe arrangement;
\[ h_{f_A} = h_{f_B} \]
\[ f_A l_A Q_A^2 = f_B l_B Q_B^2 \]
\[ 12.1 \times d_A^3 = 12.1 \times d_B^3 \]
Given \( d_A = d_B \), \( l_A = l_B \), \( f_A = 2f_B \)
\[ \left( \frac{Q_A}{Q_B} \right)^2 = \frac{f_B}{f_A} \]
\[ \frac{Q_A}{Q_B} = \sqrt{\frac{f_B}{2f_B}} = \sqrt{\frac{1}{2}} = 0.707 \]

15. The maximum wavelength corresponding to radiation at a temperature of 2000 K is \[\text{________} \] (in \( \mu \text{m} \)).

15. Ans: 1.449 \( \mu \text{m} \) (range 1.4 to 1.5)

Sol: \[ \lambda_{\text{max}} \times T = 2898 \quad \text{m K}; \]
Hence, \[ \lambda_{\text{max}} = \frac{2898}{2000} = 1.449 \quad \text{m}. \]

16. If the probability of hitting a target is \[ \frac{1}{5} \] and if 10 shots are fired, what is the conditional probability that the target being hit at least twice assuming that at least one hit is already scored?

(A) 0.6999 \quad (B) 0.624 \quad (C) 0.892 \quad (D) 0.268

16. Ans: (A)

Sol:
\[ P(x \geq 2 \mid x \geq 1) = \frac{P(x \geq 2)}{P(x \geq 1)} = \frac{1-q^n-npq^{n-1}}{1-q^n} \]
\[
1 - \left( \frac{4}{5} \right)^{10} - 10 \left( \frac{1}{5} \right) \left( \frac{4}{5} \right)^{9} - \left( \frac{4}{5} \right)^{10} = 0.6999
\]

17. For which value of \( \alpha \) the following system of equations is inconsistent?
\[
\begin{align*}
3x + 2y + z &= 10 \\
2x + 3y + 2z &= 10 \\
x + 2y + \alpha z &= 10
\end{align*}
\]
(A) \( \frac{7}{5} \)  
(B) \( \frac{-7}{5} \)  
(C) \( \frac{-5}{7} \)  
(D) \( \frac{5}{7} \)

17. Ans: (A)
Sol: 
\[
\begin{pmatrix} 3 & 2 & 1 \\ 2 & 3 & 2 \\ 1 & 2 & \alpha \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}
\]
\[
\Rightarrow 3(3\alpha - 4) - 2(2\alpha - 2) + (4 - 3) = 0
\]
\[
\Rightarrow 5\alpha - 7 = 0
\]
\[
\therefore \alpha = \frac{7}{5}
\]

18. A Solid disc rolls from rest from the top of an incline of vertical height \( h \). The speed of the centre of mass of the disc at the bottom of incline if rolling is without slipping is

(A) \( \sqrt{2gh} \)  
(B) \( \frac{10}{\sqrt{7}} gh \)  
(C) \( \sqrt{\frac{1}{2}gh} \)  
(D) \( \sqrt{\frac{4}{3}gh} \)

18. Ans: (D)
Sol: Energy at the top = \( mgh \)
Energy at the bottom = \[
\frac{1}{2}mV^2 + \frac{1}{2}I\omega^2
\]
\[
= \frac{1}{2}mV^2 + \frac{1}{2}mR^2 \left( \frac{V}{R} \right)^2
\]
\[
= \frac{3}{4}mV^2
\]
\[
mgh = \frac{3}{4}mV^2
\]
\[
\Rightarrow V = \sqrt{\frac{4}{3}gh}
\]

19. By increasing cross section area by 4% and decreasing the thickness by 2% the percentage change in rate of heat transfer for same material and differential temperature is

(A) Increases by 6 %  
(B) Decreases by 6%  
(C) Increases by 2%  
(D) Decreases by 2%

19. Ans: (A)
Sol:
\[
\frac{dQ}{Q} \times 100 = \frac{dA}{A} \times 100 - \frac{dL}{L} \times 100
\]
\[
= 4 - (-2) = 6 \%
\]

20. Consider the following statements:
The Fourier heat conduction equations
\[
Q = kA \frac{dT}{dx}
\]
presumes
1. Steady-state conditions
2. Constant value of thermal conductivity.
3. Uniform temperatures at the wall surfaces
4. One dimensional heat flow
Of these statements
(A) 1, 2 and 3 are correct  
(B) 1, 2 and 4 are correct  
(C) 2, 3 and 4 are correct  
(D) 1, 3 and 4 are correct

20. Ans: (D)
Sol: In the Fourier equation “k” may considered as variable also.
21. In January, a car dealer predicted “February” demand as 200 cars but the actual demand turned out to be 235 cars. The forecast for the month of March using smoothing constant as 0.4 is
   (A) 214  (B) 186
   (C) 294  (D) 235

