GATE 2018
Mechanical Engineering
Questions & Solutions
Session 2

GENERAL APTITUDE

1. The perimeters of a circle, a square and an equilateral triangle are equal. Which one of the following statements is true?
   A. The circle has the largest area.
   B. The square has the largest area.
   C. The equilateral triangle has the largest area.
   D. All the three shapes have the same area.

   Answer: A

   Solution

   Let us take a circle, square and an equilateral triangle each of equal perimeter say 100m.

$$\pi D = 4a = 3s = 100$$

   D=31.84; a=25; s=33.33;

$$\frac{\pi}{4}d^2 = 796.22$$
$$a^2 = 625$$
$$\frac{\sqrt{3}}{4}s^2 = 481.03$$

   Hence circle has largest area.

2. The value of the expression $\frac{1}{1+\log_u vw}+\frac{1}{1+\log_u wu}+\frac{1}{1+\log_u uv}$ is ________.

   A. -1
   B. 0
   C. 1
   D. 3

   Answer: C

   Solution

$$\frac{1}{1+\log_u vw}+\frac{1}{1+\log_v wu}+\frac{1}{1+\log_w uv}$$
$$\frac{1}{\log_u u+\log_u wv}+\frac{1}{\log_v v+\log_v uw}+\frac{1}{\log_w w+\log_w uv}$$
$$\frac{1}{\log_u uvw}+\frac{1}{\log_v uvw}+\frac{1}{\log_w uvw}$$

$$\log_{uvw} u+\log_{uvw} v+\log_{uvw} w$$
$$\log_{uvw} uvw$$
   =1

3. Find the missing group of letters in the following series:
   BC, FGH, LMNO, ________
   A. UVWXY

B. TUVWX
C. STUVW
D. RSTUV
Answer: B
Solution
~~A~~ BC ~~DE~~ FGH ~~IJK~~ LMNO ~~PQRS~~ TUVWX

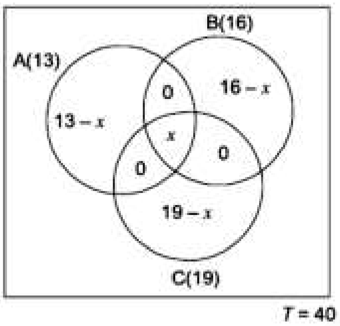
4. “The dress _______ her so well that they all immediately ________ her on her appearance.”
The words that best fill the blanks in the above sentence are
A. complemented, complemented
B. complimented, complemented
C. complimented, complimented
D. complemented, complimented
Answer: D
Solution
Complement: a thing that contributes extra features to something else in such a way as to improve or emphasize its quality.
Compliment: a polite expression of praise or admiration

5. “The judge’s standing in the legal community, though shaken by false allegations of wrongdoing, remained _________.”
The word that best fills the blank in the above sentence is
A. undiminished
B. damaged
C. illegal
D. uncertain
Answer: A
Solution
Even though there were false allegations, but judge’s standing remained same.
Undiminished: Not reduced.

6. A house has a number which needs to be identified. The following three statements are given that can help in identifying the house number.
i. If the house number is a multiple of 3, then it is a number from 50 to 59.
ii. If the house number is NOT a multiple of 4, then it is a number from 60 to 69.
iii. If the house number is NOT a multiple of 6, then it is a number from 70 to 79.
What is the house number?
A. 54
B. 65
C. 66
D. 76
Answer: D
Solution

I. 51,54,57, but none of them is multiple of 4, hence none is valid
II. 61, 62, 63, 65, 66, 67, 69: 63, 66 and 69 are multiple of three hence not valid.
Rest 61, 62, 65, 67 are not a multiple of 6, Hence not valid
III. 70, 71, 73, 74, 75, 76, 77, 79: 75 is multiple of three, hence not valid.
Except 76 none is a multiple of 4, hence only 76 is a valid entry.

7. Forty students watched films A, B and C over a week. Each student watched either only one film or all three. Thirteen students watched film A, sixteen students watched film B and nineteen students watched film C. How many students watched all three films?
A. 0
B. 2
C. 4
D. 8
Answer: C
Solution



Total student = 40
$13 - x + 16 - x + 19 - x + x = 40$
Students watches all three movies,
$x = 4$

8. An unbiased coin is tossed six times in a row and four different such trials are conducted. One trial implies six tosses of the coin. If H stands for head and T stands for tail, the following are the observations from the four trials:
(1) HTHTHT
(2) TTHHHT
(3) HTTHHT
(4) HHHT ___ ___.
Which statement describing the last two coin tosses of the fourth trial has the highest probability of being correct?
A. Two T will occur.
B. One H and one T will occur.
C. Two H will occur.
D. One H will be followed by one T.
Answer: B

Solution

Since the coin is unbiased, the probability of getting heads is equal of tail.
In unbiased coin previous trials does not matter.

Probability of getting both heads $=\frac{1}{2}\times\frac{1}{2}$=1/4

Probability of getting a head and a tail(HT+TH) = $2\times\frac{1}{2}\times\frac{1}{2}$=1/2

Probability of getting both tails $=\frac{1}{2}\times\frac{1}{2}$=1/4

9. A wire would enclose an area of $1936\ m^2$, if it is bent into a square. The wire is cut into two pieces. The longer piece is thrice as long as the shorter piece. The long and the short pieces are bent into a square and a circle, respectively. Which of the following choices is closest to the sum of the areas enclosed by the two pieces in square meters?

A. 1096
B. 1111
C. 1243
D. 2486

Answer: C

Solution

$$\text{Area} = 1936\ m^2$$
$$a^2 = 1936\ m^2$$
$$a = 44\ m$$
$$\text{Length of wire} = 4a$$
$$= 4 \times 44 = 176\ m$$
$$\text{part-1 length} = 3 \times 44 = 132\ m$$
$$\text{part-2 length} = 1 \times 44 = 44\ m$$

Long wire is bent in square.

$$4a = 132$$
$$a = 33\ m$$
$$\text{Area of square} = 33^2 = 1089\ m^2$$

Now, small wire is bent in circle,

So, $\pi D = 44$

$$\frac{22}{7} \times D = 44$$
$$D = 44$$
$$\text{Area of circle} = \frac{\pi}{4} \times D^2 = \frac{\pi}{4} \times 14^2$$
$$= 153.94\ m^2$$
$$\text{Total area enclosed} = \text{Area of square} + \text{Area of circle}$$
$$= 1089 + 153.94$$
$$= 1242.97 \approx 1243\ m^2$$

10. A contract is to be completed in 52 days and 125 identical robots were employed, each operational for 7 hours a day. After 39 days, five-seventh of the work was completed. How many additional robots would be required to complete the work on time, if each robot is now operational for 8 hours a day?

