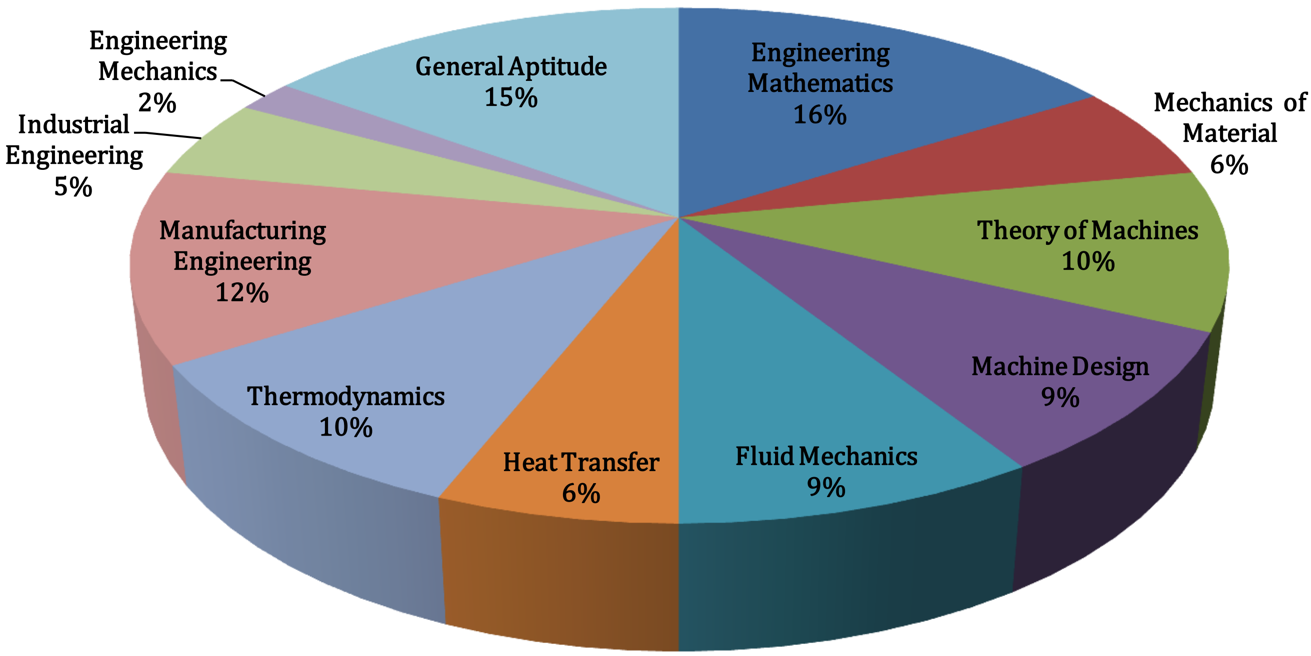
ANALYSIS OF GATE 2017*
Mechanical Engineering



ME ANALYSIS-2017_4-Feb_Afternoon

SUBJECT	Ques. No.	Topics Asked in Paper(Memory Based)	Level of Toughness	Total Marks
Engineering Mathematics	1 Marks: 6 2 Marks: 5	Calculus; Probability and Distribution Linear Algebra; Laplace Transform Differential Equations; Complex Variables	Moderate	**16**
Mechanics of Material	1 Marks: 4 2 Marks: 1	Simple Stress and Strain; Shear Force and Bending Moment; Deflection of Beams	Easy	**6**
Theory of Machines	1 Marks: 2 2 Marks: 4	Mechanisms; Flywheel; Vibrations; Balancing of Rotating Masses; Mechanisms	Easy	**10**
Machine Design	1 Marks: 1 2 Marks: 4	Design of Brakes and Clutches; Design for Combined Loading; Design of Bearings	Easy, Moderate	**9**
Fluid Mechanics	1 Marks: 3 2 Marks: 3	Fluid Statics; Boundary Layer Hydraulic Machines; Fluid Dynamics	Easy, Moderate	**9**
Heat Transfer	1 Marks: 2 2 Marks: 2	Radiation; Conduction; Heat Exchanger	Easy, Moderate	**6**
Thermodynamics	1 Marks: 2 2 Marks: 4	Psychrometrics; Basics of Thermodynamics Properties of Gases and Pure Substances Thermodynamic Cycles and Power Engineering Entropy, Availability and Irreversibility	Moderate	**10**
Manufacturing Engineering	1 Marks: 4 2 Marks: 4	Engineering Materials; Machining and Machine Tool Operations; Metrology and Inspection; Forming Process	Easy, Moderate	**12**
Industrial Engineering	1 Marks: 1 2 Marks: 2	Production, Planning and Control(Queing Theory, Project Complection)	Moderate	**5**
Engineering Mechanics	1 Marks: 0 2 Marks: 1	Kinematics and Dynamics of Particle	Moderate	**2**
General Aptitude	1 Marks: 2 Marks:	Verbal Ability; Numerical Ability	Tough	**15**
Total	**65**			**100**
Faculty Feedback	Majority of the question were direct concept based. MPE, TD, TOM, Maths and FM weightage was comparatively high. Surprise was GA, it was comparatively tough as compared to the last year.			

GATE 2017 Examination

Mechanical Engineering

Test Date: 04/02/2017

Test Time: 2:00 AM to 5:00 PM

Subject Name: MECHANICAL ENGINEERING

Section: General Aptitude

1. A couple has 2 children. The probability that both children are boys if the older one is a boy is

(A) 1/4
(B) 1/3
(C) 1/2
(D) 1

[Ans. C]

$$\text{Probability} = \frac{\text{Number of favorable cases}}{\text{Total number of possible cases}}$$

Among two children's (boys), the older one is a boy = 1 and two children's are boys only.

$$\therefore \text{Probability} = \frac{1}{2}$$

2. If you choose plan P, you will have to _____ plan Q, as these two are mutually _____.

(A) forgo, exclusive
(B) forget, inclusive
(C) accept, exhaustive
(D) adopt, intrusive

[Ans. A]

Choosing plan 'P', you will have for go plan 'Q'. Both are different plans so they are exclusive.

3. P looks at Q while Q looks at R. P is married, R is not. The number of pairs of people in which a married person is looking at an unmarried person is

(A) 0
(B) 1
(C) 2
(D) Cannot be determined

[Ans. B]

P → Q → R
(Married) (Unmarried)

P is a married person is looking Q

But Q is married (or) unmarried is not given so,

∴ Cannot be determined

4. The ways in which this game can be played ____ potentially infinite.

(A) is
(B) is being
(C) are
(D) are being

[Ans. C]

Subject verb agreement 'Two ways' is plural so the verb also should be plural (are)

5. If a and b are integers and $a - b$ is even, which of the following must always be even?

(A) ab

(B) $a^2 + b^2 + 1$

(C) $a^2 + b + 1$

(D) $ab - b$

[Ans. D]

According to the given relation of $a - b$ = even, there is a possibility of odd-odd (or) even-even is equal to even

From the given Option (D)

Odd × odd – odd (or) even × even – even → is always even number

Odd = odd number, even = even number

All other options are not satisfied this condition.

6. X bullocks and Y tractors take 8 days to plough a field. If we halve the number of bullocks and double the number of tractors, it takes 5 days to plough the same field. How many days will it take X bullocks alone to plough the field?