21. Ans: (A)
Sol: New forecast = Forecast + α (forecast error)
Prediction = Forecast
⇒ \( F_{\text{feb}} = 200 ; D_{\text{feb}} = 235 \)
F_{t+1} = F_t + \alpha (D_t - F_t)
F_{\text{mar}} = F_{\text{feb}} + \alpha (D_{\text{feb}} - F_{\text{feb}})
= 200 + 0.4 (235 – 200)
= 214

22. In the basic EOQ model, annual demand is 10,000 units, ordering cost is equal to Rs. 500 per order. If the Economic Order Quantity is 2000 units then the minimum inventory cost per annum is
   (A) Rs. 10,000
   (B) Rs. 500
   (C) Rs. 2500
   (D) Rs. 5000

22. Ans: (D)
Sol: At EOQ
Carrying cost / year = ordering cost / year
Total inventory cost per annum = carrying cost / year + ordering cost / year
= 2 × ordering cost /year
= 2 × 10000 × 500 = 5000

(or)
No. of orders (N) = \( \frac{\text{Annual demand}}{\text{EOQ}} \)
Minimum inventory cost / year = Total inventory cost / year at EOQ
= 2 × ordering cost /year
= 2 × 5 × 500 = Rs. 5000

23. Match the following
   List – I
   1. Martensite
   2. Pearlite
   3. Troosite
   4. Sorbite

   List – II
   P. Coarse particles of cementite in ferrite phase
   Q. Short needle shapes of grains
   R. Alternate layers of ferrite and cementite
   S. Fine particles of cementite in ferrite phase
   (A) 1-Q, 2-R, 3-P, 4-S
   (B) 1-Q, 3-R, 2-P, 4-S
   (C) 1-Q, 4-R, 2-P, 3-S
   (D) 1-Q, 2-R, 3-S, 4-P

23. Ans: (D)

24. A double parallel fillet weld of length 75mm and thickness 2.85mm. The yield stress of 200 MPa. The strength of weld with a factor of safety of 2.0 is
   (A) 7556 N
   (B) 15112 N
   (C) 21375 N
   (D) 10687 N

24. Ans: (B)
Sol: \( P = \left( \frac{S_{yt}}{2 \times FS} \right) \times 0.707 \times t \times 2L \)
(for double parallel fillet weld)
\( P = \frac{200}{2 \times 2} \times 0.707 \times 2.85 \times 2 \times 75 \)
\therefore P = 15112 N

25. The pattern material used for producing wave guides of radar system using casting process will be
   (A) Plaster of paris
   (B) Frozen Mercury
   (C) Wax
   (D) Polystyrene
25. Ans: (C)
Sol: Due to complex shape of the casting and possibility of reusability of the pattern the wax pattern with investment casting will be used for producing wave guides for radar system.

26. Diamond cutting tools are not recommended for machining of ferrous materials, because of
(A) High frictional wear at the chip tool interface
(B) High abrasive wear at the tool work interface
(C) High diffusion wear at the chip tool interfaces
(D) All of the above

26. Ans: (C)
Sol: Due to complex shape of the casting and possibility of reusability of the pattern the wax pattern with investment casting will be used for producing wave guides for radar system.

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(A) High frictional wear at the chip tool interface
(B) High abrasive wear at the tool work interface
(C) High diffusion wear at the chip tool interfaces
(D) All of the above

26. Ans: (C)
Sol: During machining of ferrous materials, because of presence of atomic attraction between the carbon atoms of diamond tool and iron work piece, the diffusion wear is high.

27. Which of the following method is used for producing a 1mm × 1mm square hole with perfect square corners in a Tungsten carbide die
(A) Ultrasonic machining method
(B) Electric discharge machining method
(C) Broaching operation
(D) Electrochemical machining method

27. Ans: (A)
Sol: Broaching cannot be used because such a small size broaching tool cannot be made, EDM can be used but perfect corners cannot be made and ECM is not preferable for producing holes.

28. Relieving internal residual stresses, reducing brittleness and increasing toughness can achieved by
(A) Carrying out preheating of joint
(B) Carrying out the Post heating of weld bead
(C) Removing the slag
(D) All of the above

28. Ans: (B)
Sol: By carrying out the post heating in welding operation (It is like tempering heat treatment), it possible to relieve the internal residual stresses, reduce the brittleness and increase the toughness.

