Q. No. 1 – 5 Carry One Mark Each

1. Choose the most appropriate word from the options given below to complete the following sentence.

   Communication and interpersonal skills are_____ important in their own ways.

   (A) each (B) both (C) all (D) either

Answer: (B)

2. Which of the options given below best completes the following sentence?

   She will feel much better if she ________________.

   (A) will get some rest (B) gets some rest

   (C) will be getting some rest (D) is getting some rest

Answer: (B)

3. Choose the most appropriate pair of words from the options given below to complete the following sentence.

   She could not _____ the thought of _________ the election to her bitter rival.

   (A) bear, loosing (B) bare, loosing (C) bear, losing (D) bare, losing

Answer: (C)

4. A regular die has six sides with numbers 1 to 6 marked on its sides. If a very large number of throws show the following frequencies of occurrence: $1 \rightarrow 0.167$; $2 \rightarrow 0.167$; $3 \rightarrow 0.152$; $4 \rightarrow 0.166$; $5 \rightarrow 0.168$; $6 \rightarrow 0.180$. We call this die

   (A) irregular (B) biased (C) Gaussian (D) insufficient

Answer: (B)

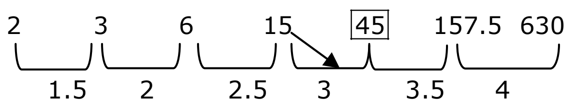
Exp: For a very large number of throws, the frequency should be same for unbiased throw. As it not same, then the die is baised.

5. Fill in the missing number in the series.

   2 3 6 15 ___ 157.5 630

Answer: 45

Exp:



$\frac{\text{2nd number}}{\text{1st number}}$ is in increasing order as shown above

Q. No. 6 – 10 Carry One Mark Each

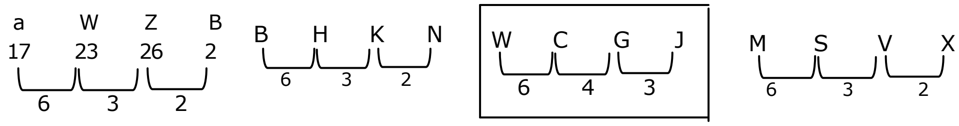
6. Find the odd one in the following group

Q,W,Z,B B,H,K,M W,C,G,J M,S,V,X

(A) Q,W,Z,B (B) B,H,K,M (C) W,C,G,J (D) M,S,V,X

Answer: (C)

Exp:



7. Lights of four colors (red, blue, green, yellow) are hung on a ladder. On every step of the ladder there are two lights. If one of the lights is red, the other light on that step will always be blue. If one of the lights on a step is green, the other light on that step will always be yellow. Which of the following statements is not necessarily correct?

(A) The number of red lights is equal to the number of blue lights

(B) The number of green lights is equal to the number of yellow lights

(C) The sum of the red and green lights is equal to the sum of the yellow and blue lights

(D) The sum of the red and blue lights is equal to the sum of the green and yellow lights

Answer: (D)

8. The sum of eight consecutive odd numbers is 656. The average of four consecutive even numbers is 87. What is the sum of the smallest odd number and second largest even number?

Answer: 163

Exp: Eight consecutive odd number =656

a-6, a-1, a-2, a ,a+2 ,a+4, a+6

a+8=656

a=81

Smallest m=75 … (1)

Average consecutive even numbers

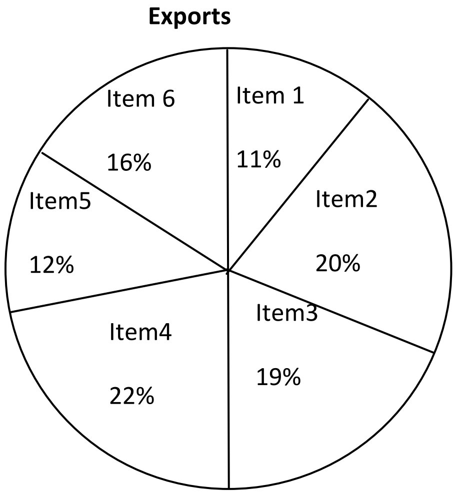
$$\Rightarrow \frac{a-2+a+a+2+a+4}{4} = 87$$

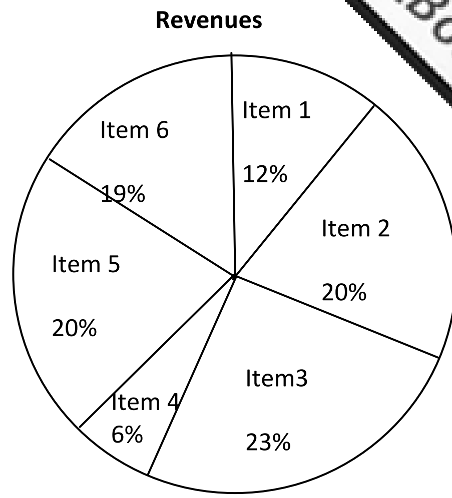
$\Rightarrow a = 86$

Second largest number =88

1+2=163

9. The total exports and revenues from the exports of a country are given in the two charts shown below. The pie chart for exports shows the quantity of each item exported as a percentage of the total quantity of exports. The pie chart for the revenues shows the percentage of the total revenue generated through export of each item. The total quantity of exports of all the items is 500 thousand tonnes and the total revenues are 250 crore rupees. Which item among the following has generated the maximum revenue per kg?





(A) Item 2 (B) Item 3 (C) Item 6 (D) Item 5

Answer: (D)

Exp: Item:2

$$\frac{\frac{20}{100}\times 250\times 10^{7}}{\frac{20}{100}\times 500\times 10^{3}}$$

$0.5\times 10^{4}=5\times 10^{3}$ $\boxed{1}$ = Item 2

Item:3

$$\frac{23\times 250\times 10^{7}}{19\times 500\times 10^{3}}$$

$1.2 =$ Item 3

Item: 6

$\frac{19}{16}=1.18=$ Item 6

Item:5

$\frac{20}{12}=\frac{5}{3}=1.6\Rightarrow$ $\boxed{1.6 = \text{Item 5}}$

10. It takes 30 minutes to empty a half-full tank by draining it at a constant rate. It is decided to simultaneously pump water into the half-full tank while draining it. What is the rate at which water has to be pumped in so that it gets fully filled in 10 minutes?