(A) 30

(B) 35

(C) 40

(D) 45

[Ans. A]

No. of bullocks = x

No. of tractors = y,

From the given data,

$(x + y) = 8 \text{ days}, 1 \text{ day } (x + y) = \frac{1}{8} \dots \dots . ①$

$\left(\frac{x}{2} + 2y\right) = 5 \text{ days}, 1 \text{ day } \left(\frac{x}{2} + 2y\right) = \frac{1}{5} \dots \dots . ②$

$x + y = \frac{1}{8} \dots \dots . ① \times 2$

$2x + 2y = \frac{1}{4}$

$\frac{x}{y} + 2y = \frac{1}{5}$

$- \quad - \quad -$

$2x - \frac{x}{2} - \frac{1}{20}$

$\frac{4x - x}{2} = \frac{1}{20}$

$3x = \frac{1}{10}$

$x = \frac{1^{th}}{30}$

One day work of bulllocks $= \frac{1}{30}$th

∴x bullocks alone to plough the field = 30 days

7. There are 4 women P, Q, R, S, and 5 men V, W, X, Y, Z in a group. We are required to form pairs each consisting of one woman and one man. P is not to be paired with Z, and Y must necessarily be paired with someone. In how many ways can 4 such pairs be formed?

(A) 74 (C) 78
(B) 76 (D) 80

[Ans. C]

If P is paired with y; they Q has 4 choices
R has 3 choices
S has 2 choices
Total 24 choices

(or)

If Q is paired with y; then P has 3 choices
R has 3 choices
S has 2 choices
Total 18 choices

(or)

If R is paired with y; then P has 3 choices
Q has 3 choices
S has 2 choices
Total 18 choices

(or)

If S is paired with y; then P has 3 choices
Q has 3 choices
S has 2 choices
Total 18 choices

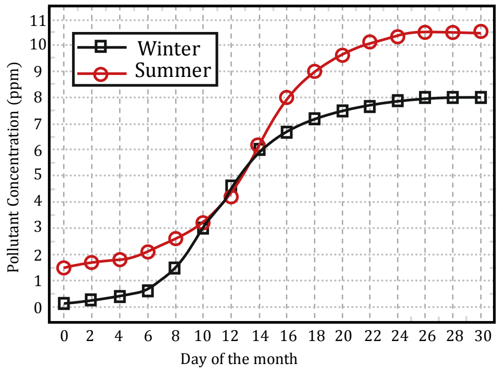
∴ Total number of ways = 24 + 18 + 18 + 18 = 78

8. All people in a certain island are either 'Knights' or Knaves' and each person knows every other person's identify. Knights NEVER lie, and knaves ALWAYS lie.
P says "Both of us are knights". Q says "None of us are Knaves".
Which one of the following can be logically inferred from the above?

(A) Both P and Q are knights
(B) P is a knight; Q is a knave
(C) Both P and Q are knaves
(D) The identities of P, Q cannot be determined

[Ans. D]

9. In the graph below, the concentration of a particular pollutant in a lake is plotted over (alternate) days of a month in winter (average temperature 10°C) and a month in summer (average temperature 30°C).



Consider the following statements based on the data shown above:

i. Over the given months, the difference between the maximum and the minimum pollutant concentrations is the same in both winter and summer.

ii. There are at least four days in the summer month such that the pollutant concentrations on those days are within 1 ppm of the pollutant concentrations on the corresponding days in the winter month.

Which one of the following options is correct?

(A) Only i
(B) Only ii
(C) Both i and ii
(D) Neither i nor ii

[Ans. B]

From the given graph,

The difference between the maximum and the minimum pollutant concentrations in the winter $= 8 - 0 = 8$ ppm

The difference between the maximum and the minimum pollutant concentrations in the summer $= 10.5 - 1.5 = 9$ ppm

Over the given months, these differences are not equal.

∴ Statement (i) is not correct.

From the given graph, the statement (ii) is correct.

10. "If you are looking for a history of India, or for an account of the rise and fall of the British Raj, or for the reason of the cleaving of the subcontinent into two mutually antagonistic parts and the effects this mutilation will have in the respective sections, and ultimately on Asia, you will not find it in these pages; for though I have spent a lifetime in the country, I lived too near the seat of events, and was too intimately associated with the actors, to get the perspective needed for the impartial recording of these matters."

Which of the following is closest in meaning to 'cleaving'?

(A) deteriorating
(B) arguing
(C) departing
(D) splitting

[Ans. D]

Cleaving means to divide by or to separate into distinct parts.

Section: Technical

1. The emissive power of a black body is P. If its absolute temperature is doubled, the emissive power becomes
   (A) 2P
   (B) 4P
   (C) 8P
   (D) 16P

   [Ans. D]

   $E \propto T^4, T_2 = 2T_1, E_1 = P$

   $\frac{E_1}{E_2} = \frac{T_1^4}{T_2^4}$

   $\frac{E_1}{E_2} = \frac{(T_1)^4}{(2T_1)^4}$

   $\frac{E_1}{E_2} = \frac{T_1^4}{16T_1^4}$

   $E_2 = 16E_1$

   $E_2 = 16P$

2. The divergence of the vector $-yi + xj$ is_____

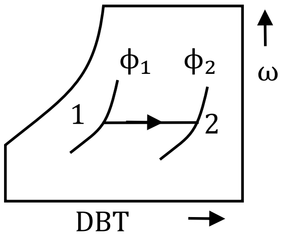
   [Ans. *] Range 0 to 0

   $\text{div}\,(-yi + Xj) = \frac{\partial}{\partial X}(-Y) + \frac{\partial}{\partial Y}(X) = 0$

3. If a mass of moist air contained in a closed metallic vessel is heated, then its
   (A) relative humidity decreases
   (B) relative humidity increases
   (C) specific humidity increases
   (D) specific humidity decreases

   [Ans. A]

   Sensible heating process, RH decreases



4. A sample of 15 data is as follows; 17,18,17,17,13,18,5,5,6,7,8,9,20,17,3. The mode of the data is
   (A) 4
   (B) 13
   (C) 17
   (D) 20

   [Ans. C]

   In sample, the mode is defined as the sample point which occur maximum number of times.
   In the given sample, 17 occurs maximum number of times.
   ∴ Mode = 17

5. The state of stress at a point is $\sigma_x = \sigma_y = \sigma_z = \tau_{xz} = \tau_{zx} = \tau_{zy} = 0$ and $\tau_{xy} = \tau_{yx} = 50$ MPa. The maximum normal stress (in MPa) at that point is ________

[Ans. *] Range 50 to 50

The state of stress is pure shear

Hence, $\sigma_1 = \sigma_2 = \tau$

$\therefore \sigma_{max} = 50$ MPa

6. For the stability of a floating body the
   (A) centre of buoyancy must coincide with the centre of gravity
   (B) centre of buoyancy must be above the centre of gravity
   (C) centre of gravity must be above the centre of buoyancy
   (D) metacentre must be above the centre of gravity

[Ans. D]

For stability of floating bodies GM > 0 or M must be above G.

7. A machine component made of a ductile material is subjected to a variable loading with $\sigma_{min} = -50$ MPa and $\sigma_{max} = 50$ MPa If the corrected endurance limit and the yield strength for the material are $\sigma'_e = 100$ MPa and $\sigma_y = 300$ MPa, respectively, the factor of safety ______

[Ans. *] Range: 2 to 2

$\sigma_{min} = -50$ MPa,

$\sigma_{max} = 50$ MPa,

$s_e = 100$ MPa,

$s_{yt} = 300$ MPa

The stress is completely reversed stress and mean stress, $\sigma_m = 0$ and stress amplitude. $\sigma_a = 50$ MPa.

$$50 = \frac{100}{FS} \Rightarrow F.s = 2$$

8. For a single server with Poisson arrival and exponential service time, the arrival rate is 12 per hour. Which one of the following rates will provide a steady state finite queue length?
   (A) 6 per hour
   (B) 10 per hour
   (C) 12 per hour
   (D) 24 per hour

[Ans. D]

Arrival rate $= \lambda = 12 hr^{-1}$

For finite Que length departure rate must be greater than arrival rate. $(\mu > \lambda)$

$\therefore \mu = 24 hr^{-1}$

9. Given the atomic weight of Fe is 56 and that of C is 12, the weight percentage of carbon in cementite (Fe_3C) is________

[Ans. *] Range 6.7 to 6.7

$$\text{The percentage of carbon}(Fe_3c) = \frac{12}{56 \times 3 + 12 \times 1} \times 100 = 6.67\%$$

10. It is desired to make a product having T-shaped cross – section from a rectangular aluminium block. Which one of the following processes is expected to provide the highest strength of the product?