A. 50
B. 89
C. 146
D. 175

All options are incorrect.

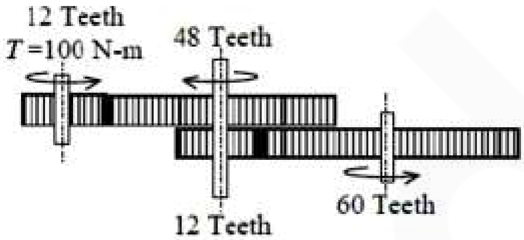
Solution

$$125 \times 7 (39) = \frac{5}{7} W$$
$$W = 47775 \text{ Robot hrs.}$$
$$\text{Left work} = 47775 - 125 \times 7 \times 39$$
$$= 13650 \text{ Robot hrs.}$$
$$13 \times x \times 8 = 13650$$
$$x = 131.25$$

Additional robots required $= 131.25 - 125 = 6.25 \approx 7$

MECHANICAL ENGINEERING

1. A frictionless gear train is shown in the figure. The leftmost 12-teeth gear is given a torque of 100 N-m. The output torque from the 60-teeth gear on the right in N-m is



A. 5
B. 20
C. 500
D. 2000

Answer: D

Solution

$$\frac{N_4}{N_1} = \frac{12 \times 12}{60 \times 48} = \frac{1}{20}$$
$$T_1 N_1 = T_4 N_4$$
$$100 \times N_1 = T_4 \times \frac{N_1}{20}$$
$$T_4 = 2000$$

2. For an ideal gas with constant properties undergoing a quasi-static process, which one of the following represents the change of entropy from state 1 to 2?

A. $\Delta s = C_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$

B. $\Delta s = C_v \ln\left(\frac{T_2}{T_1}\right) - C_p \ln\left(\frac{V_2}{V_1}\right)$

C. $\Delta s = C_p \ln\left(\frac{T_2}{T_1}\right) - C_v \ln\left(\frac{P_2}{P_1}\right)$

D. $\Delta s = C_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_1}{V_2}\right)$

Answer: A

Solution

Standard Equation for change of entropy from state 1 to 2

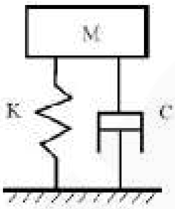
3. Select the correct statement for 50% reaction stage in a steam turbine.
   A. The rotor blade is symmetric.
   B. The stator blade is symmetric.
   C. The absolute inlet flow angle is equal to absolute exit flow angle.
   D. The absolute exit flow angle is equal to inlet angle of rotor blade.

   Answer: D

   Solution

   In Parsons Reaction Turbine (50% reaction), $\alpha_2 = \beta_1$

4. In a single degree of freedom underdamped spring-mass-damper system as shown in the figure, an additional damper is added in parallel such that the system still remains underdamped. Which one of the following statements is ALWAYS true?

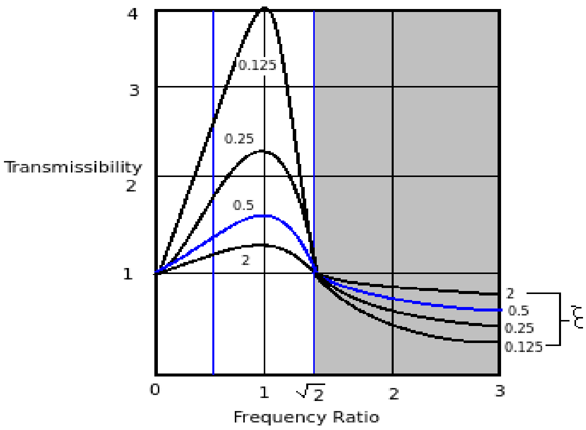


   A. Transmissibility will increase.
   B. Transmissibility will decrease.
   C. Time period of free oscillations will increase.
   D. Time period of free oscillations will decrease.

   Answer: C

   Solution

   Transmissibility can increase or decrease depending upon the frequency of oscillation.



But due to under-damping, frequency $\omega_D = \sqrt{1-\xi^2}\,\omega_n$ decreases, hence time period of free oscillations will increase.

5. The divergence of the vector field $\vec{u} = e^x(\cos y\hat{i} + \sin y\hat{j})$ is

A. 0

B. $e^x \cos y + e^x \sin y$

C. $2e^x \cos y$

D. $2e^x \sin y$

Answer: C

Solution

$\vec{u} = e^x \cos y\, i + e^x \cdot \sin y\, j$

$$\nabla \cdot \vec{u} = \frac{\partial}{\partial x}(u_1) + \frac{\partial}{\partial y}(u_2)$$

$$= \frac{\partial}{\partial x}(e^x.\cos y) + \frac{\partial}{\partial y}(e^x.\sin y)$$

$$= e^x \cos y + e^x \cos y$$

$$\nabla \cdot \vec{u} = 2e^x.\cos y$$

6. Fatigue life of a material for a fully reversed loading condition is estimated from

$$\sigma_a = 1100\ N^{-0.15},$$

Where, σ_a is the stress amplitude in MPa and is the failure life in cycles. The maximum allowable stress amplitude (in MPa) for a life of 1×10^5 cycles under the same loading condition is ________ (correct to two decimal places).

Answer: 195.61

Solution

For a completely reversed loading, amplitude of stress is maximum stress.

$$\sigma = 1100 \times (10^5)^{-0.15}$$

$$\sigma = 195.61\ MPa$$

7. Denoting L as liquid and M as solid in a phase-diagram with the subscripts representing different phases, a eutectoid reaction is described by

A. $M_1 \rightarrow M_2 + M_3$

B. $L_1 \rightarrow M_1 + M_2$

C. $L_1 + M_1 \rightarrow M_2$

D. $M_1 + M_2 \rightarrow M_3$

Answer: A and D both

Solution

Option A represents cooling, while option D represents heating.

8. Metal removal in electric discharge machining takes place through

A. ion displacement

B. melting and vaporization

C. corrosive reaction

D. plastic shear

Answer: B

Solution

Metal removal in electric discharge machining takes place through melting and vaporization.

