MADE EASY

GATE 2023

MECHANICAL ENGINEERING

Questions & Solutions

Exam held on 04th Feb, 2023 Afternoon Session

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Mechanical Engineering Paper Analysis of ESE 2023 Preliminary Examination		
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UPSC ESE Prelims 2023
Mechanical Engineering analysis
by MADE EASY faculties

https://www.youtube.com/watch?v=CnB8VG4rLLY

1. What is the section modulus (Z) for a triangular section of base width b and height h?

(a) $\frac{bh^2}{12}$ (b) $\frac{bh^2}{24}$

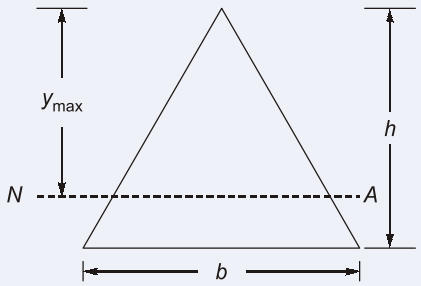
(c) $\frac{bh^3}{12}$ (d) $\frac{bh^3}{24}$

Ans. (b)

Section modulus is given by,

$$z = \frac{I}{y_{max}}$$

For a triangular section as shown below,



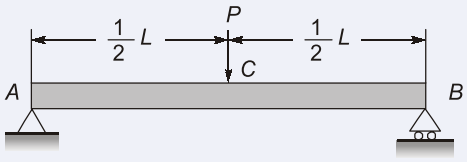
$$y_{max} = \frac{2h}{3}$$

and $$I = \frac{bh^3}{36}$$

$$\therefore \quad z = \frac{\frac{bh^3}{36}}{\frac{2h}{3}} = \frac{bh^2}{24}$$

End of Solution

2. What is the maximum bending moment for the simply supported beam as shown in figure?

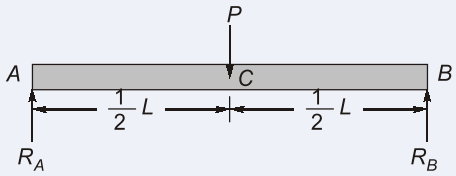


(a) $\frac{PL^4}{4}$ (b) $\frac{PL^2}{4}$

(c) $\frac{PL^2}{2}$ (d) $\frac{PL}{4}$

Ans. (d)

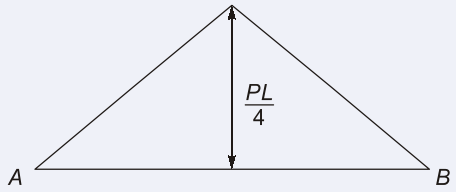
FBD of the beam is as shown below:



From symmetry,

$$R_A = R_B = \frac{P}{2}$$

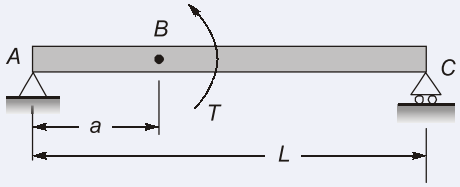
Thus, the BMD of the beam is as shown below.



$\therefore$ $\text{BMD}_{max} = \frac{PL}{4}$

End of Solution

3. What is the maximum shear force for the simply supported beam loaded by a couple of moment T applied at point B as shown in figure?



(a) $\frac{T}{L}$

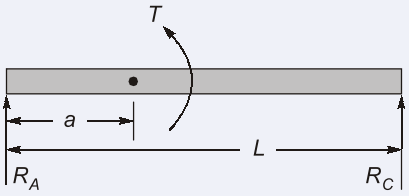
(b) $\frac{Ta}{4}$

(c) $\frac{TL^2}{2}$

(d) $\frac{TL}{4}$

Ans. (a)

FBD of the beam is as shown below;



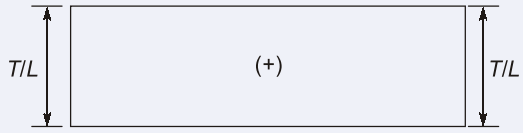
Taking moment about A,

$$R_C \times L + T = 0$$

$$R_C = -\frac{T}{L}$$

Also, $$R_A = -R_C = \frac{T}{L}$$

Now SFD of the beam is as shown below



∴Maximum shear force is $\frac{T}{L}$.

End of Solution

4. A Surveyor's steel tape 30 m long has a cross-section of 15 mm × 0.75 mm. With this, line AB is measured as 150 m. If the force applied during measurement is 120 N more than the force applied at the time of calibration, what is the elongation? (Take modulus of elasticity for steel as 200 kN/mm^2).