(A) Welding
(B) Casting
(C) Metal forming
(D) Machining

[Ans. C]

Metal forming gives grain orientation and fine grains. Hence strength is high.

11. A steel bar is held by two fixed supports as shown in the figure and is subjected to an increase of temperature $\Delta T = 100°C$. If the coefficient of thermal expansion and Young's modulus of elasticity of steel are $11 \times 10^{-6}/°C$ and 200 GPa, respectively, the magnitude of thermal stress (in MPa) induced in the bar is______

[Ans. *] Range 220 to 220

Temperature increase, $T = 100°C$

Young's modulus of elasticity, $E = 200 \times 10^3$ MPa

Coefficient of thermal expansion, $\alpha = 11 \times 10^{-6}/°C$

Thermal stress, $\sigma = (\alpha\, t)E$

$$= (11 \times 10^{-6})(100)(200 \times 10^3) = 220 \text{ MPa}$$

12. Consider a laminar flow at zero over a flat plate. The shear stress at the wall is denoted by τ_W. The axial positions x_1 and x_2 on the plate are measured from the leading edge in the direction of flow. If $x_2 > x_1$, then

(A) $\tau_W|_{x_1} = \tau_W|_{x_2} = 0$
(B) $\tau_W|_{x_1} = \tau_W|_{x_2} \neq 0$
(C) $\tau_W|_{x_1} > \tau_W|_{x_2}$
(D) $\tau_W|_{x_1} < \tau_W|_{x_2}$

[Ans. C]

$$\tau_W(x) = \frac{1}{2} C_{fx} \rho U_\infty^2 = \frac{1}{2} \times \frac{0.332}{\sqrt{\frac{\rho U_\infty X}{\mu}}} \times \rho U_\infty^2$$

$$\propto \frac{1}{\sqrt{x}}$$

$$\therefore \frac{\tau_W}{x_1} > \frac{\tau_W}{x_2}$$

13. Two coins are tossed simultaneously. The probability (upto two decimal points accuracy) of getting at least one head is_______

[Ans. *] Range 0.75 to 0.75

Sample space = {HH, HT, TH, TT}

Total cases = 4

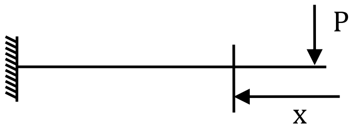
Favourable cases for atleast one head = 3

$$\therefore \text{Require Probabitlity, } P = \frac{3}{4} = 0.75$$

14. Which one of the following statements is TRUE for the ultrasonic machining (USM) process?
(A) In USM, the tool vibrates at subsonic frequency.
(B) USM does not employ magnetostrictive transducer.
(C) USM is an excellent process for machining ductile materials.
(D) USM often uses a slurry comprising abrasive-particles and water.
[Ans. D]
In USM vibration is in ultrasonic range, it uses piezoelectric (or) magnetostrictive transducer for producing high frequency vibrations and it is used only for brittle materials.

15. For a loaded cantilever beam of uniform cross-section, the bending moment (in N-mm) along the length is $M(x) = 5x^2 + 10x$, where x is the distance (in mm) measured from the free end of the beam The magnitude of shear force (in N) in the cross-section at x = 10 mm is_____
[Ans. *] Range 110 to 110
$M(x) = 5x^2 + 10x$
shear force $F = \frac{dM}{dx} = 10x + 10 = 10 \times 10 + 10 = 110$ N

16. A cantilever beam of length L and flexural modulus EI is subjected to a point load P at the free end. The elastic strain energy stored in the beam due to bending (neglecting transverse shear) is
(A) $\frac{P^2L^3}{6EI}$
(B) $\frac{P^2L^3}{3EI}$
(C) $\frac{PL^3}{3EI}$
(D) $\frac{PL^3}{6EI}$
[Ans. A]



$U = \frac{M^2 dx}{2EI}$

$= \int_0^l \frac{(Px)^2 dx}{2EI}$

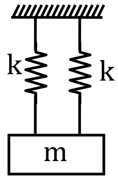
$= \frac{P^2}{2EI}\left[\frac{x^3}{3}\right]_0^l$

$U = \frac{P^2 l^3}{6EI}$

17. The determinant of a 2×2 matrix is 50. If one eigenvalue of the matrix is 10, the other eigenvalue is ________.
[Ans. *] Range 5 to 5
Let, λ_1, λ_2 be two eigen values of A
Let, $\lambda_1 = 10$.
Given that, det(A) = 50
$\Rightarrow \lambda_1\lambda_2 = 50$($\because$ Product of Eigen Values of A = det(A)]
$\Rightarrow 10\lambda_2 = 50$
$\Rightarrow \lambda_2 = 5$

18. Which one of the following statements is TRUE?
(A) Both Pelton and Francis turbines are impulse turbines.
(B) Francis turbine is a reaction turbine but Kaplan turbine is an impulse turbine.
(C) Francis turbine is an axial-flow reaction turbine.
(D) Kaplan turbine is an axial-flow reaction turbine.
[Ans. D]

19. A mass m is attached to two identical springs having spring constant k as shown in figure. The natural frequency ω of this single degree of freedom system is



(A) $\sqrt{\frac{2k}{m}}$ (C) $\sqrt{\frac{k}{2m}}$
(B) $\sqrt{\frac{k}{m}}$ (D) $\sqrt{\frac{4k}{m}}$
[Ans. A]
Springs are in parallel connections; $k_{eq} = k + k = 2k$

$$\omega_n = \sqrt{\frac{k_{eq}}{m_{eq}}} = \sqrt{\frac{2k}{m}} \text{rad/sec}$$

20. The standard deviation of linear dimensions P and Q are 3 μm and 4 μm, respectively. When assembled, the standard deviation (in μm) of the resulting linear dimension (P+Q) is______
[Ans. *] Range 5 to 5
$\text{Variance}(P + Q) = \text{Variance}(P) + \text{Variance}(Q)$
$\text{Variance}(P + Q) = 3^2 + 4^2;\ \sigma^2 = 25$
$\text{Standard deviation } (P + Q) = \sqrt{25} = 5\ \mu m$

21. A mass m of a perfect gas at pressure p_1 and volume V_1 undergoes an isothermal process. The final pressure is p_2 and volume is V_2. The work done on the system is considered positive. If R is the gas constant and T is the temperature, then the work done in the process is
(A) $p_1V_1 \ln\frac{V_2}{V_1}$ (C) $RT \ln\frac{V_2}{V_1}$
(B) $-p_1V_1 \ln\frac{p_1}{p_2}$ (D) $-mRT\ln\frac{p_2}{p_1}$
[Ans. B]
$p_1V_1 = p_2V_2$(isothermal)
$\frac{p_1}{p_2} = \frac{V_2}{V_1}$
$\text{Isothermal work} = -p_1V_1 \ln\frac{V_2}{V_1} = -p_1V_1 \ln\frac{p_1}{p_2}$

22. The crystal structure of aluminium is
(A) body –centred cubic
(B) face – centred cubic
(C) close – packed hexagonal
(D) body – centred tetragona
[Ans. B]

23. The heat loss from a fin is 6 W. The effectiveness of the fin are 3 and 0.75, respectively. The heat loss (in W) from the fin, keeping the entire fin surface at base temperature, is_______
[Ans. *] Range: 8 to 8
$Q_{act} = 6$ W
Effictiveness$(\in) = 3$
Efficiency$(\eta) = 0.75$
Entire fin is maintained at base temperature means Q_{max}