9. Match the following products with the suitable manufacturing process

Product		Manufacturing process	
P	Toothpaste tube	1	Centrifugal casting
Q	Metallic pipes	2	Blow moulding
R	Plastic bottles	3	Rolling
S	Threaded bolts	4	Impact extrusion

A. P-4, Q-3, R-1, S-2

B. P-2, Q-1, R-3, S-4

C. P-4, Q-1, R-2, S-3

D. P-1, Q-3, R-4, S-2

Answer: C

Solution

Toothpaste tube	Impact Extrusion
Metallic pipes	Centrifugal Casting
Plastic bottles	Blow Moulding
Threaded bolts	Rolling

10. Pre-tensioning of a bolted joint is used to
    A. strain harden the bolt head
    B. decrease stiffness of the bolted joint
    C. increase stiffness of the bolted joint
    D. prevent yielding of the thread root
    Answer: C
    Solution
    Pre-tensioning of bolt increases the stiffness of bolted joint.

11. The peak wavelength of radiation emitted by a black body at a temperature of 2000 K is 1.45 um. If the peak wavelength of emitted radiation changes to 2.90 um, then the temperature (in K) of the black body is
    A. 500
    B. 1000
    C. 4000
    D. 8000
    Answer: B
    Solution
    $\lambda_m T = constant$
    $2000 \times 1.45 = 2.9 \times T$
    T=1000

12. A hollow circular shaft of inner radius 10 mm, outer radius 20 mm and length 1 m is to be used as a torsional spring. If the shear modulus of the material of the shaft is 150 GPa, the torsional stiffness of the shaft (in kN-m/rad) is ________ (correct to two decimal places).
    Answer:35.343
    Solution
    $$\text{Torsional stiffness} = \frac{GI_P}{L}$$
    $$= \frac{150 \times 10^9 \times \frac{\pi}{32}\left[0.04^4 - 0.02^4\right]}{1}$$
    $$= 35343 \text{ N/m/rad} = 35.343 \text{ kNm/rad}$$

13. The Fourier cosine series for an even function is given by
    $$f(x) = a_0 + \sum_{n=1}^{\infty} a_n \cos(nx).$$
    The value of the coefficient a_2 for the function $f(x) = \cos^2(x)$ in $[0, \pi]$ is

A. -0.5
B. 0.0
C. 0.5
D. 1.0

Answer: C

Solution

$$\cos^2 x = \frac{1+\cos 2x}{2}$$
$$f(x) = \frac{1}{2} + \frac{\cos 2x}{2}$$
$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cdot \cos nx$$
$$a_0 = 1$$
$$a_1 = 0,$$
$$a_2 = \frac{1}{2}$$

14. If y is the solution of the differential equation $y^3 \frac{dy}{dx} + x^3 = 0, y(0) = 1,$ the value of $y(-1)$ is

A. -2
B. -1
C. 0
D. 1

Answer: C

Solution

$$y^3 \frac{dy}{dx} = -x^3$$
$$y^3 dy = -x^3\, dx$$
$$\int y^3 dy = -\int x^3 dx$$
$$\frac{y^4}{4} = \frac{-x^4}{4} + C$$
$$\frac{x^4 + y^4}{4} = C$$
$$y(0) = 1,$$
$$\frac{0+1}{4} = C$$
$$C = \frac{1}{4}$$
$$x^4 + y^4 = 1$$
$$y^4 = 1 - x^4$$
$$y = \sqrt[4]{1 - x^4}$$
$$y(-1) = 0$$

15. If $A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 4 & 5 \\ 0 & 0 & 1 \end{bmatrix}$ then $\det(A^{-1})$ is _______ (correct to two decimal places).

Answer: 0.25

Solution

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 4 & 5 \\ 0 & 0 & 1 \end{bmatrix}$$

$$|A| = 4$$

$$|A^{-1}| = \frac{1}{|A|} = \frac{1}{4}$$

16. Consider a function u which depends on position x and time t. The partial differential equation

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}$$

is known as the

A. Wave equation

B. Heat equation

C. Laplace's equation

D. Elasticity equation

Answer: B

Solution

The above equation is known as heat equation.

17. The viscous laminar flow of air over a flat plate results in the formation of a boundary layer. The boundary layer thickness at the end of the plate of length L is δ_L. When the plate length is increased to twice its original length, the percentage change in laminar boundary layer thickness at the end of the plate (with respect to δ_L) is (correct to two decimal places).

Answer: 41.42

Solution

$$\delta \propto \sqrt{x}$$

$$\frac{\delta_1}{\delta_2} = \sqrt{\frac{x_1}{x_2}} = \frac{1}{\sqrt{2}}$$

Percentage change= $\frac{\delta_2 - \delta_1}{\delta_1} \times 100$= 41.42%

18. Feed rate in slab milling operation is equal to
    A. rotation per minute (rpm)
    B. product of rpm and number of teeth in the cutter
    C. product of rpm, feed per tooth and number of teeth in the cutter
    D. product of rpm, feed per tooth and number of teeth in contact

    Answer: C

    Solution

    Feed rate in slab milling= $f_t ZN$

    Where, f_t=feed/tooth

    Z= number of teeth

    N= rpm

19. The minimum axial compressive load, P, required to initiate buckling for a pinned-pinned slender column with bending stiffness EI and length L is
    A. $P = \frac{\pi^2 EI}{4L^2}$
    B. $P = \frac{\pi^2 EI}{L^2}$
    C. $P = \frac{3\pi^2 EI}{4L^2}$
    D. $P = \frac{4\pi^2 EI}{L^2}$

    Answer: B

    Solution

    Pinned-pinned column means hinged on both sides. And the minimum load required to buckle is given by $P = \frac{\pi^2 EI}{L^2}$

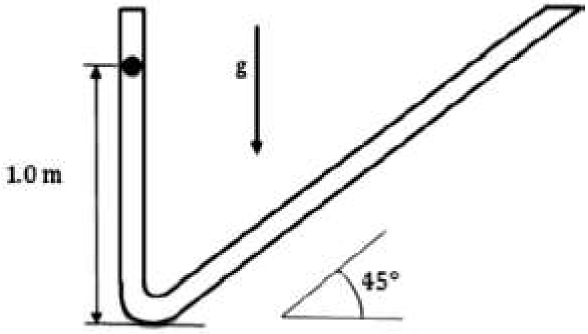
20. During solidification of a pure molten metal, the grains in the casting near the mould wall are
    A. coarse and randomly oriented
    B. fine and randomly oriented
    C. fine and ordered
    D. coarse and ordered

    Answer: B

    Solution

    Grain orientation is random at time of solidification because of many different nucleation sites. Coarse grain structure is obtained after solidification at slower rates.

21. A ball is dropped from rest from a height of 1 m in a frictionless tube as shown in the figure. If the tube is approximated by two straight lines (ignoring the curved portion), the total distance travelled (in m) by the ball is _________ (correct to two decimal places).