(A) 4 times the draining rate (B) 3 times the draining rate

(C) 2.5 times the draining rate (D) 2 times the draining rate

Answer: (A)

Exp: $V_{half}=30(s)$ drawing rate $= s$

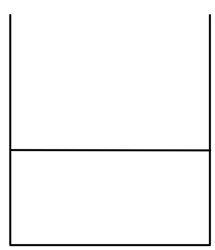
Total volume =60 S tank

$(s^{1})(10)-(s)10=30s$

$s^{1}(s)-s=3s$

$s1=4s$

$s^{1}=4$drawing rate



Q. No. 1 – 25 Carry One Mark Each

1. One of the eigenvectors of the matrix $\begin{bmatrix} -5 & 2 \\ -9 & 6 \end{bmatrix}$ is

(A) $\begin{Bmatrix} -1 \\ 1 \end{Bmatrix}$ (B) $\begin{Bmatrix} -2 \\ 9 \end{Bmatrix}$ (C) $\begin{Bmatrix} 2 \\ -1 \end{Bmatrix}$ (D) $\begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$

Answer: D

Exp: Eigen values of the matrix $\begin{bmatrix} -5 & 2 \\ -9 & 6 \end{bmatrix}$ are 4, -3

$\therefore$ the eigen vector corresponding to eigen vector λ is $Ax = \lambda x$ (verify the options)

$\begin{pmatrix} 1 \\ 1 \end{pmatrix}$ is eigen vector corresponding to eigen value $\lambda = 3$

2. $\underset{x\to 0}{Lt}\left(\frac{e^{2x}-1}{\sin(4x)}\right)$ is equal to

(A) 0 (B) 0.5 (C) 1 (D) 2

Answer: B

Exp: $\lim\limits_{x\to 0}\frac{e^{2x}-1}{\sin 4x}$ is $\left(\frac{0}{0}\right)$

So, Applying L-Hospital Rule, $\lim\limits_{x\to 0}\frac{2e^{2x}}{4\cos 4x}$

$= \frac{2}{4} = 0.5$

3. Curl of vector $\vec{F} = x^2z^2\hat{i} - 2xy^2z\hat{j} + 2y^2z^3\hat{k}$ is

(A) $(4yz^3 + 2xy^2)i + 2x^2z\hat{j} - 2y^2z\hat{k}$ (B) $(4yz^3 + 2xy^2)\hat{i} + 2x^2z\hat{j} - 2y^2z\hat{k}$

(C) $2xz^2\ \hat{i} - 4xyz\hat{j} + 6y^2z^2\hat{k}$ (D) $2xz^2\hat{i} + 4xyz\hat{j} + 6y^2z^2\hat{k}$

Answer: A

Exp: Given $\vec{F} = x^2 z^2 i\ \ 2xy^2 zJ + 2y^2 z^3 k$

$$\text{curl}\vec{F} = \nabla\times\vec{F} = \begin{vmatrix} i & j & k \\ \frac{\partial}{2x} & \frac{\partial}{2y} & \frac{\partial}{2z} \\ x^2z^2 & -2xy^2z & 2y^2z^3 \end{vmatrix}$$

$= i(4yz^3 + 2xy^2) - j(0 - 2x^2z) + k(-2y^2z - 0)$

$= (4yz^2 + 2xy^2 + 2x^2zj) - 2y^2zk$

4. A box contains 25 parts of which 10 are defective. Two parts are being drawn simultan in a random manner from the box. The probability of both the parts being

(A) $\frac{7}{20}$ (B) $\frac{42}{125}$ (C) $\frac{25}{29}$ (D) $\frac{5}{9}$

Answer: A

Exp: Two parts can be selected in the following way $15C_2 \times 10C_0$

Good	Bad
15	10
2	0
1	1
0	2

Total no. of parts = 25.

Two parts can e selected in $25C_2$ ways

Required probability $= \frac{15C_2 \times 10C_o}{25C_2} = \frac{105}{300} = \frac{7}{20}$

5. The best approximation of the minimum value attained by $e^{-x}\sin(100x)$ for $x \geq 0$ is _______

Answer: 1.00 to – 0.94

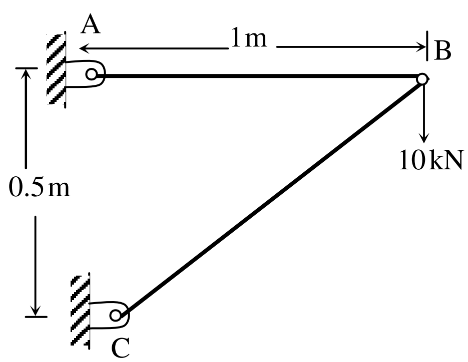
6. A steel cube, with all faces free to deform, has Young's modulus, *E*, Poisson's ratio *v*, and coefficient of thermal expansion, α. The pressure (hydrostatic stress) developed within the cube, when it is subjected to a uniform increase in temperature, ΔT, is given by

(A) 0 (B) $\frac{\alpha(\Delta T)E}{1-2\nu}$ (C) $-\frac{\alpha(\Delta T)E}{1-2\nu}$ (D) $\frac{\alpha(\Delta T)E}{3(1-2\nu)}$

Answer: A

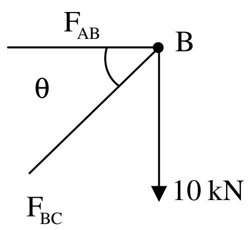
Exp: Since all the faces are free to expand the stresses due to temperature rise is equal to 0.

7. A two member truss *ABC* is shown in the figure. The force (in kN) transmitted in member *AB* is _______



Answer: 18 to 22

Exp: FBD of joint B



$$\theta = \tan^{-1}\left(\frac{0.5}{1}\right) = 26.5$$

$$\Sigma V = 0$$

$$\frac{F_{BC}\sin\theta}{F_{BC}\cos\theta} = \frac{10\text{ kN}}{F_{AB}}$$

$$F_{AB} = \frac{10}{\tan 26.2}$$

$$= 20\text{ kN.}$$

8. A 4-bar mechanism with all revolute pairs has link lengths l_f = 20 mm, l_{in} = 40 mm, l_{co} = 50 mm and l_{out} = 60 mm. The suffixes 'f', 'in', 'co' and 'out' denote the fixed link, the input link, the coupler and output link respectively. Which one of the following statements is true about the input and output links?

(A) Both links can execute full circular motion

(B) Both links cannot execute full circular motion

(C) Only the output link cannot execute full circular motion

(D) Only the input link cannot execute full circular motion

Answer: A

Exp: $S+l<P+Q$

$20+60<40+50 \Rightarrow 80<90$

If smaller link is fixed both input and Output link execute full circular motion.

9. In vibration isolation, which one of the following statements is NOT correct regarding Transmissibility (T)?

(A) *T* is nearly unity at small excitation frequencies

(B) *T* can be always reduced by using higher damping at any excitation frequency

(C) *T* is unity at the frequency ratio of $\sqrt{2}$

(D) *T* is infinity at resonance for undamped systems

Answer: B

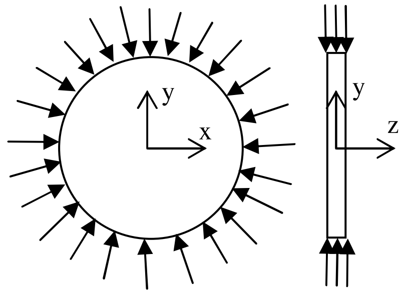
10. In a structure subjected to fatigue loading, the minimum and maximum stresses developed in a cycle are 200 MPa and 400 MPa respectively. The value of stress amplitude (in MPa) is ______

Answer: 99 to 101

Exp: Stress Amplitude $\dfrac{(\sigma_{max} - \sigma_{min})}{2}$

$$= \frac{400-200}{2} = 100.$$

11. A thin plate of uniform thickness is subject to pressure as shown in the figure below



Under the assumption of plane stress, which one of the following is correct?

(A) Normal stress is zero in the z-direction

(B) Normal stress is tensile in the z-direction

(C) Normal stress is compressive in the z-direction

(D) Normal stress varies in the z-direction

Answer: A

Exp: For a plane stress criteria.

Normal stress in Z direction = 0.