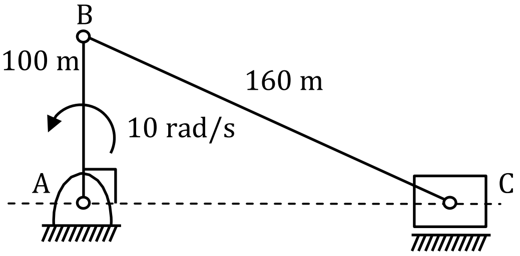
$$\eta = \frac{Q_{act}}{Q_{max}}$$

$$0.75 = \frac{6}{Q_{max}}$$

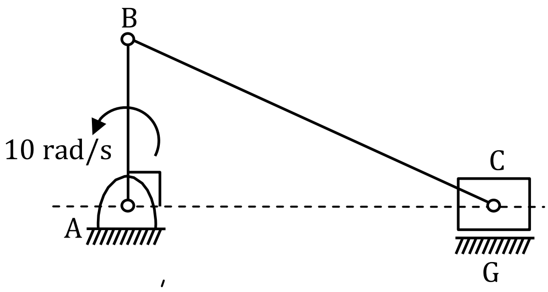
$$Q_{max} = \frac{6}{0.75}$$

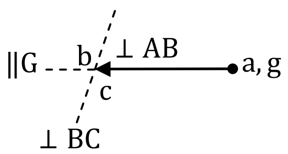
$$Q_{max} = 8 \text{ W}$$

24. In a slider-crank mechanism, the lengths of the crank and the connecting rod are 100 mm and 160 mm, respectively. The crank is rotating with an angular velocity of 10 radian/ counterclockwise. The magnitude of linear velocity (in m/s) of the piston at the instant corresponding to the configuration shown in the figure is________



[Ans. *] Range: 1 to 1





(Velocity Diagram)

From the velocity diagram when crank is perpendicular to the line of stroke, the velocity of slider = velocity of crank and angular velocity of connecting rod is zero.

$\omega_2 = 10$ rad/s

At this position, i.e. crank angle $\theta = 90°$ $V_{slider} = r\omega_2 = 10 \times 100$ mm/s

$\therefore$ Slider velocity = 1 m/s

25. The Laplace transform of te^t is

(A) $\frac{s}{(s=1)^2}$

(B) $\frac{1}{(s-1)^2}$

(C) $\frac{1}{(s+1)^2}$

(D) $\frac{s}{s-1}$

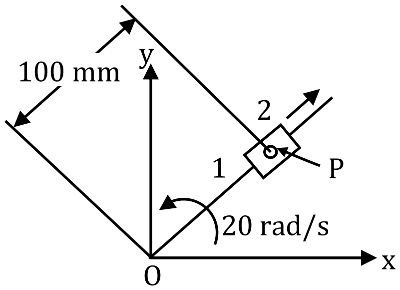
[Ans. B]

We know that, $L(t) = \frac{1}{s^2}$

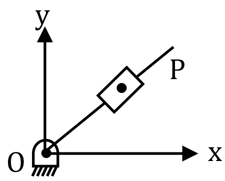
By first shifting property,

$L(te^t) = \frac{1}{(s-1)^2}$

26. Block 2 slides outward on link 1 at a uniform velocity of 6 m/s as shown in the figure. Link 1 is rotating at a constant angular velocity of 20 radian/s counterclockwise. The magnitude of the total acceleration (in m/s^2) of point P of the block with respect to fixed point O is_______



[Ans. *] Range: 243.31 to 243.31



r = 100 mm = 0.1 m

Uniform angular velocity = ω = 20 rad/s

Angular acceleration, $\alpha = 0$

Uniform sliding Velocity = V_S = 6 m/s

$\therefore$ Sliding acceletion $f^s = 0$

Coriolis acceleration, $f^c = 2V_\omega = 2 \times 6 \times 20$

$= 240$ m/ $\sec^2$ $\perp$lr to OP

Centripetal acceleration $= r\omega^2 = 0.1 \times 20^2$

$= 40$ m/$\sec^2$ towards the center of rotation

Resultant acceleration $= \sqrt{(f^c)^2 + (f^{cor})^2} = \sqrt{40^2 + 240^2} = 243.3$ m/s^2

27. In an orthogonal machining with a tool of 9° orthogonal rake angle, the uncut chip thickness is 0.2 mm. The chip thickness fluctuates between 0.25 mm and 0.4 mm. The ratio of the maximum shear angle to the minimum shear angle during machining is ________

[Ans. *] Range 1.4933 to 1.4933

$\alpha = 9°, t_1 = 0.2, t_2 = 0.25 \text{ to } 0.4$

$$r_{max} = \frac{t_1}{t_{2min}} = \frac{0.2}{0.25} = 0.8$$

$$\phi_{max} = \tan^{-1}\left(\frac{r_{max}\cos\alpha}{1 - r_{max}\sin\alpha}\right) = 42.087$$

$$r_{min} = \frac{t_1}{t_{2max}} = \frac{0.2}{0.4} = 0.5$$

$$\phi_{min} = \tan^{-1}\left(\frac{r_{min}\cos\alpha}{1 - r_{min}\sin\alpha}\right) = 28.18$$

$$\text{Ratio} = \frac{\phi_{max}}{\phi_{min}} = \frac{42.087}{28.18} = 1.493 = 1.5$$

28. During the turning of a 20 mm-diameter steel bar at a spindle speed of 400 rpm, a tool life of 20 minute is obtained. When the same bar is turned at 200 rpm, the tool life becomes 60 minute. Assume that Taylor's tool life equation is valid. When the bar is turned at 300 rpm, the tool life (in minute) is approximately

(A) 25
(B) 32
(C) 40
(D) 50

[Ans. B]

$D = 20 \text{ mm}, \quad N_1 = 400 \text{ rpm} = V_1, \quad T_1 = 20 \text{ min}$

$N_2 = 200 \text{ rpm} = V_2, T_2 = 60 \text{ min},$

$N_3 = 300 \text{ rpm} = V_3, T_3 = ?$

$$V_1 T_1^n = V_2 T_2^n$$

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

$$n = \frac{\ln\left(\frac{V_2}{V_1}\right)}{\ln\left(\frac{T_1}{T_2}\right)} = \frac{\ln\left(\frac{200}{400}\right)}{\ln\left(\frac{20}{60}\right)} = 0.631$$

$$V_3 T_3^n = V_1 T_1^n$$

$$T_3 = T_1\left(\frac{V_1}{V_3}\right)^{\frac{1}{n}}$$

$$= 20\left(\frac{400}{300}\right)^{\frac{1}{0.631}} = 31.557 = 32 \text{ min}$$

29. A product made in two factories, P and Q is transported of two destinations, R and S. The per unit costs of transportation (in Rupees) from factories to destinations are as per the following matrix.

Factory \ Destination	R	S
P	10	7
Q	3	4

Factory P produces 7 units and factory Q produces 9 units of the product. Each destination requires 8 units. If the north-west corner method provides the total transportation cost as X(in Rupees) and the optimized (the minimum) total transportation cost is Y (in rupees), then (X-Y), in rupees, is

(A) 0
(B) 15
(C) 35
(D) 105

[Ans. A]

30. A metal ball of diameter 60 mm is initially at 220°C. The ball is suddenly cooled by an air jet of 20°C. The heat transfer coefficient is 200 $W/m^2.K$. The specific heat, thermal conductivity and density of the metal ball are 400 J/kg.K, 400 W/m.K and 9000 kg/m^3, respectively. The ball temperature (in °C) after 90 seconds will be approximately

(A) 141
(B) 163
(C) 189
(D) 210

[Ans. A]