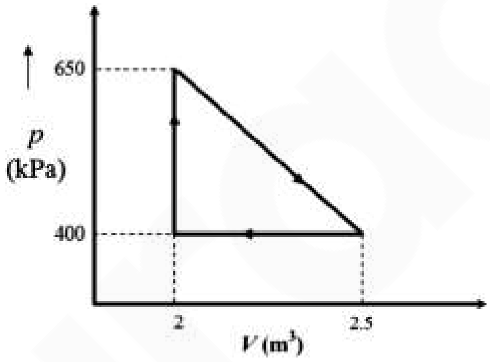


Answer: **MARKS GIVEN TO ALL, INDETERMINATE ANSWER**

Solution

Since the tube is frictionless, the ball will travel to and fro, up-down motion without being stopped, hence the total distance travelled by ball is infinite.

22. An engine operates on the reversible cycle as shown in the figure. The work output from the engine (in kJ/cycle) is _______ (correct to two decimal places).



Answer: 62.5

Solution

Work Output from cycle= Area under PV curve.

$$= \frac{1}{2} \times 0.5 \times 250$$
$$= 62.5$$

23. The preferred option for holding an odd-shaped workpiece in a centre lathe is

A. live and dead centres

B. three jaw chuck

C. lathe dog

D. four jaw chuck

Answer: D

Solution

A four jaw chuck is preferred to handle odd-shaped work piece in centre lathe, because the motion of 4 different jaws are not dependent on each other, hence most of the odd shapes can be fit in.

24. A local tyre distributor expects to sell approximately 9600 steel belted radial tyres next year. Annual carrying cost in Rs. 16 per tyre and ordering cost is Rs. 75. The economic order quantity of the tyres is

A. 64

B. 212

C. 300

D. 1200

Answer: C

Solution

$$EOQ = \sqrt{\frac{2DC_o}{C_h}} = \sqrt{\frac{2 \times 9600 \times 75}{16}} = 300$$

25. The arrival of customers over fixed time intervals in a bank follow a Poisson distribution with an average of 30 customers/hour. The probability that the time between successive customer arrivals is between 1 and 3 minutes is ________ (correct to two decimal places).

Answer: 0.383

Solution

Given, arrival rate, $\lambda = 30/\text{hour}$

$$\lambda = \frac{1}{2}\text{min.}$$

$$P = \text{prob.} = 1 - e^{-\lambda t}$$

$$P(1) = 1 - e^{-\frac{1}{2}\times 1} = 0.393$$

$$P(3) = 1 - e^{-\lambda t} = 1 - e^{-\frac{1}{2}\times 3}$$

$$= 1 - e^{-1.5} = 0.7768$$

$$P(1 \le T \le 3 \text{ min}) = 0.7768 - 0.393 = 0.383$$

26. A bar is subjected to a combination of a steady load of 60 kN and a load fluctuating between -10 kN and 90 kN. The corrected endurance limit of the bar is 150 MPa, the yield strength of the material is 480 MPa and the ultimate strength of the material is

600 MPa. The bar cross-section is square with side a. If the factor of safety is 2, the value of a (in mm), according to the modified Goodman's criterion, is ________ (correct to two decimal places).

Answer: 31.62

Solution

$$P_m = \frac{P_{max} + P_{min}}{2}$$

$$P_a = \frac{P_{max} - P_{min}}{2}$$

$$P_m = 100 \text{ kN}$$

$$Pa = 50 \text{ kN}$$

$$\sigma_m = \frac{100 \times 10^3}{a^2} \text{MPa}$$

$$\sigma_a = \frac{50 \times 10^3}{a^2} \text{MPa}$$

Solution by Goodman Equation,

$$\frac{\sigma_m}{S_{ut}} + \frac{\sigma_a}{\sigma_e} = \frac{1}{N}$$

$$1000\left[\frac{100}{a^2 \times 600} + \frac{50}{150a^2}\right] = \frac{1}{2}$$

$$a^2 = 1000$$

$$a = 31.62 \text{ mm}$$

Solution by Langar euation,

$$\frac{\sigma_m}{S_{yt}} + \frac{\sigma_a}{S_{yt}} = \frac{1}{N}$$

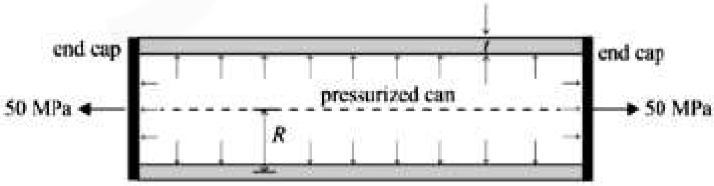
$$100\left[\frac{100}{480a^2} + \frac{50}{480a^2}\right] = \frac{1}{2}$$

$$a^2 = 625$$

$$a = 25 \text{ mm}$$

Hence final answer by modified Goodman's Griterion is 31.62 mm.

27. A thin-walled cylindrical can with rigid end caps has a mean radius $R = 100$ mm and a wall thickness of $t = 5$ mm. The can is pressurized and an additional tensile stress of 50 MPa is imposed along the axial direction as shown in the figure. Assume that the state of stress in the wall is uniform along its length. If the magnitudes of axial and circumferential components of stress in the can are equal, the pressure (in MPa) inside the can is ________ (correct to two decimal places).



Answer: 5

Solution

$$\frac{PD}{2t} = \frac{PD}{4t} + 50$$
$$\frac{PD}{4t} = 50MPa$$
$$P = \frac{50\times4\times5}{200} = 5MPa.$$

28. The true stress (in MPa) versus true strain relationship for a metal is given by

$$\sigma = 1020\ \varepsilon^{0.4}.$$

The cross-sectional area at the start of test (when the stress and strain values are equal to zero) is 100 mm². The cross-sectional area at the time of necking (in mm²) is ________ (correct to two decimal places).

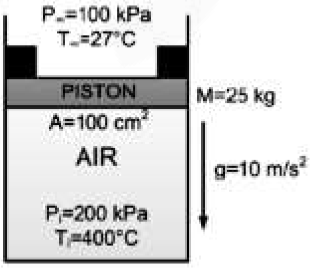
Answer: 67.032

Solution

At necking, true strain equals the strain hardening exponent.

$$\varepsilon_T = 0.4 = \ln\left(\frac{A_0}{A_f}\right)$$
$$0.4 = \ln\left(\frac{100}{A_f}\right)$$
$$\frac{A_0}{A_f} = e^{0.4}$$
$$A_f = \frac{100}{e^{0.4}}$$
$$A_f = 67.032\ mm^2$$

29. Air is held inside a non-insulated cylinder using a piston (mass M=25 kg and area A=100 cm²) and stoppers (of negligible area), as shown in the figure. The initial pressure P_i and temperature T_i of air inside the cylinder are 200 kPa and 400°C, respectively. The ambient pressure P_∞ and temperature T_∞ are 100 kPa and 27°C, respectively. The temperature of the air inside the cylinder (°C) at which the piston will begin to move is ________ (correct to two decimal places).