29. A beam simply supported at ends and subjected to udl throughout its length. Left half of the beam is rigid and right half is flexible with uniform flexural rigidity of EI. The bending moment at mid span is

\[ \frac{w \ell^2}{8} \]

29. Ans: (B)
Sol: The shear force and bending moment diagram are independent of EI values.

30. Hook’s law is valid upto
(A) Elastic limit
(B) Proportionality limit
(C) Plastic limit
(D) Failure point

30. Ans: (B)
Sol: Upto proportionality limit stress is linearly proportional to strain. Therefore Hooke’s law is perfectly valid.
31. \( Z = f(x,y) \) and \( dz = Mdx + Ndy \), then \( \left( \frac{dy}{dx} \right)_z \) is given by

\[
\begin{align*}
(A) & \quad -\frac{M^2}{N} \\
(B) & \quad -\frac{N^2}{M} \\
(C) & \quad -\frac{M}{N} \\
(D) & \quad -\frac{N}{M}
\end{align*}
\]

31. Ans: (C)

Sol: \( dz = Mdx + Ndy \), \( [z = \text{constant}] \)

\[
\Rightarrow dz = 0
\]

\[
\Rightarrow Mdx + Ndy = 0
\]

\[
Ndy = -Mdx
\]

\[
\Rightarrow \left( \frac{dy}{dx} \right)_z = -\frac{M}{N}
\]

32. Three gases are throttled at atmospheric pressure and temperature then which of the following gases exhibit a fall in temperature

(A) Air, CO\(_2\), Helium
(B) N\(_2\), O\(_2\), Hydrogen
(C) CO\(_2\), N\(_2\), Neon
(D) Air, CO\(_2\), O\(_2\)

32. Ans: (D)

Sol: All gases at room temperature and pressure have (\( \mu > 0 \)). Hence they suffer cooling when throttled.

Exceptions are hydrogen ; Helium and Neon ; they have a heating effect. As their maximum temperature of inversion are very much below room temperature.

33. To avoid leakage of refrigerant from the tubes of the refrigerant should have

(A) high density
(B) low density
(C) high specific heat
(D) low specific heat

33. Ans: (A)

Sol: High density and refrigerant clings to tubes.

34. Degrees of freedom for the planer mechanism shown in below figure is

\[
\begin{align*}
(A) & \quad 0 \\
(B) & \quad 1 \\
(C) & \quad 2 \\
(D) & \quad 3
\end{align*}
\]

34. Ans: (D)

Sol: No of links, \( l = 10 \)

No of joints, \( J = 12 \) (all class 1 pairs)

No of degree of freedom = \( 3(l - 1) - 2J \)

\[
= 3(10 - 1) - 2 \times 12
\]

\[
= 27 - 24 = 3
\]

35. The Natural frequency (in rad/sec) for the spring mass system shown in figure is (all the springs are inclined to the direction of oscillation at an angle \( \alpha = 45^\circ \) and the amplitude of oscillation is small).

\[
\begin{align*}
(A) & \quad \sqrt{\frac{2k}{2m}} \\
(B) & \quad \sqrt{\frac{k}{2m}} \\
(C) & \quad \sqrt{\frac{4k}{2m}} \\
(D) & \quad \sqrt{\frac{8k}{2m}}
\end{align*}
\]

35. Ans: (A)
Sol: When the spring is inclined to the direction of oscillation at an angle $\alpha$. The equivalent stiffness is $k \cos^2 \alpha = \frac{k}{2} (\alpha = 45^\circ)$.

The four springs are parallel

$\therefore k_{eq} = 4 \times \frac{k}{2} = 2k$

Natural frequency $= \sqrt{\frac{2k}{2m}} = \sqrt{\frac{k}{m}}$

TWO MARK QUESTIONS (Q.36 – Q.65)

36. Let $f(x, y) = kxy - x^3y - xy^3$ for $(x, y) \in \mathbb{R}^2$, where ‘$k$’ is a real constant. The directional derivative of $f(x, y)$ at the point $(1, 2)$ in the direction of unit vector $\hat{i} \hat{j}$ is $\frac{15}{\sqrt{2}}$. Then the value of $k$ is ______.

36. Ans: 4

Sol: (grad $f$). $\hat{a} = \frac{15}{\sqrt{2}} \hat{i} + \hat{j}$

$\{ [ky - 3x^2y - y^3]\hat{i} + [kx - x^3 - 3xy^2]\hat{j} \}$

$\left[ \left( \frac{-\hat{i}}{\sqrt{2}} \frac{-\hat{j}}{\sqrt{2}} \right) \right] = \frac{15}{\sqrt{2}}$

$\left[ (2k - 6 - 8)\hat{i} + (k - 1 - 12)\hat{j} \right] \cdot \left[ \left( \frac{-\hat{i}}{\sqrt{2}} \frac{-\hat{j}}{\sqrt{2}} \right) \right] = \frac{15}{\sqrt{2}}$

$\therefore k = 4$

37. Given the differential equation $y' = x - y$ with initial condition $y(0) = 0$. The value of $y(0.1)$ calculated numerically up to the third place of decimal by the 2nd order Runge-Kutta method with step size $h = 0.1$ is ______