Given data

$R = 0.03$ m

$T_0 = 220°C$

$T_\infty = 20°C$

$h = 200\ W/m^2K$

$c = 400\ J/kg.K$

$k = 400\ W/mK$

$\rho = 9000\ kg/m^3$

$T = ?$

$t = 90$ sec

$$L_c = \frac{V}{A_s} = \frac{\frac{4}{3}\pi R^3}{4\pi R^2} = \frac{R}{3} = 0.01$$

$$\text{Biot Number Bi} = \frac{hL_c}{k} = \frac{200 \times 0.01}{400}$$

$$= 5 \times 10^{-3}$$

Bi < 0.1 hence lumped analysis is valid

$$T - \frac{T_\infty - T_\infty}{T_0 - T_\infty} = e^{\frac{-ht}{\rho c l_c}}$$

$$T = T_\infty + (T_0 - T_\infty) = e^{\frac{-ht}{\rho c l_c}}$$

$T = 141°C$

31. The volume and temperature of air (assumed to be an ideal gas) in a closed vessel is 2.87 m^3 and 300 K, respectively. The gauge pressure indicated by manometer fitted to the wall of the vessel is 0.5 bar. If the gas constant of air is R = 287 J/kg.K and the atmospheric pressure is 1 bar, the mass of air (in kg) in the vessel is

(A) 1.67
(B) 3.33
(C) 5.00
(D) 6.66

[Ans. C]

$V_1 = 2.87\ m^3$

$T_1 = 300k$

$P_{abc} = P_{atm} + P_{gauge}$

$R = 0.287\ kJ/kg.k$

$R = 0.287\ kJ/kg.k$

$$m = \frac{P_1V_1}{RT_1} = \frac{150 \times 2.87}{0.287 \times 300} = 5\ kg$$

32. A helical compression spring made of a wire of circular cross-section is subjected to a compressive load. The maximum shear stress induced in the cross-section of the wire is 24 MPa. For the same compressive load, if both the wire diameter and the mean coil diameter are doubled, the maximum shear stress (in MPa) induced in the cross-section of the wire is ________

[Ans. *] Range 6 to 6

Shear stress in helical spring is

$$\tau_{max} = \frac{8PD}{\pi d^3} \times k_W$$

$$k_w = \text{Wahl'sfactor} = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

$\tau_{max} = 24\ MPa$

For same load, D and d are doubled

∴ Wahl's factoreis same

$$\tau'_{max} = k_w \times \frac{8PD}{\pi d^3} \times \frac{2}{8} = \frac{\tau_{max}}{4}$$

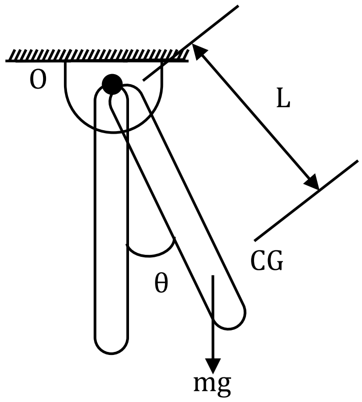
$$\tau'_{max} = \frac{24}{4} = 6\ MPa$$

33. The radius of gyration of a compound pendulum about the point of suspension is 100 mm. The distance between the point of suspension and the centre of mass is 250 mm. Considering the acceleration due to gravity as 9.81 m/s^2, the natural frequency (in radian/s) of the compound pendulum is ________

[Ans. *] Range 15.66 to 15.66

Radius of gyration, $r = 100\ mm = 0.1\ m$, $L = 250\ mm = 0.25\ m$, $g = 9.81\ m/sec^2$

$\omega_n = ?$



The equation of motion is $I_o\ddot{\theta} + mgL\sin\theta = 0$

For small value of $\theta, \sin\theta \simeq \theta$

$\therefore \omega_n = \sqrt{\dfrac{mgL}{I_o}}$

$\therefore I_o = mr^2$

$\therefore \omega_n = \sqrt{\dfrac{mgL}{mr^2}} = \sqrt{\dfrac{gL}{r^2}} = \sqrt{\dfrac{9.81 \times 0.25}{0.1^2}}\text{rad/s} = 15.66\ \text{rad/s}$

34. Consider the differential equation $3y''(x) + 27\,y(x) = 0$ with initial conditions $y(0) = 0$ and $y'(0) = 2000$. The value of y at $x = 1$ is ______

[Ans. *] Range: 93 to 95

$3y''(x) + 27y(x) = 0, y(0) = 0, y'(0) = 2000$

Auxiliary equation, $3m^2 + 27 = 0 \Rightarrow m^2 + 9 = 0 \Rightarrow m = 0 + 3i$

$y_c = c_1\cos 3x + c_2 \sin 3x$ and $y_p = 0$

$\therefore y_c = c_1\cos 3x + c_2\sin 3x$

$y(0) = 0 \Rightarrow c_1 + 0 = 0 \Rightarrow c_1 = 0$

$\therefore y = c_2 \sin 3x$

$y' = 3c_2\cos 3x$

$y'(0) = 2000 \Rightarrow 2000 = 3c_2 \Rightarrow c_2 = \dfrac{2000}{3}$

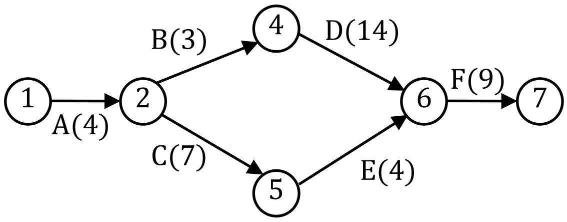
$\therefore y = \dfrac{2000}{3}\sin 3x, y(1) = \dfrac{2000}{3}\sin 3 = 94.08$

35. A project starts with activity A and ends with activity F. The precedence relation and durations of the activities are as per the following table:

Activity	Immediate predecessor	Duration (days)
A	-	4
B	A	3
C	A	7
D	B	14
E	C	4
F	D,E	9

The minimum project completion time (in days) is ______

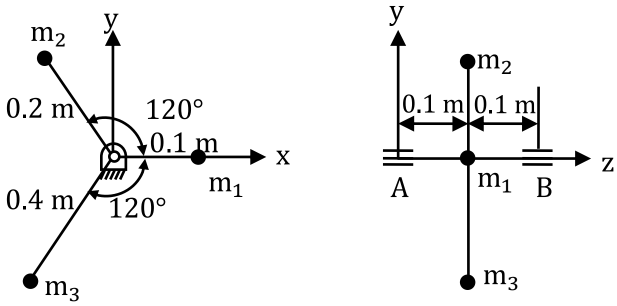
[Ans. *] Range: 30 to 30



Paths	
ABDF	4 + 3 + 14 + 9 = 30 days
ACEF	4 + 7 + 4 + 9 = 24 days

Longest path is critical path duration = 30 days

36. Three masses are connected to a rotating shaft supported on bearings A and B as shown in the figure. The system is in a space where the gravitational effect is absent. Neglect the mass of shaft and rods connecting the masses. For $m_1 = 10$ kg, $m_2 = 5$ kg and $m_3 = 2.5$ kg and for a shaft angular speed of 1000 radian/s, the magnitude of the bearing reaction (in N) at location B is ______



[Ans. *] Range: 0 to 0

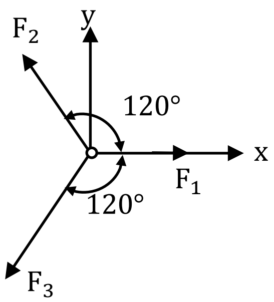
$F_1 = m_1 r_1 \omega^2 = 10 \times 0.1 \times \omega^2 = \omega^2$

$F_2 = m_2 r_2 \omega^2 = 5 \times 0.2 \times \omega^2 = \omega^2$

$F_2 = m_2 r_2 \omega^2 = 2.5 \times 0.4\omega^2 \times \omega^2$

$\sum F_x = \omega^2[1 + \cos 120° + \cos 120°] = 0$

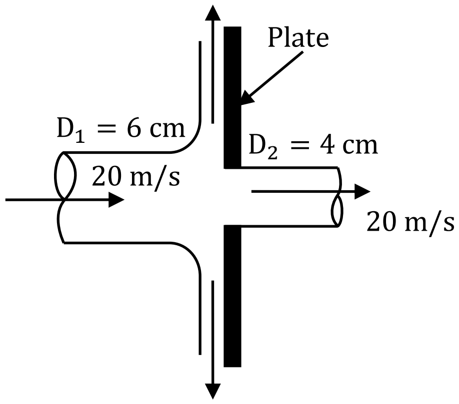
$\sum F_y = F_2 \cos 30° - F_3 \cos 30° = 0$