12. For laminar forced convection over a flat plate, if the free stream velocity increases by a factor of 2, the average heat transfer coefficient

(A) remains same (B) decreases by a factor of $\sqrt{2}$

(C) rises by a factor of $\sqrt{2}$ (D) rises by a factor of 4

Answer: C

Exp: For laminar flow,

$$Nu = 0.664\,(Re)^{0.5}\,(Pr)^{0.33}$$

$$\frac{hL}{k} = 0.664\left(\frac{\rho VD}{\mu}\right)^{0.5}(Pr)^{0.33}$$

$$h \propto V^{0.5};\ \ h \propto \sqrt{V}.$$

So when free stream velocity increases by a factor of 2, then the average heat transfer coefficient rises by a factor of $\sqrt{2}$.

13. The thermal efficiency of an air-standard Brayton cycle in terms of pressure ratio r_p and $\gamma\left(=c_p/c_p\right)$ is given by

(A) $1-\frac{1}{r_p^{r-1}}$ (B) $1-\frac{1}{r_p^{r}}$ (C) $1-\frac{1}{r_p^{1/r}}$ (D) $1-\frac{1}{r_p^{(\gamma-1)/\gamma}}$

Answer: D

Exp: Thermal efficiency of air standard efficiency $=1-\dfrac{1}{\left(r_p\right)^{\frac{\gamma-1}{\gamma}}}$

14. For an incompressible flow field, $\vec{v}$, which one of the following conditions must be sati

(A) $\nabla.\vec{v} = 0$
(B) $\nabla \times \vec{v} = 0$
(C) $(\vec{v}.\nabla)\times\vec{v} = 0$
(D) $\frac{\partial V}{\partial t} + (\vec{V}.\nabla)\vec{V} = 0$

Answer: A

Exp: Incompressible flow condition

$\nabla.\vec{V} = 0$

15. A pure substance at 8 MPa and 400 °C is having a specific internal energy of 2864 kJ/kg and a specific volume of 0.03432 m^3/kg. Its specific enthalpy (in kJ/kg) is _______

Answer: 3135 to 3140

Exp: h = u+pv

h = 2864+ (8000 kPa) × (0.03432)

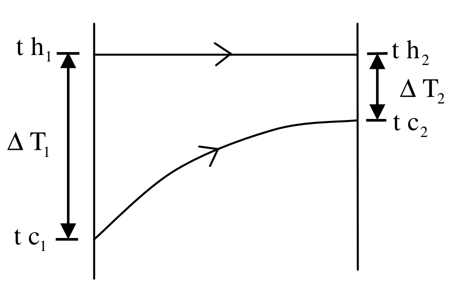
= 2864 + 274.56 = 3138.56 = 3139

16. In a heat exchanger, it is observed that $\Delta T_1 = \Delta T_2$, where ΔT_1 is the temperature difference between the two single phase fluid streams at one end and ΔT_2 is the temperature difference at the other end. This heat exchanger is

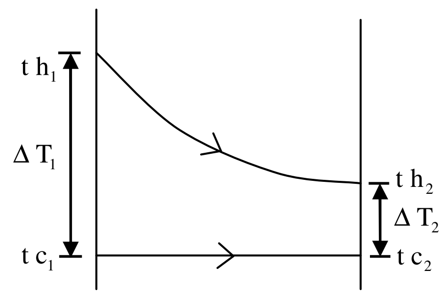
(A) a condenser
(B) an evaporator
(C) a counter flow heat exchanger
(D) a parallel flow heat exchanger

Answer: C

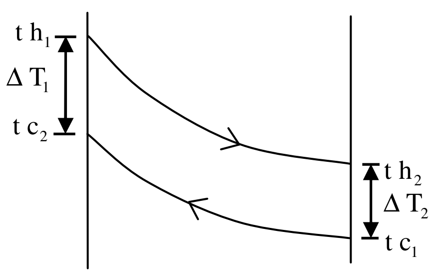
Temperature distribution



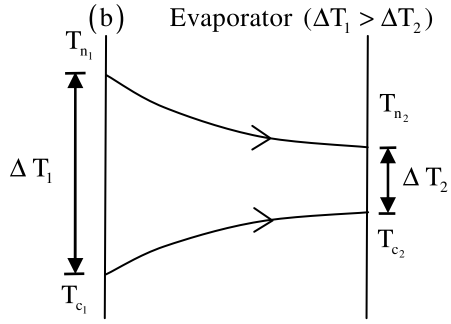
(a) Condenser $(\Delta T_1 > \Delta T_2)$



(b) Evaporator $(\Delta T_1 > \Delta T_2)$



(c) Counter flow Heat Exchanger $(\Delta T_1 = \Delta T_2)$



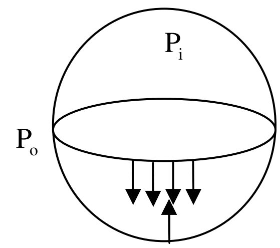
(d) Parallel flow Exchanger $(\Delta T_1 > \Delta T_2)$

From the above temperature distribution, we can say option 'c' is the correct answer.

17. The difference in pressure (in N/m^2) across an air bubble of diameter 0.001 m immersed in water (surface tension = 0.072 N/m) is ________

Answer: 287 to 289

Exp: Surface tension in a bubble $= \frac{\Delta p.r}{4}$



$$\text{we know, } P_i - P_o = \frac{4T}{r}$$

$$\Delta p = \frac{4 \times 0.072}{0.001} = 288 \ N/m^2 .$$

18. If there are m sources and *n* destinations in a transportation matrix, the total number of basic variables in a basic feasible solution is

(A) m + n (B) m + n + 1 (C) m + n - 1 (D) m

Answer: C

Exp:

ORIGIN \ DESTINATION		1	2	⋮3⋮	n	TOTAL
	1	x_{11}	x_{12}	----		a_1
	2	x_{21}	x_{22}	----		a_2
	⋮	----	----	----	----	----
	m	x_{m_1}	x_{m_2}		x_{m_n}	a_m
TOTAL		b_1	b_2	----	b_n	$\sum_{i=1}^{m} a_i = \sum_{J=1}^{n} b_J$

$$\sum_{J=1}^{n} x_{iJ} = a_i, (i = 1, 2, ...m) \_\_\_\_(1)$$

$$\sum_{L=1}^{m} x_{iJ} = b_J, (J = 1, 2, ...n) \_\_\_\_(2)$$

$$x_{iJ} \geq 0 \_\_\_(3)$$

$$\sum_{i=1}^{m} \sum_{J=1}^{m} C_{iJ} x_{iJ} = mn \_\_\_\_(4)$$

It is evident from the above diagram, that m+n equations (1) and (2) constitute m+n-1 independent equations in mn unknowns.

19. A component can be produced by any of the four processes I, II, III and IV. The fixed and the variable cost for each of the processes are listed below. The most economical process for producing a batch of 100 pieces is

Process	Fixed cost(in Rs.)	Variable cost per piece (in Rs.)
I	20	3
II	50	1
III	40	2
IV	10	4

(A) I (B) II (C) III (D) IV

Answer: B

Exp:

Process	Cost of production for 100
I	$F.c + \theta \times v_c = 20 + 100 \times 3 = 320$
II	$50 + 100 \times 1 = 150$
III	$40 + 100 \times 2 = 240$
IV	$10 + 100 \times 4 = 410$

Hence process (B) is most economical.