37. Ans: 0.005

Sol: Given, $y' = x - y$

Also given $y(0) = 0$ and $h = 0.1$

$y(0.1) = ?$

Let $x_0 = 0, x_1 = x_0 + 1. h = 0 + 0.1 = 0.1$

The 2nd order Runge-Kutta method is given by

$y_1 = y(x_1) = y_0 + \frac{1}{2} (k_1 + k_2)$

where $k_1 = h f(x_0, y_0)$ and

$k_2 = h f(x_0 + h, y_0 + k_1)$

$k_1 = (0.1) [x_0 - y_0] = (0.1) (0 - 0) = 0$

$k_2 = (0.1) [x_0 + h - (y_0 + k_1)]$

$= (0.1) [0 + 0.1 - (0 + 0)] = 0.01$

$y_1 = y(0.1) = 0 + \frac{1}{2} (0 + 0.01) = \frac{0.01}{2}$

$= 0.005$

38. Find the value of co-efficient of dynamic friction between 500 N block of incline is ______ (Assume $g = 10 \text{ m/sec}^2$)

38. Ans: 0.3625 (range 0.35 to 0.37)

Sol:

$T = \frac{100 + 10}{2} = 55 \text{ N}$

$f_d = 300 - (100 + 55) = 145 \text{ N}$

$f_d = \mu_d N$

$145 = \mu_d (400)$

$\mu_d = 0.3625$

39. In a pump the suction and delivery pipes are of the same size and are at the same level. At a given discharge the loss of head between a point A on the suction side and a
point B on the delivery side is 3.0 m. if the pressure at point B is 120 kPa and the head developed by the pump is 10 m, the pressure at point A, in kPa is __________.

(Water is the flowing fluid)

39. Ans: 51.33 kPa (range 51 to 52)
Sol: Apply Bernoulli’s equation to pump

\[ \frac{P_A}{\rho g} + Z_A + \frac{V_A^2}{2g} + \text{head developed} = \frac{P_B}{\rho g} + Z_B + \frac{V_B^2}{2g} + H_{\text{Loss}} \]

Where head developed = Head raised = 10 m
Since pipes are same size\n\[ V_A = V_B \quad \text{and} \quad Z_A = Z_B \]
\[ \frac{P_A}{\rho g} + 10 = \frac{120 \times 10^3}{1000 \times 9.81} + 3 \]
\[ P_A = (12.23 + 3 - 10) \times \rho g \]
\[ P_A = (5.234)(1000 \times 9.81) \]
\[ 51.33 \times 10^3 \text{ N/m}^2 = 51.33 \text{ kPa} \]

40. A project consists of 7 activities with the following data

<table>
<thead>
<tr>
<th>Activity</th>
<th>Predecessor</th>
<th>Duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>A</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>B, C</td>
<td>5</td>
</tr>
<tr>
<td>F</td>
<td>B, C</td>
<td>6</td>
</tr>
<tr>
<td>G</td>
<td>D, E</td>
<td>8</td>
</tr>
</tbody>
</table>

The minimum time required to complete the project (in days) is __________

41. Stress at a point is given by stress tensor
\[ \sigma = \begin{bmatrix} 100 & 40 \\ 40 & 40 \end{bmatrix} \text{ MPa.} \]
Yield strength of material is 300 MPa. Operating factor of safety according to Guest theory of failure is _________

\[ \sigma_{x1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\frac{(\sigma_x - \sigma_y)^2}{4} + \tau_{xy}^2} \]
\[ = \frac{100 + 40}{2} \pm \sqrt{\left(\frac{100 - 40}{2}\right)^2 + 40^2} \]
\[ \therefore \sigma_1 = 120 \text{ MPa}, \sigma_2 = 20 \text{ MPa} \]
\[ \tau_{\text{max}} = \left(\frac{\sigma_x - \sigma_2}{2}\right) \text{ or } \left(\frac{\sigma_1}{2}\right) \text{ or } \left(\frac{\sigma_2}{2}\right) \]
\[ = 50 \text{ or } 60 \text{ or } 10 = 60 \text{ MPa} \]
Guest theory
\[ \tau_{\text{max}} = \frac{\sigma_{y1}}{2 \times FS} \]
\[ 60 = \frac{300}{2 \times FS} \Rightarrow FS = 2.5 \]
42. When measuring the effective diameter of a Metric external screw thread of 3.5mm pitch, a 35.5mm diameter cylindrical standard and 2.00mm wires were used. The micrometer readings over the standard and wires, and thread and wires used 18.8673 and 17.8242mm respectively. The thread effective diameter in mm is ________

42. Ans: 31.4465 mm (range 31 to 32)

Sol: The best wire size = P/2 sec(α/2)

= (3.5/2) sec (30) = 2.01 mm

Micrometer reading = M = S + (R2 – R1)

= 34.4569mm

Effective diameter = M – (d + 0.5P tan(α/2))

= 34.4569 – (2 + 0.5 × 3.5 × tan30)

= 31.4465mm

43. A GO plug gauge is designed to inspect a hole by the machine operator. The L-limit and H-limit of the hole are 50.00mm and 50.30mm respectively. The gauge tolerance and wear allowance are taken as 10% of work tolerance. The H-limit of the GO gauge respectively in mm are ________