∴ Net force = 0

∴ Bearing reactions = 0 N

37. A 60 mm-diameter water jet strikes a plate containing a hole of 40 mm diameter as shown in the figure. Part of the jet passes through the hole horizontally, and the remaining is deflected vertically. The density of water is 1000 kg/m^3. If velocities are as indicated in the figure, the magnitude of horizontal force (in N) required to hold the plate is



[Ans. *] Range 628.32 to 628.32

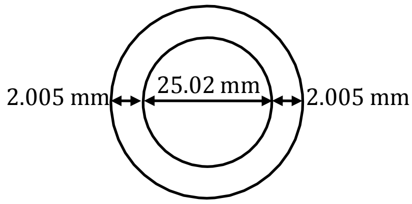
$F = \rho(A_1 - A_2)V^2$

$= 1000 \times \frac{\pi}{4} \times (0.06^2 - 0.04^2) \times 20^2$

$= 628.3$ N

38. A cylindrical pin of $25^{+0.020}_{+0.010}$ diameter is electroplated. Plating thickness is $2.0^{\pm 0.005}$ mm. Neglecting the gauge tolerance, the diameter (in mm, up to 3 decimal points accuracy) of the GO ring gauge to inspect the plated pin is________

[Ans. *] Range: 29.030 to 29.030



Pin = Shaft = $25^{+0.020}_{+0.010}$

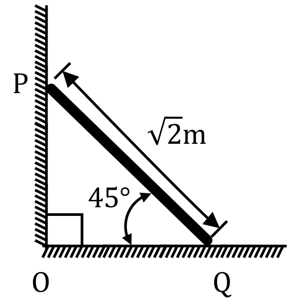
Plating thickness = 2 ± 0.005 mm

Go gauge size → Maximum material limit of shaft of shaft → H. limit of shaft

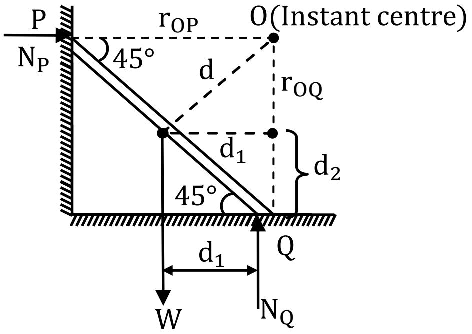
H. Limit of shaft after plating = $25.02 + 2 \times 2.005 = 29.03$ mm

Go ring size = 29.03 mm

39. The rod PQ of length $L = \sqrt{2}$ m, and uniformly distributed mass of $M = 10$ kg, is released from rest at the position shown in the figure. The ends slide along the frictionless faces OP and OQ. Assume acceleration due to gravity, $g = 10\ m/s^2$. The mass moment of inertia of the rod about its centre of mass and an axis perpendicular to the plane of the figure is $(ML^2/12)$. At this instant, the magnitude of angular acceleration (in radian/s^2) of the rod is ________



[Ans. *] Range 7.5 to 7.5



Given, $L = \sqrt{2}m, m = 10kg$

$g = 10\ m/s^2 \quad I_{CG} = \frac{mL^2}{12}$

Angular acceleration, $\alpha = ?$

The rod PQ is in general plane motion while falling down.

$$d_1 = \frac{\sqrt{2}}{2} \times \cos 45$$

$$d_1 = \frac{1}{2}m = d_2$$

$$r_{OQ} = \sqrt{2} \times \sin 45$$

$$= 1\ m = r_{OP}$$

$$d^2 = d_1^2 + (r_{OQ} - d_2)^2$$

$$d^2 = \left(\frac{1}{2}\right)^2 + \left(1 - \frac{1}{2}\right)^2$$

$$d^2 = 2 \times \left(\frac{1}{2}\right)^2 = \frac{1}{2}m^2$$

Take moment about the I centre

Moment $= M = I_o\alpha$

I_o = Mass moment of inertia With respet to instant centre $O = I_{CG} + md^2 = \frac{ml^2}{12} + md^2$

$$I_0 = \frac{m}{12}(\sqrt{2})^2 + m \times \frac{1}{2} = \frac{m}{6} + \frac{m}{2} = \frac{4\ m}{6} = \frac{2\ m}{3}$$

α = Angular acceleration

M = moment With respect $O = W \times d_1 = m \times g \times d_1$

$$m \times g \times d_1 = \frac{2\ m}{3} \times \alpha$$

$$\Rightarrow \alpha = \frac{3}{2} \times 10 \times \frac{1}{2} = 7.5\ rad/sec^2$$

40. In the Rankine cycle for a steam power plant the turbine entry and exit enthalpies are 2803 kJ/kg and 1800 kJ/kg, respectively. The enthalpies of water at pump entry and exit are 121 kJ/kg and 124 kJ/kg, respectively. The specific steam consumption (in kg/kW.h) of the cycle is _______

[Ans. *] Range 3.6 to 3.6

$W_T = h_1 - h_2 = 2803 - 1800 = 1003$ kJ/kg

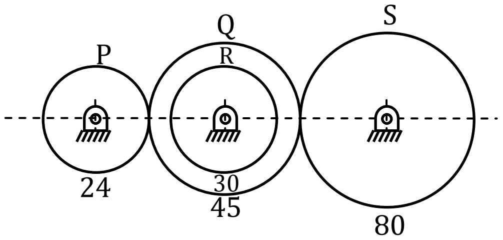
$W_P = h_4 - h_3 = 124 - 121 = 3$ kJ/kg

$W_{NET} = W_T - W_P = 1003 - 3 = 1000$ kJ/kg

$$\text{Specific steam consumption} = \frac{3600}{W_T - W_P}\ \text{kg/kWhr}$$

$$= \frac{3600}{1000} = 3.6\ \text{kg/kWhr}$$

41. A gear train shown in the figure consists of gears P, Q, R and S. Gear Q and gear R are mounted on the same shaft. All the gears are mounted on parallel shafts and the number of teeth of P, Q, R and S are 24, 45, 30 and 80, respectively. Gear P is rotating at 400 rpm. The speed (in rpm) of the gear S is _________



[Ans. *] Range 120 to 120

$N_P = 400$ rpm, $N_s = ?$

$$\therefore \frac{N_P}{N_s} = \frac{T_S}{T_P}$$

$$\therefore \frac{400}{N_s} = \frac{80}{24}$$

$\therefore N_s = 120$ rpm

42. For the laminar flow of water over a sphere, the drag coefficient C_F is defined as $C_F = F/(\rho U^2 D^2)$, where F is the drag force, ρ is the fluid density, U is the fluid velocity and D is the diameter of the sphere. The density of water is 1000 kg/m^3. When the diameter of the sphere is 100 mm and the fluid velocity is 2 m/s, the drag coefficient is 0.5. If water now flows over another sphere of diameter 200 mm under dynamically similar conditions, the drag force (in N) on this sphere is _________

[Ans. *] Range 20 to 20

For dynamic similarity

$(Re)_1 = (Re)_2$

$$\text{or} \left(\frac{\rho U D}{\mu}\right)_1 = \left(\frac{\rho U D}{\mu}\right)_2$$

$\therefore U_1 D_1 = U_2 D_2 \ldots\ldots\ldots ①$

In general $C_F = f(Re)$ hence in dynamically similar conditons $C_{F1} = C_{F2} \ldots\ldots\ldots ②$

Now, $F_2 = C_{F2}\rho U_2^2 D_2^2$

$= C_{F2}\rho U_1^2 D_1^2$ ($\because C_{F1} = C_{F2}$ & $U_1 D_1 = U_2 D_2$)

$= 0.5 \times 1000 \times 2 \times 0.1^2$

$= 20$ N

43. The surface integral $\iint_s F.ndS$ over the surface S of the sphere $x^2 + y^{-2} + z^2 = 9$, where $F = (x + y)i + (x + z)j + (y + z)k$ and n is the unit outward surface normal, yields ___________