Answer: 147.625

Solution

Using pressure balance, Pressure at which the piston will start to move,

$$P_{in} = \frac{25 \times 10}{0.01 \times 1000} + 100\ kPa$$

$$P_{in} = 125\ kPa$$

Since volume and mass remains constant.

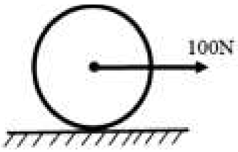
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{200}{673} = \frac{125}{T}$$

T=420.625°K

T=147.625°C

30. A force of 100 N is applied to the centre of a circular disc, of mass 10 kg and radius 1 m, resting on a floor as shown in the figure. If the disc rolls without slipping on the floor, the linear acceleration (in m/s²) of the centre of the disc is ________ (correct to two decimal places).



Answer: 6.667

Solution

$$T = I\alpha$$

T= 100×1=100Nm

At point of contact, i.e. I-centre of rotation,

$$I = \frac{mR^2}{2} + mR^2$$

$$I = 15$$

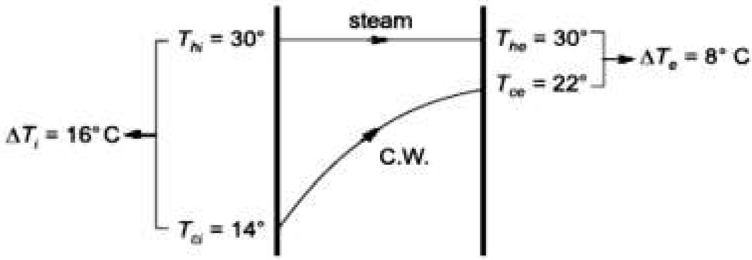
Hence, α= 100/15=6.667 rad/sec²

Acceleration at centre of disc=Rα=6.667 m/sec²

31. Steam in the condenser of a thermal power plant is to be condensed at a temperature of 30°C with cooling water which enters the tubes of the condenser at 14°C and exits at 22°C.Overall heat transfer coefficient is 2000W/m²K and the total surface area of the tubes is 50 m². Net heat transfer (in MW) is ________ (correct to two decimal places).

Answer: 1.154

Solution



$$\therefore\ (\text{LMTD})\text{ of } HE = \frac{\Delta T_i - \Delta T_e}{\ln\frac{T_i}{T_e}} = \frac{16-8}{\ln\left(\frac{16}{8}\right)}$$

$$= 11.54°\ \text{C}$$

Total heat transfer, Q= U.A.(LMTD)

Q= 2000×50×11.54

Q=1.154MW

32. A steel wire is drawn from an initial diameter (d_i) of 10 mm to a final diameter (d_f) of 7.5 mm. The half cone angle (α) of the die is 5° and the coefficient of friction (μ) between the die and the wire is 0.1. The average of the initial and final yield stress $\left[(\sigma_Y)_{avg}\right]$ is 350 MPa. The equation for drawing stress σ_f, (in MPa) is given as:

$$\sigma_f = (\sigma_Y)_{avg}\left\{1 + \frac{1}{\mu \cot \alpha}\right\}\left[1 - \left(\frac{d_f}{d_i}\right)^{2\mu\cot\alpha}\right]$$

The drawing stress (in MPa) required to carry out this operation is ________ (correct to two decimal places).

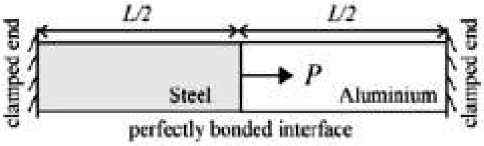
Answer: 316.25

Solution

$\mu cot\alpha = 1.143$

$$\sigma_f = 350\left\{1 + \frac{1}{1.143}\right\}\left[1 - \left(\frac{7.5}{10}\right)^{2\times1.143}\right] = 316.25$$

33. A bimetallic cylindrical bar of cross sectional area $1\ m^2$ is made by bonding Steel (Young's modulus = 210 GPa) and Aluminium (Young's modulus = 70 GPa) as shown in the figure. To maintain tensile axial strain of magnitude 10^{-6} in Steel bar and compressive axial strain of magnitude 10^{-6} in Aluminum bar, the magnitude of the required force P (in kN.) along the indicated direction is



A. 70
B. 140
C. 210
D. 280

Answer: D

Solution

$\epsilon_{Steel} = 10^{-6} = \frac{P_{steel}}{AE_{steel}}$

$P_{steel} = 210\ kN$

Similarly, $P_{aluminium} = 70\ kN$

P= 70+210=280 kN.

34. Let z be a complex variable. For a counter-clockwise integration around a unit circle C, centred at origin,

$$\oint_C \frac{1}{5z-4} dz = A\pi i$$

the value of A is

A. 2/5
B. 1/2
C. 2
D. 4/5

Answer: A

Solution

$5z - 4 = 0$

$z = \frac{4}{5}$ lies inside circle,

$$|z| = 1$$

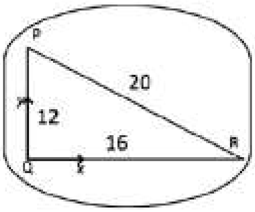
$$\int \frac{1}{(5z-4)} dz = A\pi i$$

$$\frac{1}{5}\int \frac{1}{\left(z - \frac{4}{5}\right)} dz = A\pi i$$

$$\int \frac{\left(\frac{1}{5}\right)}{\left(z - \frac{4}{5}\right)} dz = 2\pi i \cdot f\left(\frac{4}{5}\right) = 2\pi i \times \left(\frac{1}{5}\right) = \frac{2}{5}\pi i$$

$A = \frac{2}{5}$

35. In a rigid body in plane motion, the point R is accelerating with respect to point P at $10\angle 180^o$ m/s^2. If the instantaneous acceleration of point Q is zero, the acceleration (in m/s^2) of point R is



A. $8\angle 233^o$
B. $10\angle 225^o$
C. $10\angle 217^o$
D. $8\angle 217^o$

Answer:

Solution

Since acceleration of point Q is zero, so body PQR is hinged at Q.

$$\bar{a}_{RP} = \bar{a}_R - \bar{a}_P = 10\ m/s^2\ \angle 180^o$$

$$a_{RP} = (RP)\omega^2 = 10$$

$$20\omega^2 = 10$$

$$\omega = \frac{1}{\sqrt{2}}$$

$$a_R = QR(\omega^2)$$

$$= 16 \times \frac{1}{2} = 8\ \text{m/s}^2$$

So the angle of it from reference is

from ΔPQR $\tan\theta = \frac{12}{16}$

$\Rightarrow$ $\theta = 36.8698^o$

So, $180 + 36.8698 = 216.8698 ; 217^o$

36. Given the ordinary differential equation

$$\frac{d^2y}{dx^2} + \frac{dy}{dx} - 6y = 0$$

with $y(0) = 0$ and $\frac{dy}{dx}(0) = 1$, the value of $y(1)$ is _______ (correct to two decimal places).