43. Ans: 50.06mm (range 50 to 51)

Sol: Work tolerance = WT = 50.3 – 50 = 0.3mm

GT = WA = 10% of WT = 0.03mm

Actual Go size = 50.00

L – limit of Go gauge

= 50 + WA = 50.03mm

H-limit of Go gauge

= 50.03 + GT = 50.06mm

44. A column is loaded as shown in figure the maximum compressive stress developed in the column is ________

44. Ans: 7 MPa (range 6.5 to 7.5)

Sol:

\[
\sigma_{\text{max}} = \frac{20 \times 10^3}{200 \times 100} + \frac{20 \times 10^3 \times 100 \times 100}{100 \times 200} + \frac{20 \times 10^3 \times 50 \times 50}{100 \times 200}
\]

= 1 + 3 + 3 = 7 MPa

45. The strain values of a rectangular strain rosette are as shown in figure. E = 200 GPa, µ = 0.3. The major principal stress developed in the beam is ________ MPa.

45. Ans: 145 MPa (range 144 to 146)

Sol: The major and minor principal strains are respectively

\[\varepsilon_1 = 600 \mu \text{ and } \varepsilon_2 = 200 \mu\]

Principal stresses are

\[
\sigma_1 = \frac{E(\varepsilon_1 + \mu \varepsilon_2)}{1 - \mu^2}
\]

\[
= \frac{200 \times 10^3(600 \times 10^{-6} + 0.3 \times 200 \times 10^{-6})}{(1 - 0.3^2)}
\]

= 145 MPa
46. Air is entering a nozzle with negligible velocity. The ratio of exit pressure to inlet pressure is 1/6 and inlet temperature of air is 300 K. The exit velocity (in m/sec) is ___________

46. Ans: 491.52 m/sec (range 490 to 492)
Sol: \( \gamma = 1.4 \) for air, \( c_p = 1.005 \text{ kJ/kgK} \)

\[
\begin{align*}
\frac{V_e^2}{2} &= h_e + \frac{V_i^2}{2} \\
V_e &= \sqrt{2(h_i - h_e)} = \sqrt{2c_p(T_i - T_e)} \\
&= \sqrt{2c_p T_i \left(1 - \frac{T_e}{T_i}\right)}
\end{align*}
\]

From adiabatic law

\[
\frac{T_e}{T_i} = \left(\frac{P_e}{P_i}\right)^{\gamma / (\gamma - 1)}
\]

\[
V_e = \sqrt{2c_p T_i \left(1 - \left(\frac{P_e}{P_i}\right)^{0.4}\right)}
\]

\[
= \sqrt{2 \times 1005 \times 300 \left(1 - \left(\frac{1}{6}\right)^{0.4}\right)}
\]

\[
= 491.52 \text{ m/sec}
\]

47. Air flows through an adiabatic compressor at 2 kg/sec. The inlet conditions are 1 bar and 310 K and exit conditions are 7 bar and 560 K. The irreversibility if \( T_0 = 298 \text{ K} \) (in kW) is ___________

47. Ans: 21.33 kW (range 21 to 22)
Sol:

\[
\begin{align*}
W_{\text{min}} &= \frac{m}{T_0} \left[h_2 - h_1 - T_0(s_2 - s_1)\right] \\
&= \frac{m}{T_0} c_p \left(T_2 - T_1\right) - T_0(s_2 - s_1) \\
W_{\text{actual}} &= \frac{m}{T_0} c_p \left(T_2 - T_1\right)
\end{align*}
\]

Irreversibility = \( W_{\text{actual}} - W_{\text{min}} \)

\[
= \frac{m}{T_0} \left(\frac{T_2}{T_1}\right) - R \left(\ln\left(\frac{P_2}{P_1}\right)\right)
\]

\[
= 2 \times 298 \left(1.005 \ln\left(\frac{560}{310}\right) - 0.287 \ln\left(\frac{7}{1}\right)\right)
\]

\[
= 2 \times 298 \left(0.5943 - 0.5585\right)
\]

\[
= 21.33 \text{ kW}
\]

48. Refer to the four bar mechanism shown in figure. AB = 40 cm, BC = 50 cm, DC = 30 cm, AD = 20 cm. At the instant when AB makes an angle of 180° with AD and rotates with an angular velocity of 3 rad/sec in counter clock wise direction. The angular velocity of the coupler link BC is ___________

48. Ans: 2 rad/sec (range 1.5 to 2.5)
Sol:

Identify the instantaneous centers as shown in figure.

\( \omega_2 = 3 \text{ rad/sec} \)
using Relative velocity for the instantaneous centre 23.

\[ V_{23} = (12 - 23) \omega_2 = (13 - 23) \omega_3 \]

\[ \Rightarrow \omega_3 = \frac{12 - 23}{13 - 23} \times \omega_2 \]

\[ = \frac{40}{60} = 2 \text{ rad/sec} \]

\[ \therefore \text{Angular velocity of the coupler BC} = 2 \text{ rad/sec} \]

Note: \((12 - 23)\) is the distance between the centres 12 and 23.