20. The flatness of a machine bed can be measured using

(A) Vernier calipers (B) Auto collimator

(C) Height gauge (D) Tool maker's microscope

Answer: B

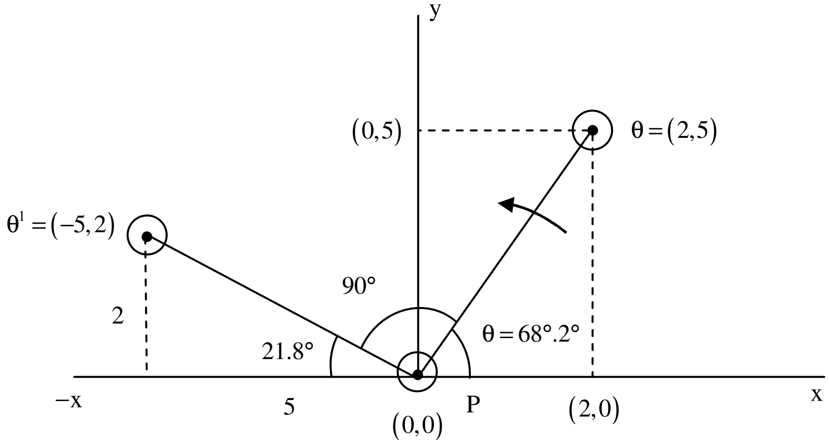
Exp: Flatness of machine bed can be measured from Auto collimator.

21. A robot arm PQ with end coordinates P(0,0) and Q(2,5) rotates counter clockwise about P in the XY plane by 90°. The new coordinate pair of the end point Q is

(A) (-2,5) (B) (-5,2) (C) (-5, -2) (D) (2, -5)

Answer: B

Exp:



$\tan\theta = \frac{5}{2}$

$\therefore \theta = \tan^{-1}\frac{5}{2}$

$\theta = 68.2°$

$\tan 21.8° = \frac{2}{5}$

$\therefore \theta' = (-5,2).$

22. Match the Machine Tools (Group A) with the probable Operations (Group B):

Group A	Group B
(p) Centre lathe	(1) Slotting
(q) Milling	(2) Counter-boring
(r) Grinding	(3) Knurling
(s) Drilling	(4) Dressing

(A) P-1, Q-2, R-4, S-3
(B) P-2, Q-1, R-4, S-3
(C) P-3, Q-1, R-4, S-2
(D) P-3, Q-4, R-2, S-1

Answer: C

23. The following four unconventional machining processes are available in a shop floor. The most appropriate one to drill a hole of square cross section of 6 mm × 6 mm and 25 mm deep

(A) is abrasive Jet Machining
(B) is Plasma Arc Machining
(C) is Laser Beam Machining
(D) is Electro Discharge Machining

Answer: D

24. The relationship between true strain (ε_T) and engineering strain (ε_E) in a uniaxial tension test is given as

(A) $\varepsilon_g = \ln(1+\varepsilon_T)$
(B) $\varepsilon_g = \ln(1-\varepsilon_T)$
(C) $\varepsilon_T = \ln(1+\varepsilon_E)$
(D) $\varepsilon_T = \ln(1-\varepsilon_E)$

Answer: C

Exp: $\in_{True} = \int_{L_o}^{L_f} \frac{dL}{L} = \ln\left[1+\frac{\Delta L}{L_o}\right]$

But $\frac{\Delta L}{L_o} = \in_E \Rightarrow \in_{True} = \ln(1+\in_E)$.

25. With respect to metal working, match Group A with Group B:

Group A	Group B
(p) Defect in extrusion	I: alligatoring
(q) Defect in rolling	II: scab
(r) Product of skew rolling	III: Fish tail
(s) Product of rolling through cluster mill	IV: Seamless tube
	V: thin sheet with tight tolerance
	VI: semi-finished balls of ball bearing

(A) P-II, Q-III, R-VI, S-V
(B) P-III, Q-I, R-VI, S-V
(C) P-III, Q-I, R-IV, S-VI
(D) P-I, Q-II, R-V, S-VI

Answer: B

Q. No. 26 – 55 Carry Two Marks Each

26. An analytic function of a complex variable z = x + i y is expressed as $f(z) = u(x, y) + i\,v(x, y)$, where $i = \sqrt{-1}$. If u(x, y) = 2 x y, then v(x, y) must be

(A) $x^2 + y^2$ + constant
(B) $x^2 - y^2$ + constant
(C) $-x^2 + y^2$ + constant
(D) $-x^2 - y^2$ + constant

Answer: C

Exp: Given $f(z) = u + iv$ is analytic and $u = 2xy$

We know that if f(z) is analytic then CR equations will be satisfied.

ie., $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}$

Verify the options which satisfy the above C-R equations.

$v = -x^2 + y^2 + \text{constant}$, satisfies the C-R equation.

27. The general solution of the differential equation $\frac{dy}{dx} = \cos(x+y)$, with c as a constant, is

(A) $y + \sin(x+y) = x + c$
(B) $\tan\left(\frac{x+y}{2}\right) = y + c$
(C) $\cos\left(\frac{x+y}{2}\right) = x + c$
(D) $\tan\left(\frac{x+y}{2}\right) = x + c$

Answer: D

Exp:

$$\frac{dy}{dx} = \cos(x+y)$$

Put $x + y = v \Rightarrow 1 + \frac{dy}{dx} = \frac{dv}{dx} \Rightarrow \frac{dy}{dx} = \frac{dv}{dx} - 1$

$$\Rightarrow \frac{dv}{dx} - 1 = \cos v$$

$$\Rightarrow \frac{1}{1+\cos v} dv = dx \text{ (variable separable)}$$

$$\int \frac{1}{2\cos^2\frac{v}{2}} dv = \int dx + c \quad \left[\begin{array}{l} 1+\cos 2\theta = 2\cos^2\theta \\ 1+\cos\theta = 2\cos^2\frac{\theta}{2} \end{array}\right]$$

$$\frac{1}{2}\int \sec^2\frac{v}{2} dv = x + c$$

$$\text{Tan}\frac{v}{2} = x + c \Rightarrow \text{Tan}\left(\frac{x+y}{2}\right) = x + c$$

28. Consider an unbiased cubic dice with opposite faces coloured identically and each face coloured red, blue or green such that each colour appears only two times on the dice. If the dice is thrown thrice, the probability of obtaining red colour on top face of the dice at least twice is ________

Answer: 0.25 to 0.27

Exp: $p = \frac{2}{6} = \frac{1}{3}$

$q = 1 - \frac{1}{3} = \frac{2}{3}$

using Binomial distribution

$$p(x \geq 2) = 3_{C_2}\left(\frac{1}{3}\right)^2\left(\frac{2}{3}\right)^1 + 3_{C_3}\left(\frac{1}{3}\right)^3\left(\frac{2}{3}\right)^0 = \frac{6}{27} + \frac{1}{27} = \frac{7}{27}.$$

29. The value of $\int_{2.5}^{4} \ln(x)\,dx$ calculated using the Trapezoidal rule with five subintervals is ________

Answer: 1.74 to 1.76

Exp: Given $\int_{2.5}^{4} \ln x\, dx$ $\quad n = 5$

Let $y = \ln x$ $\quad h = \frac{4 - 2.5}{5} = \frac{1.5}{5} = 0.30$

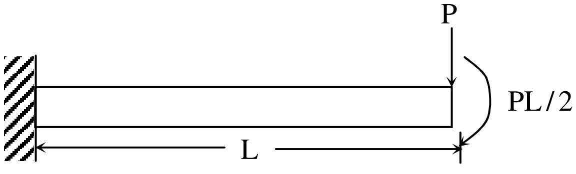
x	2.5	2.8	3.1	3.4	3.7	4.0
$y = \ln x$	0.9163	1.0296	1.1314	1.2238	1.3083	1.3863