Answer: 1.4678

Solution

$$\left(D^2+D-6\right)y=0$$
$$y(0)=0,$$
$$y(0)=1$$
$$(D+3)(D-2)y=0$$
$$D=2,-3$$
$$\text{C.F.}=C_1e^{2x}+C_2e^{-3x}$$
$$y=C_1e^{2x}+C_2e^{-3x}$$
$$y(0)=0$$

So, $0=C_1+C_2$ ...(i)

$$\frac{dy}{dx}=2C_1e^{2x}-3C_2e^{-3x}$$
$$y'(0)=1,$$

$1=2C_1-3C_2$ ...(ii)

From equation (i) and (ii),

$$C_1=\frac{1}{5},$$
$$C_2=\frac{-1}{5}$$
$$y=\frac{1}{5}e^{2x}-\frac{1}{5}e^{-3x}$$

When, $x=1$

$$y(1)=\frac{e^2-e^{-3}}{5}=1.4678$$

37. A circular hole of 25 mm diameter and depth of 20 mm is machined by EDM process. The material removal rate (in mm³/min) is expressed as

$$4\times10^4\,IT^{-1.23},$$

where $I=300$ A and the melting point of the material $T=1600°C$. The time (in minutes) for machining this hole is _________ (correct to two decimal places).

Answer: 7.1431

Solution

$$MRR=4\times10^4\times300\times1600^{-1.23}=1374.4\text{ mm3/min}$$

$$\text{Time required}=\frac{9817.477}{1374.4}$$
$$=7.1431\text{ min.}$$

38. In a cam-follower, the follower rises by h as the cam rotates by δ (radians) at constant angular velocity ω (radians/s). The follower is uniformly accelerating during the first half of the rise period and it is uniformly decelerating in the latter half of the rise period.

Assuming that the magnitudes of the acceleration and deceleration are same, the maximum velocity of the follower is

A. $\frac{4h\omega}{\delta}$

B. $h\omega$

C. $\frac{2h\omega}{\delta}$

D. $2h\omega$

Answer: C

Solution

$$time, t = \frac{\delta/2}{\omega}$$

Since the cam is having uniform velocity, first half of rise will be accelerating, other half will be decelerating. Hence velocity will be maximum at height=h/2

$$h/2 = 0 \times t + \frac{1}{2}at^2$$

$$a = \frac{h}{t^2}$$

$$v = u + at$$

$$v = at = \frac{h}{t^2} \times t = \frac{h}{t} = \frac{2h\omega}{\delta}$$

39. Let X_1 and X_2 be two independent exponentially distributed random variables with means 0.5 and 0.25, respectively. Then $Y = \min(X_1, X_2)$ is

A. exponentially distributed with mean 1/6

B. exponentially distributed with mean 2

C. normally distributed with mean 3/4

D. normally distributed with mean 1/6

Answer: A

Solution

$$\text{Mean}(x_1) = 0.5$$

$$\frac{1}{\lambda_1} = 0.5$$

$$\lambda_1 = \frac{1}{0.5} = 2$$

$$\text{Mean}(x_2) = 0.25$$

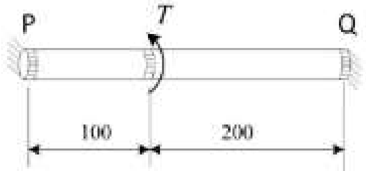
$$\frac{1}{\lambda_2} = 0.25$$

$$\lambda_2 = \frac{1}{0.25} = 4$$

$$y = \text{mean}(x_1, x_2)$$

$$\text{Mean}(y) = \frac{1}{\lambda_1 + \lambda_2} = \frac{1}{2+4} = \frac{1}{6}$$

40. A bar of circular cross section is clamped at ends P and Q as shown in the figure. A torsional moment $T = 150$ Nm is applied at a distance of 100 mm from end P. The torsional reactions (T_P, T_Q) in Nm at the ends P and Q respectively are



(All dimensions are in mm)

A. (50,100)
B. (75,75)
C. (100,50)
D. (120,30)

Answer: C

Solution

Since, G and are constant for bar,

$T_1 L_1 = T_2 L_2$

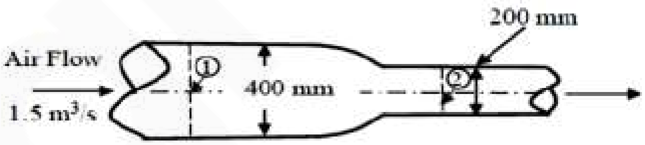
$T_1 . 100 = T_2 . 200$

$T_1 = 2T_2$

And, $T_1 + T_2 = T$

Hence, $T_1 = 100Nm \; and \; T_2 = 50Nm$

41. Air flows at the rate of $1.5 \text{ m}^3/\text{s}$ through a horizontal pipe with a gradually reducing cross-section as shown in the figure. The two cross-sections of the pipe have diameters of 400 mm and 200 mm. Take the air density as 1.2 kg/m^3 and assume inviscid incompressible flow. The change in pressure $(p_2 - p_1)$ (in kPa) between sections 1 and 2 is



A. -1.28
B. 2.56
C. -2.13
D. 1.28

Answer: A

Solution

$Q = a_1 v_1 = a_2 v_2 = 1.5 \; m^3/sec$

$d_1^2 v_1 = d_2^2 v_2$

$v_2 = 4v_1$

$also, v_1 = \frac{Q}{a_1} = 11.93\ m/sec$

$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$

$\frac{P_1 - P_2}{\rho g} = 15\frac{v_1^2}{2g}$

$P_1 - P_2 = 15\frac{v_1^2 \times \rho}{2} = 1282.346\ Pa = 1.28 kPa$

$P_2 - P_1 = -1.28\ kPa$

42. The problem of maximizing $z = x_1 - x_2$ subject to constraints $x_1 + x_2 \le 10, x_1 \ge 0,\ \ x_2 \ge 0$ and $x_2 \le 5$ has