50. In a counter flow heat exchanger the cold fluid and hot fluids have mass flow rate of 2 kg/sec and 4 kg/sec with specific heats of 1 kJ/kgK and 0.5 kJ/kgK respectively. The overall Heat transfer coefficient is 150 W/m²K, surface area is 20 m². If the hot fluid enters at 100 °C and cold fluid leaves at 45 °C, then rate of heat transfer is ________ (in kW).

50. Ans: 165 kW (range 164.5 to 166)

Sol: LMTD method fails when \(m_h c_h = m_c c_c\); but when LMTD fails use GMTD which either of end temperature differences. Hence Mean temperature difference is 100 – 45 = 55 °C.

\[ \Delta \theta_m = \Delta \theta_1 = \Delta \theta_2 \]

\[ Q = U A \Delta \theta_m \]

\[ = 150 \times 20 \times 55 = 165 \text{ kW} \]

51. Let \(w (y_1, y_2)\) be the wronskian of two linearly independent solutions \(y_1\) and \(y_2\) of the equation, \(y'' + p(x) y' + Q(x) y = 0\). The product of \(w(y_1, y_2), p(x) = \)

(A) \(y_2 y_1 - y_1 y_2^*\)  
(B) \(y_1 y_1' - y_2 y_2'\)  
(C) \(y_1 y_2' - y_2 y_1'\)  
(D) \(y_1 y_2 - y_2^* y_1^*\)

51. Ans: (A)

Sol: \(y_1'' + p(x) y_1' + Q(x) y_1 = 0 \ldots \ldots (1)\)

\(y_2'' + p(x) y_2' + Q(x) y_2 = 0 \ldots \ldots (2)\)

\((1) \times y_2 - (2) \times y_1 \)

\[ \Rightarrow p(x) (y_1 y_2' - y_1' y_2) = y_2'' y_1 - y_1'' y_2 \]

\[ \therefore w (y_1, y_2) p(x) = y_1 y_2' - y_1' y_2' \]

52. If \(X = \cos \left( \frac{\pi}{3} r \right) + i \sin \left( \frac{\pi}{3} r \right)\) for \(r = 1, 2, 3, \ldots\) Then \(X_1, X_2, X_3, \ldots\) (upto infinity) equal to \(\) (Where, \(i = \sqrt{-1}\))

(A) \(1 + i\)  
(B) \(1\)  
(C) \(i\)  
(D) \(\frac{1}{2} + \frac{\sqrt{3}}{2} i\)
52. Ans: (C)

Sol: \[ X_1 = \cos \left( \frac{\pi}{3^r} \right) + \sin \left( \frac{\pi}{3^r} \right) = e^{i \left( \frac{\pi}{3} \right)} , \]
\[ r = 1, 2, 3, ... \]
\[ X_1, X_2, X_3, ... \]
\[ e^{i \left( \frac{1}{3} \frac{\pi}{3^r} \frac{1}{3^r} \frac{\pi}{3^r} \right)} = e^{i \pi} = 1 \]

53. Let \( M \) be the matrix \[
\begin{bmatrix}
2 & 3 \\
1 & -1
\end{bmatrix}
\]
Which of the following matrix equations does \( M \) satisfy.
(A) \( M^3 + 3M + 5I = 0 \)
(B) \( M^3 - M^2 - 5M = 0 \)
(C) \( M^3 - 3M^2 + M = 0 \)
(D) \( M^2 - M + 5I = 0 \)

53. Ans: (B)

Sol: The characteristic equation is \[
\lambda^2 - \lambda - 5 = 0
\]
we have \( M^2 - M = 5I = 0 \) (using Cayley Hamilton theorem)
Multiplying both sides by \( M \).
we get, \( M^3 - M^2 - 5M = 0 \)

54. The chezy coefficient of a wide rectangular open channel is 60. The model scale ratio is 1:64. The chezy’s coefficient of model river is
(A) 60
(B) 30
(C) 7.5
(D) Data insufficient

54. Ans: (A)

Sol: \[ V = C \sqrt{RS} \rightarrow \text{Chezy’s formula} \]
\[ F_r = \frac{V}{\sqrt{gy}} \]
\[ (F_r)_m = (F_r)_p \]
\[ \left( \frac{V}{\sqrt{gy}} \right)_m = \left( \frac{V}{\sqrt{gy}} \right)_p \]
\[ V_r = \sqrt{g_r}, \sqrt{V_r} = \sqrt{g_r}, \sqrt{L_r} \]
\[ C_r = \frac{V_r}{\sqrt{R_s, S_t}} = \frac{\sqrt{g_r}}{\sqrt{L_r, g_t}} = \frac{\sqrt{g_r}}{\sqrt{g_t}} \]
‘C’ is independent of scale ratio
\[ \therefore C_m = C_p \]