(a) 4.400 mm (b) 3.375 mm
(c) 2.125 mm (d) 1.600 mm

Ans. (d)

Given, cross section area, $A = 15 \times 0.75 = 11.25$ mm^2
Excess load during measurement, $P = 120$ N
$E = 200$ kN/mm^2
Length of tape, $L = 30$ m
Elongation due to excess load,

$$\Delta = \frac{PL}{AE} = \frac{120 \times 30 \times 1000}{11.25 \times 200 \times 10^3}$$

$$\Delta = 1.6 \text{ mm}$$

End of Solution

5. Which one of the following is defined as the ratio of shearing stress to shearing strain within elastic limit?

(a) Shear modulus (b) Poisson's ratio
(c) Modulus of rigidity (d) Young's modulus

Ans. (c)

The terms modulus and modulus of rigidity are synonymous. But, the most appropriate option as answer is option (c).

End of Solution

6. The extension of a bar uniformly tapering from a diameter of (d + a) to (d – a) in a length L is calculated by treating it as a bar of uniform cross-section of average diameter d. What is the percentage error?

(a) $25\frac{a^2}{d^2}$ (b) $50\frac{a^2}{d^2}$
(c) $75\frac{a^2}{d^2}$ (d) $100\frac{a^2}{d^2}$

Ans. (d)

Actual extension, $\Delta_a = \dfrac{4PL}{\pi d_1 d_2 E} = \dfrac{4PL}{\Delta(d+a)(d-a)E}$

$$= \frac{4PL}{\pi\left(d^2 - a^2\right)E}$$

If it is treated as a bar of uniform cross-section of average diameter d, then its extension is given by

$$\Delta = \frac{PL}{AE} = \frac{4PL}{\pi d^2 E}$$

$$\therefore \quad \text{Percentage error} = \frac{\dfrac{4PL}{\pi\left(d^2 - a^2\right)E} - \dfrac{4PL}{\pi d^2 E}}{\dfrac{4PL}{\pi\left(d^2 - a^2\right)E}} \times 100$$

$$= \frac{\dfrac{1}{\left(d^2 - a^2\right)} - \dfrac{1}{d^2}}{\dfrac{1}{\left(d^2 - a^2\right)}} \times 100 = \left(1 - \frac{d^2 - a^2}{d^2}\right) \times 100$$

$$= 100\frac{a^2}{d^2}$$

End of Solution

7. What is the torque, if a shaft of 200 mm diameter can transmit safely and the shear stress is not to exceed 50 N/mm^2?

(a) 78.54 N-m (b) 78.54 kN-m
(c) 152.45 kN-m (d) 152.45 N-m

Ans. (b)

Given, diameter of shaft, d = 200 mm
Maximum shear stress, τ_{max} = 50 N/mm^2
Torque that can be transmitted,

$$T = \frac{\pi d^3}{16}\tau_{max} = \frac{\pi \times 200^3}{16} \times 50$$

$$T = 78539816.34 \text{ N.mm}$$
$$= 78.54 \text{ kN.m}$$

End of Solution

8. For the design of a thin cylindrical shell, if f_a is allowable tensile stress for the material of the shell, thickness t of the cylindrical shell of a diameter d and internal pressure p, then the criterion for the thickness is

(a) $t \geq \frac{p}{2f_a}$ (b) $t \geq \frac{d}{2f_a}$

(c) $t \leq \frac{pd}{2f_a}$ (d) $t \geq \frac{pd}{2f_a}$

Ans. (d)

For a thin cylindrical shell,

$$\sigma_{max} = \sigma_h = \frac{pd}{2t}$$

If f_a is the allowable tensile stress then,

$$\sigma_{max} \leq f_a$$

$$\frac{pd}{2t} \leq f_a$$

or, $$t \geq \frac{pd}{2f_a}$$

End of Solution

9. Consider the following assumptions for Lame's problem of stress distribution in the thick shells:

1. The material of the shell is heterogeneous and isotropic.
2. Plane sections of the cylinder, perpendicular to the longitudinal axis, remain plane under the pressure.
3. The material of the shell is homogeneous and isotropic.

Which of the above statements is/are correct?

(a) 1 only (b) 3 only

(c) 2 and 3 only (d) 1 and 2 only

Ans. (c)

End of Solution

Directions: Each of the next (06) items consists of two statements, one labelled as the 'Statement (I)' and the other as 'Statement (II)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) Both statement (I) and statement (II) are individually true and statement (II) is the correct explanation of statement (I).

(b) Both statement (I) and statement (II) are individually true, but statement (II) is not the correct explanation of statement (I).

(c) Statement (I) is true, but Statement (II) is false.

(d) Statement (I) is false, but Statement (II) is true.