Trapezoidal Rule is $\int_{x_0}^{x_n} f(x)dx = \frac{h}{2}\left[(y_0 + y_n) + 2y_1 + \ldots\ldots.. y_{n-1}\right]$

$$\int_{2.5}^{4} \ln x\, dx = \frac{0.3}{2}\left[(0.9163 + 1.3863) + (1.0296 + 1.314 + 1.2238 + 1.3083)\right]$$

$$= 0.15(2.3026 + 9.3862) = 1.7533$$

30. The flexural rigidity (*EI*) of a cantilever beam is assumed to be constant over the length of the beam shown in figure. If a load P and bending moment *PL*/2 are applied at the free end of the beam then the value of the slope at the free end is



(A) $\frac{1}{2}\frac{PL^2}{EI}$ (B) $\frac{PL^2}{EI}$ (C) $\frac{3}{2}\frac{PL^2}{EI}$ (D) $\frac{5}{2}\frac{PL^2}{EI}$

Answer: B

Exp: Slope due to point load

$$\theta_1 = \frac{PL^2}{2EI}$$

$$\theta_2 = \frac{ML}{EI}$$

$$\theta = \frac{PL^2}{2EI} + \frac{PL}{2}\frac{L}{EI} = \frac{PL^2}{EI}$$

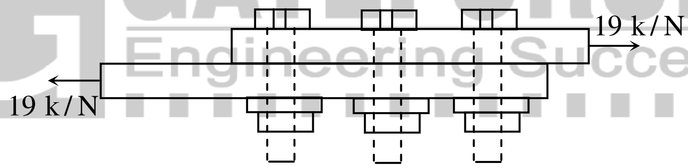
31. A cantilever beam of length, *L*, with uniform cross-section and flexural rigidity, *EI*, is loaded uniformly by a vertical load, w per unit length. The maximum vertical deflection of the beam is given by

(A) $\frac{wL^4}{8EI}$ (B) $\frac{wL^4}{16EI}$ (C) $\frac{wL^4}{4EI}$ (D) $\frac{wL^4}{24EI}$

Answer: A

Exp: Maximum deflection for cantilever subjected to UDL is $\frac{Wl^4}{8EI}$.

32. For the three bolt system shown in the figure, the bolt material has shear yield strength of 200 MPa. For a factor of safety of 2, the minimum metric specification required for the bolt is



(A) M8 (B) M10 (C) M12 (D) M16

Answer: B

Exp: $\sigma_y = 200\text{ MPa}$

$P = 19 \times 10^3\text{ N}$

$$\sigma = \frac{P}{\frac{\pi}{4}d^2} \Rightarrow d = 10.9\text{ mm}$$

M10

33. Consider a flywheel whose mass M is distributed almost equally between a heavy, ring-like rim of radius *R* and a concentric disk-like feature of radius *R/2*. Other parts of the flywheel, such as spokes, etc, have negligible mass. The best approximation for α, if the moment of inertia of the flywheel about its axis of rotation is expressed as αMR^2, is _______

Answer: 0.55 to 0.57

Exp: Moment of Inertia of fly wheel

$I = m_r R^2$

$$R = \text{mean Radius of Rim} = M\left(\frac{R + R/2}{2}\right)^2 = 0.56\,MR^2 \Rightarrow \alpha = 0.56.$$

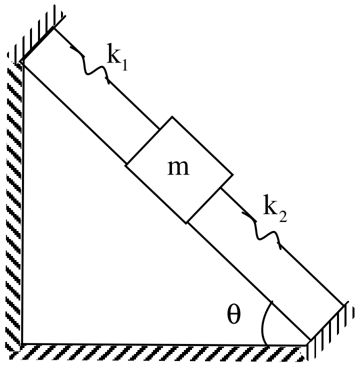
34. What is the natural frequency of the spring mass system shown below? The contact between the block and the inclined plane is frictionless. The mass of the block is denoted by m and the spring constants are denoted by k_1 and k_2 as shown below.

(A) $\sqrt{\frac{k_1+k_2}{2m}}$

(B) $\sqrt{\frac{k_1+k_2}{4m}}$

(C) $\sqrt{\frac{k_1-k_2}{m}}$

(D) $\sqrt{\frac{k_1+k_2}{m}}$



Answer: D

Exp: It is parallel

$$k_{eq} = k_1 + k_2$$

$$\omega_n = \sqrt{\frac{k_{eq}}{m}}$$

$$\omega_n = \sqrt{\frac{k_1+k_2}{m}}$$

35. A disc clutch with a single friction surface has coefficient of friction equal to 0.3. The maximum pressure which can be imposed on the friction material is 1.5 MPa. The outer diameter of the clutch plate is 200 mm and its internal diameter is 100 mm. Assuming uniform wear theory for the clutch plate, the maximum torque (in N.m) that can be transmitted is _______

Answer: 529 to 532

Exp: As per uniform wear theory

$$\text{Torque} = \frac{\pi\mu P_a d}{8}\left[D^2 - d^2\right]$$

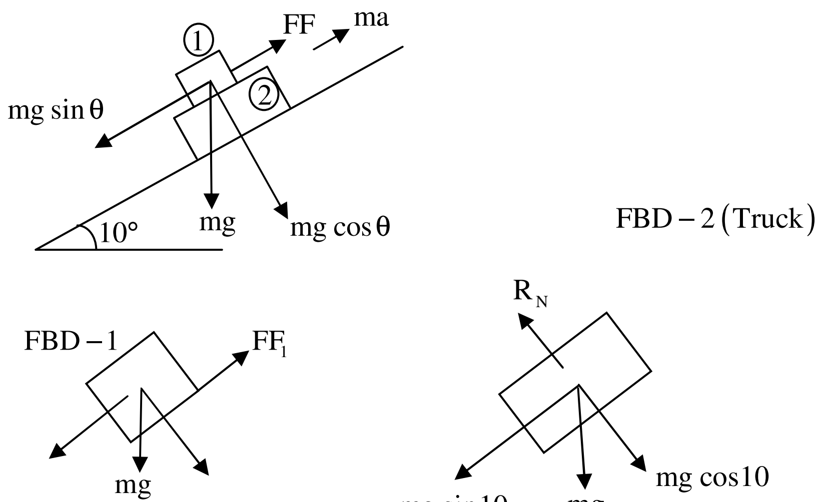
$$= \frac{\pi\times0.3\times1.5\times10^6}{8}\left[0.2^2 - 0.1^2\right]$$

$$= 530.14\text{N} - \text{m}$$

36. A truck accelerates up a 10^O incline with a crate of 100 kg. Value of static coefficient of friction between the crate and the truck surface is 0.3. The maximum value of acceleration (in m/s^2) of the truck such that the crate does not slide down is _______

Answer: 1.0 to 1.3

Exp:



$\Sigma F_{along} = ma$

$F_F - mg\sin\theta = ma$

$\Rightarrow \mu\, mg\cos 10 - mg\sin 10 = ma$

$\Rightarrow a = [0.3\cos 10 - \sin 10]9.81 = 1.19.$

37. Maximum fluctuation of kinetic energy in an engine has been calculated to be 2600 J. Assuming that the engine runs at an average speed of 200 rpm, the polar mass moment of inertia (in kg.m^2) of a flywheel to keep the speed fluctuation within $\pm 0.5\%$ of the average speed is _______