55. In Lumped heat capacity Analysis for limiting condition, the ambient temperature is 300°C, and initial temperature is 30°C. For what value of Fourier number is the temperature recorded by the thermocouple is one fifth of ambient temperature?
(A) 21.94
(B) 1.177
(C) 0.5115
(D) Data insufficient

55. Ans: (B)

Sol: At limiting condition biot number is 0.1.
Hence \[ \ln (T - T_r) / T_0 - T_r = -bi \times F_r \]
\[ 60 - 300/30 - 30 = 24 / 27 = 0.88888 \]
At limiting condition, biot no. = 0.1
Hence \( F_r = 1.177 \)

56. When cylinder is insulated inside with a material of thermal conductivity 1/10 of the parent material having same radial thickness (which is never equal to \( r \) and always less than \( r \)), then which of the following statements are correct?
(A) Heat transfer increases up to critical radius beyond which it decreases
(B) Heat transfer decreases up to critical radius beyond which it increases
(C) Heat transfer increases since its critical radius is 0
(D) Heat transfer always decreases

56. Ans: (D)

Sol: Critical radius is that outer radius where total thermal resistance offered is minimum applicable to cylinders insulated outside only since conduction resistance increases and convection resistance decreases.
When cylinders are insulated inside both conductive and convective resistance increases and total resistance increases which indicates the decrease in heat transfer always.

57. Consider the following LPP
Max Z = 2x₁ + 5x₂
Subject to
3x₁ + 2x₂ ≤ 4  
5x₁ + 3x₂ ≤ 6  
2x₁ + x₂ ≤ 5  
x₁, x₂ ≥ 0
the solution to the given LPP is
(A) Infeasible
(B) Unique optimal
(C) Multiple optimal
(D) Degenerate

57. Ans: (D)
Sol:
Zₘₐₓ = 2x₁ + 5x₂
Z₀₀ = 0
Z₀₂ = 2(0) + 5(2) = 10
Z₆₅₀ = 2(6/5) + 5(0) = 12/5
x₁ = 0, x₂ = 2
Zₘₐₓ = 10

58. Ans: (B)
Sol: Uniform pressure theory is used for bearings
\[ \sin \alpha = \frac{R - r}{b} = \frac{150 - 100}{100} = 0.9 \]
\[ \Rightarrow \alpha = 30^\circ \]
\[ T_f = 2 \frac{\mu W}{3 \sin \alpha} \frac{(R^3 - r^3)}{(R^2 - r^2)} \]
\[ = \frac{2}{3} \times 0.08 \times 10 \times 10^3 \times \frac{(0.15^3 - 0.1^3)}{(0.15^2 - 0.1^2)} \]
\[ = 0.2027 \times 10^3 \text{ N-mm} \]
\[ P = \frac{2\pi N T_f}{60} \]
\[ = \frac{2 \times \pi \times 100 \times 0.2027}{60} = 2121 \text{ W} \]

59. During welding operation with heat supply rate of 14kW, the area of weld bead is 40mm² and welding speed of 100mm/min. if the heat required for melting of weld bead is 0.1kJ/m³, the welding process used is
(A) Gas welding
(B) Arc welding
(C) Resistance welding
(D) None of the above

59. Ans: (B)
Sol: H.R / sec = [(area × velocity) / 60]× 0.1
\[ = 6.67 \text{ kJ/sec} \]
Efficiency of welding process
\[ = 6.67 / 14 = 47.61\% \]
Based on the efficiency, the welding process used is Arc welding process
Efficiency of arc welding is 45 to 55%

60. When straight tapered sprue is used in the gating system, the pressure at entry, middle height and exit of the sprue respectively are
(A) Pₐₜₘ + ve gauge & Pₐₜₘ
(B) Pₐₜₘ - ve gauge & Pₐₜₘ
(C) Pₐₜₘ, zero gauge & Pₐₜₘ
(D) Pₐₜₘ throughout

(A) 2094 W  (B) 2121 W
(C) 1047 W  (D) 1061 W
60. Ans: (A)
Sol: When parabolic sprue is used, the pressure all along length of the sprue is atmospheric and hence it avoids the aspiration effect. But it is difficult to manufacture. Due to this straight tapered sprue is used so that pressure at entry and exit is equal to atmospheric and in between the pressure is greater than atmospheric or +ve gauge pressure, hence it is avoiding aspiration effect and manufacture is also easier.