[Ans. *] Range 226.19 to 226.19

$\vec{F} = (x + y)\vec{i} + (x + z)\vec{j} + (y + z)\vec{k}$

$\text{div}\vec{F} = 1 + 1 = 2$

$$\iint_s \vec{F}.\vec{n}\, dS = \iiint_V \text{div}\,\vec{F} dx\, dy\, dz \text{ (By Gauss divergence theorem)}$$

$$= \iiint 2dx\, dy\, dz$$

$= 2$(Volume of the sphere $x^2 + y^2 + z^2 = 9$

$$= 2 \times \frac{4}{3}\pi(3)^3$$

$= 72\,\pi = 226.08$

44. A rod of length 20 mm is stretched to make a rod of length 40 mm. Subsequently, it is compressed to make a rod of final length 10 mm. Consider the longitudinal tensile strain as positive and compressive strain as negative. The total true longitudinal strain in the rod is

(A) -0.5
(B) -0.69
(C) -0.75
(D) -1.0

[Ans. B]

$L_1 = 20$ mm, $L_2 = 40$ mm, $L_3 = 10$ mm,

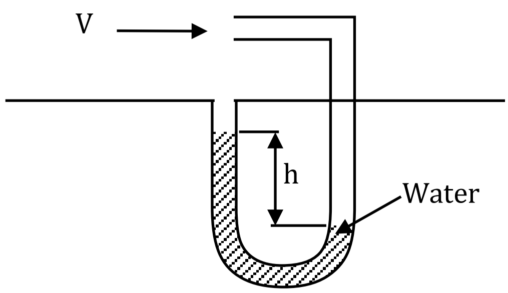
$A_1 L_1 = A_2 L_2 = A_3 L_3$

$$\frac{A_1}{A_3} = \frac{L_3}{L_1}$$

$$\text{True Strain} = \ln\left(\frac{A_1}{A_3}\right) = \ln\left(\frac{L_3}{L_1}\right)$$

$$= \ln\left(\frac{10}{20}\right) = -0.693$$

45. The arrangement shown in the figure measures the velocity V of a gas of density 1 kg/m^3 flowing through a pipe. The acceleration due to gravity is 9.81 m/s^2. If the manometric fluid is water (density 1000 kg/m^3) and the velocity V is 20 m/s, the differential head h (in mm) between the two arms of the manometer is_________



[Ans. *] Range: 20.40 to 20.40

$$V = \sqrt{2gh} = \sqrt{2gx\left(\frac{\rho_m}{\rho} - 1\right)}$$

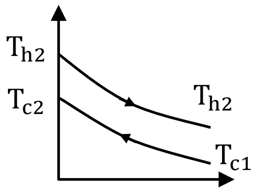
$$\therefore X = \frac{V^2}{2g\left(\frac{\rho_m}{\rho} - 1\right)} = \frac{20^2}{2 \times 9.81 \times \left(\frac{1000}{1} - 1\right)}$$

$$= 20.4 \text{ mm}$$

46. In a counter-flow heat exchanger, water is heated at the rate of 1.5 kg/s from 40°C to 80°C by an oil entering at 120°C and leaving at 60°C The specific heats of water and oil are 4.2 kJ/kg.K and 2 kJ/kg.K, respectively. The overall heat transfer coefficient is 400 W/m^2K. The required heat transfer surface are (in m^2) is

(A) 0.104
(B) 0.022
(C) 10.4
(D) 21.84

[Ans. D]



Cold fluid

$T_{c1} = 40°C$
$T_{c2} = 80°C$
$m_c = 1.5$ kg/s
$C_c = 4.2$ kJ/kg.K

Hot fluid

$T_{h1} = 120°C$
$T_{h2} = 60°C$
$c_h = 2$ kJ/kg.K

Counter flow

$\Delta T_1 = T_{h1} - T_{c2}$
$\Delta T_1 = 120 - 80$
$\Delta T_1 = 40°C$
$\Delta T_2 = T_{h2} - T_{c1}$
$\Delta T_2 = 60 - 40$

$\Delta T_2 = 20$

$$\text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = \frac{40 - 20}{\ln\left(\frac{40}{20}\right)}$$

$\text{LMTD} = 28.854°\text{C}$

$Q = m_c C_c (T_{c_2} - T_{c_1}) = UA(\text{LMTD})$

$1.5 \times 4.2 \times 10^3 \times (80 - 40) = 400 \times A \times 28.85$

$A = 21.84\ \text{m}^2$

47. A single-plate clutch has a friction disc with inner and outer radii of 20 mm and 40 mm, respectively. The friction lining in the disc is made in such a way that the coefficient of friction μ varies radially as μ = 0.01 r, where r is in mm. The clutch needs to transmit a friction torque of 18.85 kN-mm. As per uniform pressure theory, the pressure (in MPa) on the disc is ________

[Ans. *] Range 0.5 to 0.5

$r_1 = 40$ mm, $r_2 = 20$ mm, $\mu = 0.01r$,

$T = 18.85$ kN-mm,

$P = c$

Torque, $\delta T = \mu P \times 2\pi dr \times r$

$$T = P \times 2\pi \int_{r_2}^{r_1} \mu r^2 dr$$

$$= P \times 2\pi \times 0.01 \times \int_{r_2}^{r_1} r^3 dr$$

$$= P \times 2\pi \times 0.01 \times \left[\frac{r_1^4 - r_2^4}{4}\right]$$

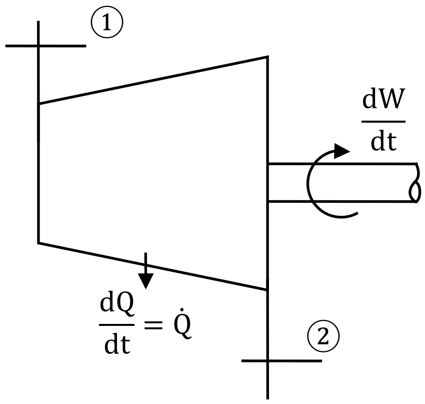
$$18.85 \times 10^3 = P \times 2\pi \times 0.01 \times \left[\frac{40^4 - 20^4}{4}\right]$$

$\Rightarrow P = 0.5\ \text{N/mm}^2$

48. A calorically perfect gas (specific heat at constant pressure 1000 J/kg.K) enters and leaves a gas turbine with the same velocity. The temperatures of the gas at turbine entry and exit are 1100 K and 400 K, respectively. The power produced is 4.6 MW and heat escapes at the rate of 300 kJ/s through the turbine casing. The mass flow rate of the gas (in kg/s) through the turbine is

(A) 6.14
(B) 7.00
(C) 7.50
(D) 8.00

[Ans. B]



$C_p = \frac{1000J}{kg.K} = 1kJ/kg.K$

$V_1 = V_2$

$T_1 = 1100\ K, T_2 = 400\ K$

Power = 4600 kW

Heat loss from turbine casing = Q = −300 kW

Mass flow rate = m (kg/sec)

Apply SFEE

$mh_1 + Q = mh_2 + W$

$m(h_1 - h_2) = w - Q \Rightarrow mc_p(T_1 - T_2) = W - Q$

$m = \frac{W - Q}{C_P(T_1 - T_2)} = \frac{4600 - 300}{1(1100 - 400)} = 7\ kg/sec$

49. Maximize $Z = 5x_1 + 3x_2$ subject to

$x_1 + 2x_2 \le 10,$

$x_1 - x_2 \le 8,$

$x_1, x_2 \ge 0$

In the starting simplex tableau, x_1 And x_2 Are non-basic variables and the value of Z is zero. The value of Z in the next simplex tableau is__________

[Ans. *] Range 40 to 40

Max $Z = 5x_1 + 3x_2$

Subject to $x_1 + 2x_2 \le 10$, $x_1 - x_2 \le 8$, $x_1, x_2 \ge 0$

$x_1 + 2x_2 + s_1 = 10; x_1 - x_2 + s_2 = 8$

$C_j \rightarrow$ sv ↓	5 x_1	3 x_2	0 s_1	0 s_2	B_0	Min Ratio
$0S_1$	1	2	1	0	10	10/1
$0S_2$	1(PE)	−1	0	1	8	8/1→ LV
Z_j	0	0	0	0	0	-
$C_j - Z_j$	5	3	0	0		
	↑ (EV)					
$0S_1$						
$5x_1$	1	−1	0	1	8	
		Z value			40	

No need to calculate other values to save time.