A. no solution

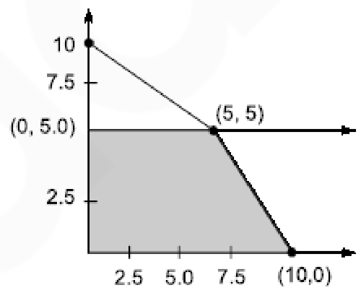
B. one solution

C. two solution

D. more than two solutions

Answer: B

Solution



Max., $Z = x_1 - x_2$

Constratins : $x_1 + x_2 \le 10;$

$x_1 \ge 0;\ x_2 \ge 0$ and $x_2 \le 5$

$Z(0,5) = 0 - 5 = -5$

$Z(5,5) = 5 - 5 = 0$

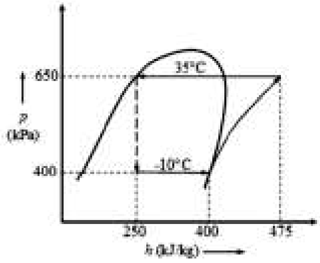
$Z(10,\ 0) = 10 - 0 = 10$

$Z_{max} = 10$ at $(10,0)$

The problem has one solution

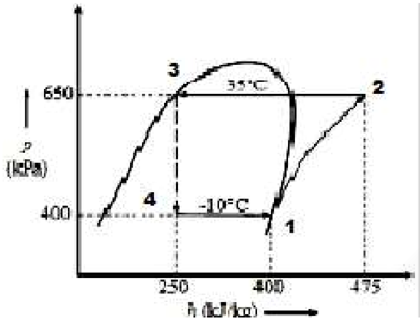
43. A standard vapor compression refrigeration cycle operating with a condensing temperature of 35°C and an evaporating temperature of -10°C develops 15 kW of cooling. The p-h diagram shows the enthalpies at various states. If the isentropic

efficiency of the compressor is 0.75, the magnitude of compressor power (in kW) is _________ (correct to two decimal places).



Answer: 10

Solution



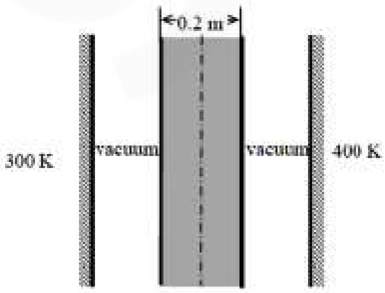
$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP = \frac{400 - 250}{475 - 400} = \frac{150}{75} = 2$$

$$Ideal\ Work\ input = \frac{Refrigeration\ Capacity}{COP} = \frac{15}{2} = 7.5$$

$$Actual\ Work\ input = \frac{Ideal\ Work\ input}{Efficiency} = \frac{7.5}{0.75} = 10$$

44. A 0.2 m thick infinite black plate having a thermal conductivity of 3.96 W/m-K is exposed to two infinite black surfaces at 300 K and 400 K as shown in the figure. At steady state, the surface temperature of the plate facing the cold side is 350 K. The value of Stefan-Boltzmann constant, σ, is 5.67×10^{-8} W/m² K⁴. Assuming 1-D heat conduction, the magnitude of heat flux through the plate (in w/m²) is _________ (correct to two decimal places).



Answer: 391.612

Solution

Since there is steady state, the heat transfer between plate and surface is equal to heat transfer between the two surfaces, which is equal to heat transferred through the plate.

$$Heat\ flux\ between\ plate\ and\ surface, q'' = \frac{\sigma \times (350^4 - 300^4)}{\frac{1}{\epsilon_1} + \frac{1}{\epsilon_2} - 1}$$

$\epsilon_1 = \epsilon_2 = 1, Surfaces\ are\ black$

$q'' = 391.612\ W/m^2$

45. Following data correspond to an orthogonal turning of a 100 mm diameter rod on a lathe. Rake angle: +15°; Uncut chip thickness: 0.5 mm; nominal chip thickness after the cut: 1.25 mm. The shear angle (in degrees) for this process is ________ (correct to two decimal places).

Answer: 23.26

Solution

$$r = chip\ thickness\ ratio = \frac{t_c}{t} = \frac{0.5}{1.25} = 0.4$$

$$\tan\varphi = \frac{r\cos\alpha}{1 - r\sin\alpha} = 0.43$$

$\varphi = 23.26°$

46. Taylor's tool life equation is used to estimate the life of a batch of identical HSS twist drills by drilling through holes at constant feed in 20 mm thick mild steel plates. In test 1, a drill lasted 300 holes at 150 rpm while in test 2, another drill lasted 200 holes at 300 rpm. The maximum number of holes that can be made by another drill from the above batch at 200 rpm is _________ (correct to two decimal places).

Answer: 253.51

Solution

Here tool life is represented by number of holes (H) and speed is represented by rpm (N)

Taylors Tool life equation: $VT^n = constant$

Since all the conditions are same for different batches, except rpm and number of holes,

$NH^n = another\ constant$

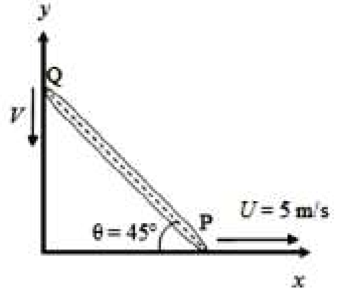
$150 \times 300^n = 300 \times 200^n$

$n = 1.71$

$300 \times 200^n = 200 \times H^n$

$H = 253.51$

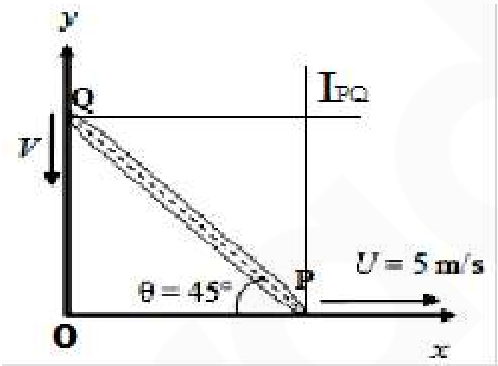
47. A rigid rod of length 1 m is resting at an angle $\theta = 45^o$ as shown in the figure. The end P is dragged with a velocity of $U = 5$ m/s to the right. At the instant shown, the magnitude of the velocity V (in m/s) of point Q as it moves along the wall without losing contact is



A. 5
B. 6
C. 8
D. 10

Answer: A

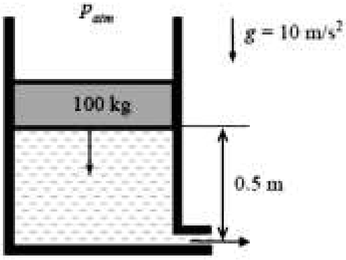
Solution



$$\frac{V_P}{I_{PQ}P} = \frac{V_Q}{I_{PQ}Q}$$

Hence, $V_p=V_Q=5$ m/sec

48. A frictionless circular piston of area $10^{-2}\,m^2$ and mass 100 kg sinks into a cylindrical container of the same area filled with water of density $1000\ kg/m^3$ as shown in the figure. The container has a hole of area $10^{-3}\,m^2$ at the bottom that is open to the atmosphere. Assuming there is no leakage from the edges of the piston and considering water to be incompressible, the magnitude of the piston velocity (in m/s) at the instant shown is ________ (correct to two decimal places).