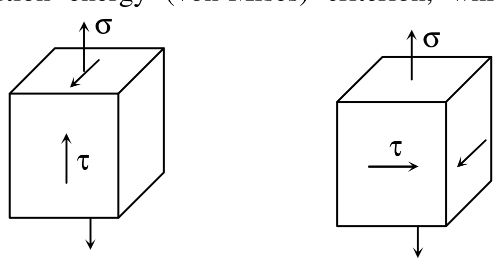
Answer: 590 to 595

Exp: $\Delta E = I\omega^2 C_s \frac{\pi}{4}$

$$\Rightarrow 2600 = I \times \left(\frac{2\pi\times 200}{60}\right)^2 \times \left(\frac{0.5}{100} - \left(\frac{-0.5}{100}\right)\right)$$

$\Rightarrow I = 595.$

38. Consider the two states of stress as shown in configurations I and II in the figure below. From the standpoint of distortion energy (von-Mises) criterion, which one of the following statements is true?



I II

(A) I yields after II

(B) II yields after I

(C) Both yield simultaneously

(D) Nothing can be said about their relative yielding

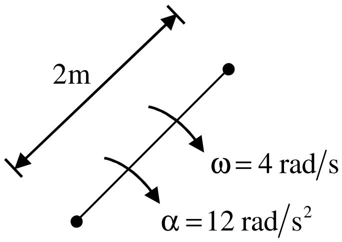
Answer: C

Exp: Both yields simultaneously.

39. A rigid link PQ of length 2 m rotates about the pinned end Q with a constant a acceleration of 12 rad/s^2. When the angular velocity of the link is 4 rad/s, the magnitude the resultant acceleration (in m/s^2) of the end P is _______

Answer: 39 to 41

Exp:



$a_t = R\alpha = 2\times 12 = 24$

$a_R = \omega^2 R = 16\times 2 = 32$

$a = \sqrt{a_t^2 + a_R^2}$

$= \sqrt{24^2 + 32^2} = 40\ m/s^2.$

40. A spur pinion of pitch diameter 50 mm rotates at 200 rad/s and transmits 3 kW power. The pressure angle of the tooth of the pinion is 20°. Assuming that only one pair of the teeth is in contact, the total force (in Newton) exerted by a tooth of the pinion on the tooth on a mating gear is _______

Answer: 638 to 639

Exp: Diameter = 50 mm = 0.05 m

$\omega = 200\ rad/s \Rightarrow N = \dfrac{\omega\times 60}{2\pi}$

$\alpha = 20°$

$P = 3KW$

$T = \dfrac{p\times 10^6\times 60}{2\pi N} = \dfrac{3\times 10^6\times 60}{2\pi\times\dfrac{\omega\times 60}{2\pi}}$

$T = 15000\ N-mm.$

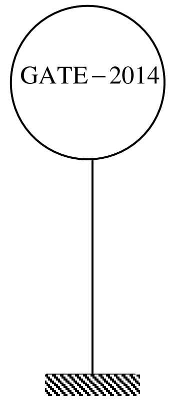
Tangential component of force

$F_t = \dfrac{2T}{d} = \dfrac{2\times 1500}{50}$

$= 600\ N$

$\text{Total force} = \dfrac{F_t}{\cos 20} = 638.5\ N.$

41. A spherical balloon with a diameter of 10 m, shown in the figure below is used for advertisements. The balloon is filled with helium (R_{He} = 2.08 kJ/kg.K) at ambient conditions of 15°C and 100 kPa. Assuming no disturbances due to wind, the maximum allowable weight (in newton) of balloon material and rope required to avoid the fall of the balloon (R_{air} = 0.289 kJ/kg.K) is ________



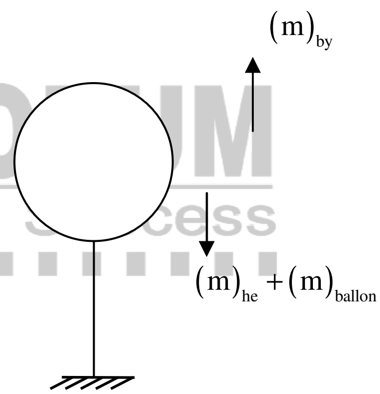
Answer: 5300 to 5330

Exp:

F_1 F_2 F_3

$$(m)_{buyoncy}\, g = (m)_{He}\, g + (m)_{ballon}\, g$$

mass due to replaced air | mass of helium filled in | mass of ballon material and rope



$$F_1 = (m)_{buyoncy} \cdot g = \frac{p.vg}{R_a.T} = \frac{100\times10^3 \times \frac{4}{3}\times\pi\times5^3\times9.81}{0.289\times10^3\times288}$$

$$\therefore F_1 = 6171.3\text{N}$$

$$F_2 = (m)_{Helium} .g = \frac{p.v.g}{R_{He}.T} = \frac{100\times10^3 \times \frac{4}{3}\times\pi\times5^3\times9.81}{2.08\times10^3\times288}$$

$$\therefore F_2 = 857.45 \text{ N}$$

$$\therefore (F)_3 = F_1 - F_2 = 6171.3 - 857.45 = 5313.85 \text{ N.}$$

42. A hemispherical furnace of 1 m radius has the inner surface (emissivity, $\varepsilon = 1$) of its roof maintained at 800 K, while its floor $(\varepsilon = 0.5)$ is kept at 600 K. Stefan-Boltzmann constant is 5.668×10^{-8} W/m^2.K^4. The net radiative heat transfer (in kW) from the roof to the floor is _______

Answer: 24.0 to 25.2

Exp: Let the base be (1) and hemispherical furnace be (2)

$\therefore F_{11} + F_{12} = 1$ ___ (1)

$F_{21} + F_{22} = 1$ ___ (2)

$\because F_{11} = 0 \ \therefore F_{12} = 2$

$A_1F_{12} = A_2F_{21} \quad \therefore F_{21} = \frac{A_1}{A_2}F_{12} = \frac{\pi R^2}{2\pi R^2}F_{12} = 0.5\,F_{12}$

$\therefore F_{21} = 0.5 \times 2 . 0.5$

$\therefore F_{22} = 0.5$

So, $F_{11} = 0, F_{12} = 1, F_{21} = 0.5 < F_{22} = 0.5$

Now Radiative heat transfer, $\Rightarrow \theta = A_1F_{12}\varepsilon_2 \times 6\left(800^4 - 600^4\right)$ watt

$\therefore \theta = \pi \times 1^2 \times 1 \times 0.5 \times 5.668 \times 10^{-8}\left(800^4 - 600^4\right)$ watt

or $\theta = 24.9$ kW.