10. **Statement (I):** Fluid motion produced due to change in density resulting from the temperature gradients is called free convection.
Statement (II): The movement of fluid in free convection is due to the fact that the fluid particles in the immediate vicinity of the hot object become warmer than the surrounding fluid resulting in a local change of density.

Ans. (a)

End of Solution

11. **Statement (I):** Heat is defined as the form of energy that is transferred between the system and surroundings due to the temperature difference between them.
Statement (II): The temperature difference is the driving force or potential for heat transfer.

Ans. (b)

End of Solution

12. **Statement (I):** The simple air standard cycle analysis cannot predict the variation of thermal efficiency with mixture strength since air is assumed to be the working medium.
Statement (II): Fuel air cycle analysis suggests that the thermal efficiency will deteriorate as the mixture supplied to an engine is enriched.

Ans. (b)

End of Solution

13. **Statement (I):** When three concurrent forces are in equilibrium then each force is inversely proportional to the sine of the angle between the remaining two forces.
Statement (II): The algebraic sum of moments of all forces about any point is equal to the moment of their resultant about that point.

Ans. (d)

End of Solution

14. **Statement (I):** When a material is subjected to a tensile strain, there is a simultaneous shortening of the cross-sectional dimensions perpendicular to the direction of the tensile strain.
Statement (II): The ratio of the shortening strain to the tensile strain is called Poisson's ratio.

Ans. (b)

End of Solution

15. **Statement (I):** Toughness is the ability of a material to absorb applied energy without failure.
Statement (II): The energy absorption value from such tests is often called impact energy or impact resistance.

Ans. (a)

Toughness is generally determined from impact tests. This energy absorbed is also known as impact energy.

End of Solution

16. Which one of the following statements is correct related to PIC16F84 microcontroller?
(a) it is a low-cost 32-bit microcontroller.
(b) It has a built-in ADC, DAC or serial communication capability.
(c) It supports 13 digital I/O lines and serves as a good learning platform.
(d) It is low-cost and has difficulty of programming.

Ans. (c)

PIC16F84

It is an 8-bit microcontroller.

F, indicates flash program memory.

Pic series is from microchip technology company which manufacture microcontrollers.

It has 13 I/O lines i.e. Input / Output lines.

A timer / counter.

It is used in applications like high speed automotive, low power remote sensor, electronic locks, security device and smart cards.

It is a low cost and high performance.

It has only 35 instructions.

End of Solution

17. What is the smallest step size (resolution) of a 4-bit ADC, which has a maximum output voltage of 12 V?
(a) 3.0 V (b) 0.8 V
(c) 4.8 V (d) 8.0 V

Ans. (d)

$$\text{Resolution of ADC} = \frac{\text{Range of output}}{2^n}$$

$$= \frac{12}{2^4} = 0.75 \text{ V}$$

End of Solution

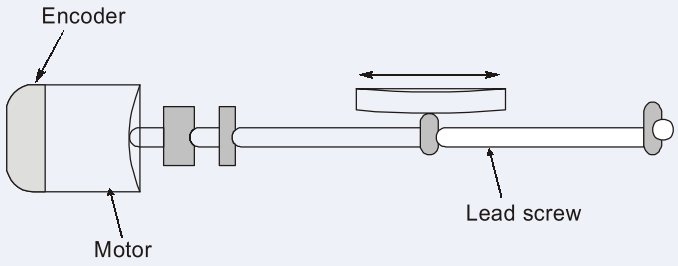
18. Which one of the following effects states that if a wave source and corresponding receiver are moving relative to each other, the frequency observed by the receiver will be greater than or smaller than the actual source frequency?
(a) Doppler effect (b) Piezoelectric effect
(c) Signal conditioning effect (d) Variable capacitance effect

Ans. (a)

Doppler effect refers to the change in wave frequency during the relative motion between a wave source and its observer.

End of Solution

19. A DC motor equipped with an incremental optical encoder is used to drive a lead screw positioning table, as shown in figure. The screw has a lead of 2.54 mm/rev., the encoder disk has 1000 lines, and the encoder is operated in quadrature mode. What is the measurement resolution of this encoder?



(a) 0.335 μm per count
(b) 0.435 μm per count
(c) 0.535 μm per count
(d) 0.635 μm per count

Ans. (d)

Least count of screw = 2.54 mm/rev
i.e. for 1 rev → 2.5 mm
For 1 rev of rotor → 1000 lines
In quadrature mode,

$$\text{Resolution} = \frac{2.54}{1000 \times 4} = 0.635\ \mu\text{m per count}$$

End of Solution

20. The hysteresis of the Schmitt trigger in typical circuit for a Hall-effect digital proximity switch is used to:
(a) increase the sensitivity of the sensor to noise and false triggering.
(b) make constant sensitivity of the sensor to noise and false triggering.
(c) reduce the sensitivity of the sensor to noise and false triggering.
(d) increase the sensitivity of the sensor to noise and true triggering.