$\therefore Z_{max} = 40$

50. One kg of an ideal gas (gas constant R = 287 J/kg.K) undergoes an irreversible process from state-I(1 bar, 300 K) to state-2 (2 bar, 300 K). The change in specific entropy ($s_2 - s_1$) of the gas (in J/kg.K) in the process is ________

[Ans. *] Range 198.93 to 198.93

$m = 1$ kg

$R = 287$ J/kgK

$P_1 = 1$ bar,

$P_2 = 2$ bar,

$T_1 = 300$ K,

$T_2 = 300$ K,

$T_1 = T_2$ isothermal process

$$s_2 - s_1 = m\left(C_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}\right)$$

$$= mR\ln\frac{P_1}{P_2}$$

$$= 1 \times 287 \ln\frac{1}{2} = -198.93 \text{ J/K}$$

51. A strip of 120 mm width and 8 mm thickness is rolled between two 300 mm-diameter rolls to get a strip of 120 mm width and 7.2 mm thickness. The speed of the strip at the exit is 30 m/min. There is no front or back tension. Assuming uniform roll pressure of 200 MPa in the roll bite and 100% mechanical efficiency, the minimum total power (in kW) required to drive the two rolls is__________.

[Ans. *] Range 9.6 to 9.6

$b = 120 \text{ mm}, H_0 = 8, H_1 = 7.2,$

$R = 150, V_1 = 30, P = 200 \text{ MPa}$

$$\alpha \tan^{-1}\left(\sqrt{\frac{\Delta H}{R}}\right) = \tan^{-1}\left(\sqrt{\frac{0.8}{150}}\right) = 4.186°$$

$L_c = R\,\alpha = \sqrt{\Delta HR} = 10.951$ mm

$\text{Area} = b \times L_c = 120 \times 10.951 = 1314.1 \text{ mm}^2$

$\text{Force} = \text{Area} \times P = 1314.1 \times 200 = 262.82 \text{ kN}$

We know that, power for two rollers

$P = 2T\omega$

$$\omega = \frac{V}{R} = \frac{30/60}{0.15} = 3.33 \text{ rad/s}$$

$$T = F \times \frac{L_c}{2} = 262.82 \times \frac{10.95}{2} = 1438.93 \text{ Nm}$$

$\text{Power} = 2 \times 3.33 \times 1438.93 = 9583.33 \text{ W}$

$\text{Power} = 9.58 \text{ kW}$

52. Consider the matrix $A = \begin{bmatrix} 50 & 70 \\ 70 & 80 \end{bmatrix}$ whose eigenvectors corresponding to eigen values λ_1 and λ_2 are $x_1 = \begin{bmatrix} 70 \\ \lambda_1 - 50 \end{bmatrix}$ and $x_2 = \begin{bmatrix} \lambda_2 - 80 \\ 70 \end{bmatrix}$, respectively. the Value of $x_1^T x_2$ is ______

[Ans. *] Range: 0 to 0

$x_1^T x_2 = [70 \quad \lambda_1 - 50]\begin{bmatrix}\lambda_2 - 80\\ 70\end{bmatrix}$

$= 70[70(\lambda_2 - 80) + (\lambda_1 - 50)70]$

$= [70(\lambda_1 + \lambda_2) - 70(80 + 50)]$

$= [70(50 + 800 - 70(50 - 80)] \qquad [\because \lambda_1 + \lambda_2 = \text{trace of A} = 50 + 80]$

$=[0]=0$

53. If $f(z) = (x^2 + ay^2) + ibxy$ is a complex analytic function of $z = x + iy$, where $I = \sqrt{-1}$, then

(A) $a = -1, b = -1$
(B) $a = -1, b - 2$
(C) $a = 1, b = 2$
(D) $a = 2, b = 2$

[Ans. B]

Let, $f(z) = (x^2 + ay^2) + ibxy = u + iv(say)$

Where, $u = x^2 + ay^2, \qquad V = bxy$

$u_X = 2x, \qquad -V_X = -by$

$u_y = 2ay, \qquad V_y = bx$

Using C-R equations, we have

$\Rightarrow u_X = v_y$ and $u_Y = -V_x$

$\Rightarrow 2x = bx$ and $2ay = -by$

$\therefore b = 2, a = -1$

54. The principal stresses at a point in a critical section of a machine component are $\sigma_1 = 60$ MPa, $\sigma_2 = 5$ MPa and $\sigma_3 = -40$ Mpa. For the material of the component, the tensile yield strength is $\sigma_y = 200$ MPa. According to the maximum shear stress theory, the factor of safety is

(A) 1.67
(B) 2.00
(C) 3.60
(D) 4.00

[Ans. B]

$\sigma_1 = 60$ MPa, $\quad \sigma_2 = 5$MPa, $\quad \sigma_3 = -40$ MPa,

$S_{yt} = 200$ MPa

According to MSST,

$\tau_{maX} = \frac{S_{yt}}{2 \times FS}$

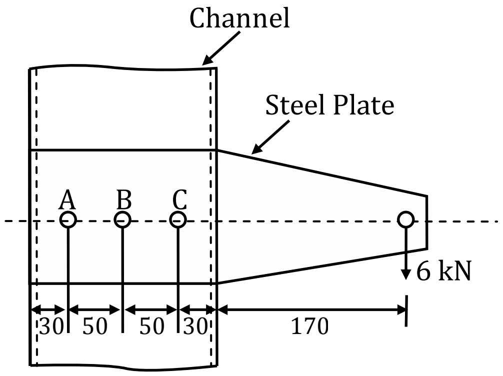
$\frac{\sigma_1 - \sigma_3}{2} = \frac{S_{yt}}{2 \times FS}$

$\sigma_1 - \sigma_3 = \frac{S_{yt}}{FS}$

$60 - (-40) = \frac{200}{FS}$

$100 = \frac{200}{FS} \Rightarrow FS = 2$

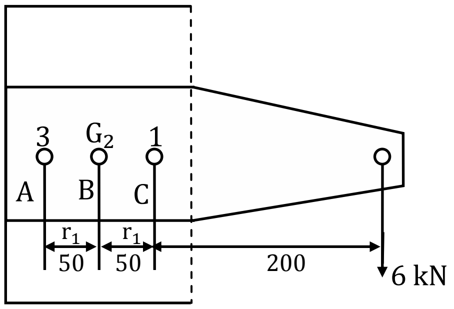
55. A steel plate, connected to a fixed channel using three identical bolts A, B and C, carries a load of 6 kN as shown in the figure. Considering the effect of direct load and moment, the magnitude of resultant shear force (in kN) on bolt C is



All dimensions are in mm

(A) 13
(B) 15
(C) 17
(D) 30

[Ans. C]



Primary Shear, load, $P_{s_1} = \frac{6}{3} = 2$ kN

Secondry shear, load $P'_{s_1} = kr_1$

$$= P \times \frac{e}{r_1^2 + r_2^2 + r_3^2} \times R_1$$

$r_1 = r_3 = 50$ and $r_2 = 0$ and $e = 250$ mm

$$\therefore P'_{s_1} = 6 \times \frac{250}{50^2 + 0^2 + 50^2} \times 50$$

$$6 \times \frac{250}{2 \times 50^2} \times 56 = 15 \text{ kN}$$

$\therefore$ Resultant load on C, $P_s = P'_{s1} + P'_{s_1} = 2 + 15 = 17$ kN