43. Water flows through a 10 mm diameter and 250 m long smooth pipe at an average velocity of 0.1 m/s. The density and the viscosity of water are 997 kg/m^3 and 855×10^{-6} N.s/m^2, respectively. Assuming fully-developed flow, the pressure drop (in Pa) in the pipe is _______

Answer: 6800 to 6900

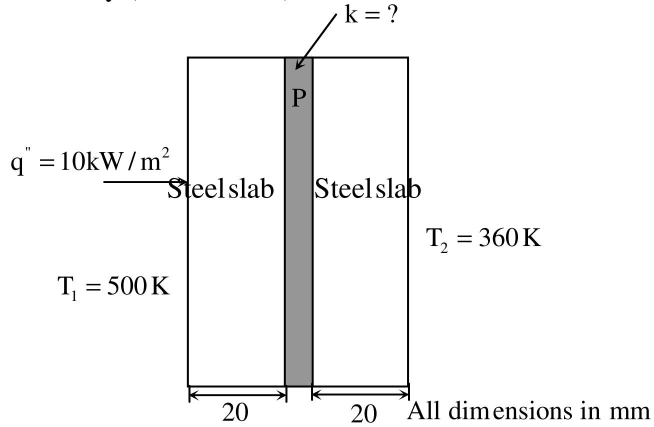
Exp: $Re = \frac{\rho VD}{\mu}$

$= \frac{997 \times 0.1 \times 10 \times 10^{-3}}{855 \times 10^{-6}} = 1166.081\,(\text{laminar flow})$

$f = \frac{64}{Re} = \frac{64}{Re} = \frac{64}{1166.081} = 0.054$

$\Delta p = \frac{fl\rho V^2}{2D} = \frac{0.054 \times 250 \times 997 \times (0.1)^2}{2 \times 10 \times 10^{-3}} = 6840$ pa.

44. A material P of thickness 1 mm is sandwiched between two steel slabs, as shown in the figure below. A heat flux 10 kW/m^2 is supplied to one of the steel slabs as shown. The boundary temperatures of the slabs are indicated in the figure. Assume thermal conductivity of this steel is 10 W/m.K. considering one-dimensional steady state heat conduction for the configuration, the thermal conductivity (k, in W/m.K) of material P is _______



Answer: 0.09 to 0.11

Exp: $t_1 = 20\text{ mm}; k_1 = 10\text{ W/mk}$

$t_2 = 1\text{ mm}; k_2 = ?$

$t_3 = 20\text{ mm}; k_3 = 1010\text{ W/mk}$

$T_1 = 500\text{ k}; T_2 = 360\text{ k}; q_{in} = 1010\text{ kW/m}^2$

Diagram

$$q_{in} = \frac{T_1 - T_2}{\frac{t_1}{k_1A_1} + \frac{t_2}{k_2A_2} + \frac{t_3}{k_3A_3}}$$

Taking unit Area

$$10\times10^3\text{ W/m}^2 = \frac{(500-360)}{\left(\frac{20\times10^{-3}}{10} + \frac{1\times10^{-3}}{k_2} + \frac{20\times10^{-3}}{10}\right)}$$

$$10\left(4+\frac{1}{k_2}\right) = 140$$

$$\frac{1}{k_2} = 10 \Rightarrow k_2 = 0.10\text{ W/m.k.}$$

45. Consider laminar flow of water over a flat plate of length 1 m. If the boundary layer thickness at a distance of 0.25 m from the leading edge of the plate is 8 mm, the boundary layer thickness (in mm), at a distance of 0.75 m, is _______

Answer: 13.5 to 14.2

Exp:

$$\therefore \frac{\delta}{x} = \frac{k}{\sqrt{x}}, \text{ here 'k' is constant}$$

$$\therefore \frac{\delta_1}{\sqrt{x_1}} = \frac{\delta_2}{\sqrt{x_2}}$$

$$\therefore \frac{8}{\sqrt{0.25}} = \frac{\delta_2}{\sqrt{0.75}} \qquad \therefore \delta_2 = 13.86\text{ mm.}$$

$$\because \frac{\delta}{x} = \frac{0.60}{\sqrt{Re_x}}$$

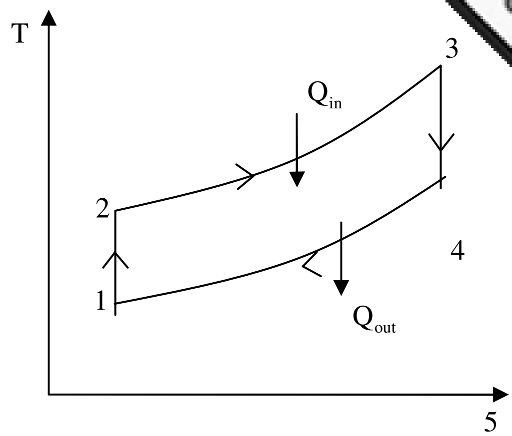
$$\text{or } \frac{\delta}{x} = \frac{0.60}{\sqrt{xu_\infty/\upsilon}} = \frac{0.60\sqrt{\upsilon}}{\sqrt{x}.\sqrt{u_\infty}}$$

$\because$ $\sqrt{\upsilon}$ and $\sqrt{u_\infty}$ is constant in both the cases

46. In an ideal Brayton cycle, atmospheric air (ratio of specific heats, $c_p/c_v = 1.4$, specific heat at constant pressure = 1.005 kJ/kg.K) at 1 bar and 300 K is compressed to 8 bar. The maximum temperature in the cycle is limited to 1280 K. If the heat is supplied at the rate of 80 MW, the mass flow rate (in kg/s) of air required in the cycle is _______

Answer: 105 to 112

Exp:



Given : $\gamma = 1.4, c_p = 1.005$ kJ/kg.k

$P_1 = 1$ bar, $P_2 = 8$ bar

$T_1 = 300$ k, $T_3 = 1280$ k

$$r = \frac{P_2}{P_1} = 8$$

$Q_{in} = 80000$ kW.

(1-2) isentropic process

$$\frac{T_2}{T_1} = (r_p)^{\frac{r-1}{r}}$$

$$T_2 = 300 \times (8)^{\frac{1.4-1}{1.4}} = 543.43 \text{ k}$$

$$Q_{in} = \dot{m} c_p (T_3 - T_2)$$

$$80,000 = \dot{m} \times 1.005 (1280 - 300)$$

$$\dot{m} = 108.07 \text{ kg/s.}$$

47. Steam at a velocity of 10 m/s enters the impulse turbine stage with symmetrical blading having blade angle 30°. The enthalpy drop in the stage is 100 kJ. The nozzle angle is 20°. The maximum blade efficiency (in percent) is _______

Answer: 85.1 to 89.9

Exp: $(\eta)_{max}$ max imum blading efficiency $= \cos^2 \alpha$

$= \cos^2 20° = 0.8830$

$\therefore (\eta_b)_{max} = 88.30\%$

48. In a concentric counter flow heat exchanger, water flows through the inner tube at 25°C and leaves at 42°C. The engine oil enters at 100°C and flows in the annular flow passage. The exit temperature of the engine oil is 50°C. Mass flow rate of water and the engine oil are 1.5 kg/s and 1 kg/s, respectively. The specific heat of water and oil are 4178 J/kg.K and 2130 J/kg.K, respectively. The effectiveness of this heat exchanger is _______

Answer: 0.65 to 0.67

Exp: $T_{c,i} = 25°C; T_{c,o} = 42°C; m_c = 1.5\ kg/s; C_c = 4.178\ kJ/kg.k$

$T_{h,i} = 100°C; T_{h,o} = 50°C; m_h = 1\ kg/s; C_h = 2.130\ kJ/kg.k$

$m_c C_c = 1.5 \times 4.178 = 6.267\ kW/°C = C_{max}$

$m_h C_h = 1 \times 2.130 = 2.130\ kW/°C = C_{min}$

$$\text{effectiveness} = E = \frac{C_h\left(T_{h,i} - T_{h,o}\right)}{C_{min}\left(T_{h,i} - T_{c,i}\right)}$$

$$= \frac{100-50}{100-25} = 0.666.$$

49. A heat pump with refrigerant R22 is used for space heating between temperature limits of -20°C and 25°C. The heat required is 200 MJ/h. Assume specific heat of vapour at the time of discharge as 0.98 kJ/kg.K. Other relevant properties are given below. The enthalpy (in kJ/kg) of the refrigerant at isentropic compressor discharge is _______