Answer: 1.456

Solution

$$Total\ gauge\ pressure\ at\ top = \frac{mg}{Piston\ area} = 100kPa$$

$$Total\ gauge\ pressure\ at\ bottom = 0$$

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

$$\frac{10^5}{\rho g} + \frac{v_1^2}{2g} + 0.5 = 0 + \frac{v_2^2}{2g} + 0$$

$$A_1V_1 = A_2V_2$$

$$10V_1 = V_2$$

$$10 + 0.5 = 99 \times \frac{v_1^2}{2g}$$

$$v_1 = 1.456\ m/sec$$

49. A test is conducted on a one-fifth scale model of a Francis turbine under a head of 2 m and volumetric flow rate of $1\ m^3/s$ at 450 rpm. Take the water density and the acceleration due to gravity as $10^3\ kg/m^3$ and $10\ m/s^2$, respectively. Assume no losses both in model and prototype turbines. The power (in MW) of a full sized turbine while working under a head of 30 m is ________ (correct to two decimal places).

Answer: 29.05

Solution

$$\left(\frac{H}{D^2N^2}\right)_m = \left(\frac{H}{D^2N^2}\right)_p$$

$$N_p = 384.56\ rpm$$

$$\left(\frac{P}{D^5N^3}\right)_m = \left(\frac{P}{D^5N^3}\right)_p$$

$$P_p = 29.05MW$$

50. A welding operation is being performed with voltage = 30 V and current = 100 A. The cross-sectional area of the weld bead is 20 mm^2. The work-piece and filler are of titanium for which the specific energy of melting is 14 J/mm^3. Assuming a thermal efficiency of the welding process 70%, the welding speed (in mm/s) is ________ (correct to two decimal places).

Answer: 7.5

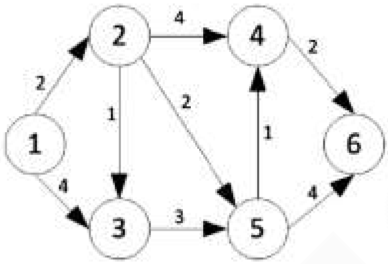
Solution

$$\eta = \frac{a \times v \times e}{V \times I}$$

$$0.7 = \frac{20 \times 10^{-6} \times v \times 14 \times 10^{9}}{30 \times 100}$$

$$v = 7.5\ mm/sec$$

51. The arc lengths of a directed graph of a project are as shown in the figure. The shortest path length from node 1 to node 6 is __________.



Answer: 7 or 11

Solution

There was ambiguity in question. In some textbooks it is mentioned that critical path is the shortest path. But the question intended to ask the shortest time taking path.

The shortest time taking path is of 7 days and critical path is of 11 days.

52. Ambient air is at a pressure of 100 kPa, dry bulb temperature of 30°C and 60% relative humidity. The saturation pressure of water at 30°C is 4.24 kPa. The specific humidity of air (in g/kg of dry air) is ________ (correct to two decimal places).

Answer: 16.24

Solution

$$\varphi = \frac{p_v}{p_{vs}}$$

$$0.6 = \frac{p_v}{4.24}$$

$$p_v = 2.544$$

$$\omega = \frac{0.622 p_v}{P - p_v}$$

$$\omega = 16.24 \frac{gram}{kg} of\ dry\ air$$

53. For a position vector $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$ the norm of the vector can be defined as $|\vec{r}| = \sqrt{x^2 + y^2 + z^2}$. Given a function $\phi = \text{In}|\vec{r}|$, its gradient $\nabla\phi$ is

A. $\vec{r}$

B. $\frac{\vec{r}}{|\vec{r}|}$

C. $\frac{\vec{r}}{\vec{r}\cdot\vec{r}}$

D. $\frac{\vec{r}}{|\vec{r}|^3}$

Answer: C

Solution

$\phi = \text{In } r$

$\nabla\phi = \nabla(\text{In } r)$

$f(r) = \text{In}(r)$

$f'(r) = \frac{1}{r}$

$\nabla f(r) = \frac{f'(r)}{r}.\vec{r} = \left(\frac{1}{r}\right)\times\left(\frac{1}{r}\right).\vec{r}$

$\nabla f(r) = \frac{\vec{r}}{r^2}$

54. A vehicle powered by a spark ignition engine follows air standard Otto cycle $(\gamma = 1.4)$. The engine generates 70 kW while consuming 10.3 kg/hr of fuel. The calorific value of fuel is 44,000 kJ/kg. The compression ratio is ________ (correct to two decimal places).

Answer: 7.61

Solution

Amount of heat supplied per second= 10.3×44000/3600 kJ/s

=125.88kW

$$Efficiency = \frac{Power}{Heat\ supplied} = 1 - \frac{1}{r^{\gamma-1}}$$

$$\frac{70}{125.88} = 1 - \frac{1}{r^{\gamma-1}}$$

$r = 7.61$

55. For sand-casting a steel rectangular plate with dimensions $80\,mm \times 120\,mm \times 20\,mm$, a cylindrical riser has to be designed. The height of the riser is equal to its diameter. The total solidification time for the casting is 2 minutes. In Chvorinov's law for the estimation of the total solidification time, exponent is to be taken as 2. For a solidification time of 3 minutes in the riser, the diameter (in mm) of the riser is _________ (correct to two decimal places).

Answer: 51.87

Solution

$$t = k\left(\frac{V}{SA}\right)^2$$

$$2 = k\left(\frac{0.08 \times 0.12 \times 0.02}{2(0.08 \times 0.12 + 0.12 \times 0.02 + 0.02 \times 0.08}\right)^2$$

$$k = 40138.88$$

$$3 = 40138.88\left(\frac{D}{6}\right)^2$$

$$D = 51.87\ mm$$

***