61. A member AB is made of steel and 1 m long the width of the bar is 200 mm and thickness is 50 mm. It is pulled by a lever as shown. Determine elongation of bar, use E = 200 GPa

\[ \delta \ell = \frac{P \ell}{AE} = \frac{40 \times 10^3 \times 1000}{200 \times 50 \times 200 \times 10^3} \]

\[ \therefore \delta \ell = 0.02 \text{ mm} \]

62. Ans: (D)
Sol:

\[ V = \frac{4}{3} \pi r^3 = \text{volume of sphere} \]

\[ \frac{dv}{dt} = \frac{4}{3} \pi r^2 \times \frac{dr}{dt} \]

\[ \frac{dv}{dt} = 4 \pi r^2 \times \frac{dr}{dt} \]

\[ 100 = 4 \pi \times 10^2 \times \frac{dr}{dt} \]

\[ \frac{dr}{dt} = \frac{1}{4 \pi} \]

\[ S = 4 \pi r^2 = \text{surface area} \]

\[ \frac{dS}{dt} = 2 \times 4 \pi r \times \frac{dr}{dt} \]

\[ = 8 \pi r \times \frac{dr}{dt} \]

\[ = 8 \pi \times 10 \times \frac{1}{4 \pi} = 20 \text{ metre}^2 / \text{min} \]

63. In a natural gas pipe line network at two different locations A and B. The measurements gave \( P_A = 0.25 \text{ MPa} \), \( P_B = 0.27 \text{ MPa} \), \( T_A = 302 \text{ K} \), \( T_B = 310 \text{ K} \). Assume natural gas behaves like an local gas with \( c_p = 29 \text{ kJ/kmol K} \). The flow is from

(A) A to B
(B) B to A
(C) No flow
(D) cannot be determined

Sol: Processes happen in a direction of increase in entropy

\[ S_B - S_A = c_p \ln \left( \frac{T_B}{T_A} \right) - R \ln \left( \frac{P_B}{P_A} \right) \]

\[ = 29 \ln \left( \frac{310}{302} \right) - 8.314 \ln \left( \frac{0.27}{0.25} \right) \]

\[ = 0.7582 - 0.6398 \]

\[ = 0.1183 \text{ kJ/kmol K} \]

Direction is from A to B.
64. A thin eccentric disk of mass 1 kg is balanced by attaching two masses to it as shown in fig. mass one, \( m_1 = 3 \text{ gms at } r_1 = 10 \text{ cm} \) while mass two, \( m_2 = 2 \text{ gms at } r_2 = 20 \text{ cm} \). The radial position and angular position of the centre of mass of the disk with respect to \( m_1 \) are respectively

(A) 5 mm @ 126.87°
(B) 0.5 mm @ 126.87°
(C) 5 mm @ 143.13°
(D) 0.5 mm @ 143.13°

64. Ans: (B)
Sol: Assuming the C.G of the disk as shown in below figure

\[
\begin{align*}
m &\quad \text{mass of the disk} \\
e &\quad \text{distance from the centre of mass to } m_1 \\
r_1 &\quad \text{radius of } m_1 \\
r_2 &\quad \text{radius of } m_2
\end{align*}
\]

Considering equilibrium is horizontal and vertical directions.
\[
\begin{align*}
me \cos \theta &= m_1 r_1 = 3 \times 10 = 30 \text{ gm cm} \\
me \sin \theta &= m_2 r_2 = 2 \times 20 = 40 \text{ gm cm}
\end{align*}
\]

Solving, \( me = \sqrt{30^2 + 40^2} = 50 \text{ gm cm} \)
\[
e = \frac{50 \text{ gm cm}}{1000 \text{ gms}} = 0.05 \text{ cm} = 0.5 \text{ mm}
\]
\[
\theta = \tan^{-1} \left( \frac{40}{30} \right) = 53.13°
\]

Angular position with respect to \( m_1 = 180° - 53.13° = 126.87° \)

65. A simple gear train is designed with a pinion of 20 teeth and a gear wheel of 60 teeth. They have a pressure angle of 20° and a module of 2mm. Both the pinion and gear have full dept involute tooth. Due to assembly constraints the centre distance was made equal to 80.8 mm what will be the effective pressure angle ?

(A) 20° (B) 21.5°
(C) 18° (D) 25°

65. Ans: (B)
Sol: For the pinion
\[
r = \frac{mt}{2} = \frac{2 \times 20}{2} = 20 \text{ mm}
\]

Gear radius \( R = \frac{mT}{2} = \frac{2 \times 60}{2} = 60 \text{ mm} \)

Designed centre distance
\( = 20 + 60 = 80 \text{ mm} \)

Assembled centre distance = 80.8 mm
\( R + r = 80 \text{ mm} \)
\( R' + r' = 80.8 \text{ mm} \)

where \( R' \) and \( r' \) are effective radii.

We know for involute gears variation in centre distance will not alter the velocity ratio
\[
\therefore \quad \frac{R'}{r'} = \frac{R}{r} = 3
\]

\( \Rightarrow \quad R' + r' = 80.8 \Rightarrow R' = 60.6 \text{ mm} \)
\( r' = 20.2 \text{ mm} \)

As the base circle radius remains unaltered the increase in centre distance leads to an increase in effective pressure angle
\[
\therefore \quad \frac{R' \cos \phi'}{R} = \frac{R \cos \phi}{R'}
\]
\[
\cos \phi' = \frac{R \cos \phi}{R'} = \frac{60 \cos 20°}{60.6}
\]

\( \Rightarrow \quad \phi = 21.5° \)