Saturation temperature	Pressure	Specific enthalpy		Specific entropy	
$T_{sat}\left({}^{o}C\right)$	$P(MN/m^2)$	h_f(kJ/kg)	hg(kJ/kg)	S_f(kJ/kg/K	S_g(kJ/kg.K)
-20	0.2448	177.21	397.53	0.9139	1.7841
25	1.048	230.07	413.02	1.1047	1.7183

Answer: 430 to 440

Exp: given

$T_1 = 253\ K$

$T_2' = 298\ K$

$S_1 = S_2' = S_2^2$

$\therefore S_1 = S_2 = S_2' + C_P \ln \frac{T_2}{T_2'}$

$1.7841 = 1.7183 + 0.98 \ln \frac{T_2}{298}$

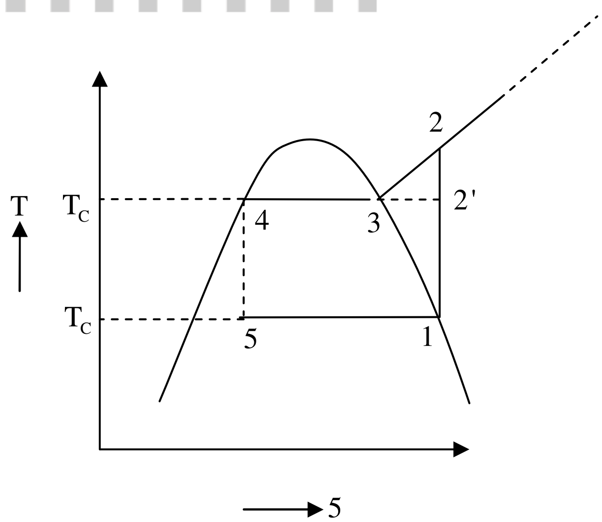
$\therefore T_2 = 318.69\ K$

$\therefore$ Enthalpy of discharge of compressor

$\Rightarrow h_2 = h_2' + C_P\left(T_2' - T_1'\right)$

$\therefore h_2 = 413.02 + 0.98(318.69 - 298)$

$\therefore h_2 = 433.3 \frac{kJ}{kg}.$



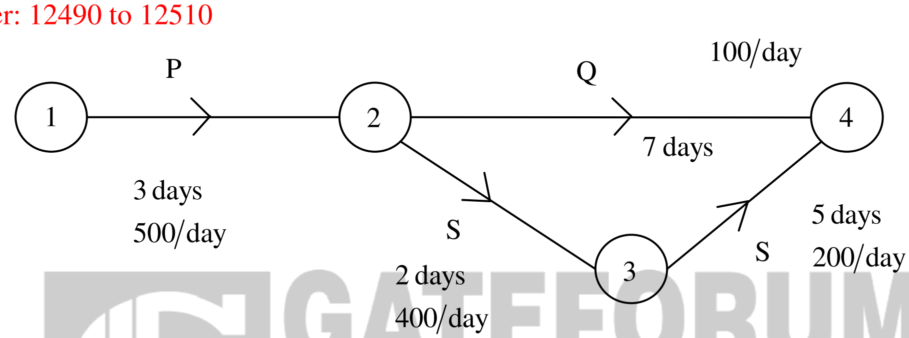
50. A project has four activities P, Q, R and S as shown below.

Activity	Normal duration (days)	Predecessor	Cost slope (Rs./day)
P	3	-	500
Q	7	P	100
R	4	P	400
S	5	R	200

The normal cost of the project is Rs. 10,000/- and the overhead cost is Rs. 200/- per day. If the project duration has to be crashed down to 9 days, the total cost (in Rupees) of the project is ________

Answer: 12490 to 12510

Exp:



Heuristic model to solve the crashing problem:

Step I - Find the normal time

Step II - Determine critical path ≡ P-R-S = 12days.

Step III - Crash the lowest cost slope from the critical path

$\equiv$ crash activity 's' by 2 days

Now critical path $= P - Q(10\text{days})$

$\therefore$ Total cost of the project

$= 10000 + 200 \times (10\text{days}) + \text{crashing cost}$

$= 10,000 + 2000 + 200 \times 2 = 10,000 + 2000 + 400 = 12,400.$

51. Consider the following data with reference to elementary deterministic economic order quantity model

Annual demand of an item	100000
Unit price of the item (in Rs.)	10
Inventory carrying cost per unit per year (in Rs.)	1.5
Unit order cost (in Rs.)	30

The total number of economic orders per year to meet the annual demand is _______

Answer: 49 to 51

Exp: Given $D = 100000/\text{year}$

$\text{unit cost} = 10$

$C_c = 1.5$

$C_o = 30/\text{order}$

$$\therefore EOQ = \sqrt{\frac{2\times D\times C_o}{C_c}} = \sqrt{\frac{2\times 100000\times 30}{1.5}} - 2000$$

$$\therefore \text{No of order's / year} = \frac{\text{Demand}}{EOQ} = \frac{100000}{2000} = 50.$$

52. For the CNC part programming, match Group A with Group B:

Group A	Group B
(p) circular interpolation, counter clock wise	I: G02
(q) dwell	II: G03
(r) circular interpolation, clock wise	III: G04
(s) point to point countering	IV: G00

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

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

Answer: A

Exp:

G00 - Point to point movement

G02 - Circular interpolation, cw

G02 - Circular interpolation, ccw

G04 - Dwell

53. A mild steel plate has to be rolled in one pass such that the final plate thickness is 2/3rd of the initial thickness, with the entrance speed of 10 m/min and roll diameter of 500 mm. If the plate widens by 2% during rolling, the exit velocity (in m/min) is ________

Answer: 14.6 to 14.8

54. A hole of 20 mm diameter is to be drilled in a steel block of 40 mm thickness. The drilling is performed at rotational speed of 400 rpm and feed rate of 0.1 mm/rev. The required approach and over run of the drill together is equal to the radius of drill. The drilling time (in minute) is

(A) 1.00 (B) 1.25 (C) 1.50 (D) 1.75

Answer: B

Exp: $T = \frac{L}{f_N}$

$L = t + Ap_1$

$Ap_1 = 0.5\,D(\text{holes diameter})$

$= 10\text{ mm}$

$t = 40\text{ mm}$

$T = \frac{50}{0.1 \times 400} = 1.25\text{ min}.$

55. A rectangular hole of size 100 mm × 50 mm is to be made on a 5 mm thick sheet of steel having ultimate tensile strength and shear strength of 500 MPa and 300 MPa, respectively. The hole is made by punching process. Neglecting the effect of clearance, the punching force (in kN) is

(A) 300 (B) 450 (C) 600 (D) 750

Answer: B

Exp: $F = \tau_0 \times A_s$

$= 300 \times 1500$

$= 450\text{ kN}.$

for Rectangular hole, $A_s = 2(a+b)t$

$= 2(100+50) \times 5$

$= 1500\text{ mm}^2$