Ans. (c)

We use hysterisis of Schmitt trigger it can make noise frequency insensitive by reducing it.

End of Solution

21. In stepper motors, which one of the following features eliminates the need for brushes and a commutator?
(a) It works without the need for a position sensor.
(b) There are no wires connected to the rotor.
(c) It does not generate large torque at low speed.
(d) It uses gears only

Ans. (a)

In stepper motors, no wires are connected to rotor rather than it is controlled by changing magnetic field in stator poles.

End of Solution

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22. Which of the following types of transducers are also known as externally powered transducers?

(a) Self-generating transducers
(b) Passive transducers
(c) Active transducers
(d) Differential transducers

Ans. (b)

Passive transducer: It is a measurement system whose output energy is supplied entirely or almost entirely by its input signal. Passive transducers are also known as externally powered transducers. Some examples are resistive, inductive, capacitive transducers.

End of Solution

23. Consider the following statements:

1. A multi-robot system whose dynamics are written is observable if and only if it is controllable.
2. Duality principle can be invoked to show that a multi-robot system is controllable if and only if it is observable.

Which of the above statements is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Ans. (b)

In multi-robot system according to principle of duality if a system is observable, then the system will be controllable, hence statement 1 becomes wrong.

End of Solution

24. Which of the following are used in material handling systems for moving raw materials or partly finished goods from one workstation to another within a manufacturing system facility?

(a) Stationary robots
(b) Mobile robots
(c) Automated guided vehicles
(d) Robotic arms

Ans. (c)

AGV: Automated guided vehicles are driverless vehicles which are used in material handling for moving raw materials or partly finished goods from one workstation to another.

End of Solution

25. Consider the following statements:

1. At the velocity level, the Manipulator Jacobian relates joint velocities to end effector velocities.
2. The Manipulator Jacobian is important in motion planning and for identifying singularities.

Which of the above statements is/are correct?

(a) 1 only
(b) 2 only
(c) Both 1 and 2
(d) Neither 1 nor 2

Ans. (c)

Jacobian is a matrix which provides relation between joint velocities and end effector velocities ($\dot{X}$) of robot manipulator

$$\dot{X} = J\dot{g} \text{ where } \dot{g} = \text{Joint velocities}$$

The manipulator Jacobian is important in motion planning and identifying singularities. A singularity occurs when the joint velocity in joint space becomes infinite to maintain Cartesian velocity.

End of Solution

26. A robotic arm made from steel has a length of 1.524 m, a breadth of 0.102 m, and a height of 0.1524 m. The payload is 444.82 kg. The density of steel, ρ, is 7.87 kg m^{-3} and its Young's modulus, E, is 206.85 GPa. What is the deflection of the robotic arm due to the payload and the robotic link mass? (Consider moment of the inertia of the arm, I, is 3×10^{-5} m^4, g = 9.81 m/s^2, and the robotic link mass is 1200 kg/m^{-1})

(a) 170 μm (b) 180 μm

(c) 190 μm (d) 200 μm

Ans. (a)

Given: $I = 3 \times 10^{-5}$ m^4

Robotic link mass, $W = 1200$ kg/m

$$\delta = \frac{PL^3}{3EI} + \frac{WL^3}{8EI} = \frac{L^3}{EI}(P + W)$$

$$= \frac{1.524^3}{206.85 \times 10^9 \times 3 \times 10^{-5}}$$

$$= 5.7 \times 10^{-7} (148.3 + 150) = 170 \text{ μm}$$

End of Solution

27. Consider the following statements:

1. Robots are normally controlled using microcomputers or microcontrollers.
2. The output from a robot needs to be transformed into usable forms using actuators.

Which of the above statements is/are correct?

(a) 1 only (b) 2 only

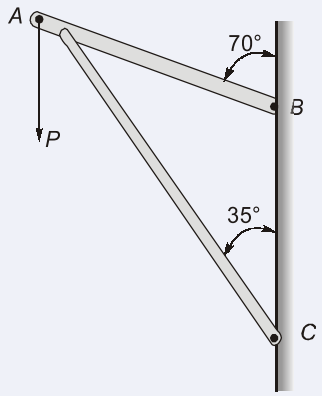
(c) Both 1 and 2 (d) Neither 1 nor 2

Ans. (c)

Both statements are correct.

End of Solution

28. In the frame as shown in figure, an external force P is applied at joint A. Which one of the equations is correct by using law of sines?



(a) $\frac{P}{\sin 55^\circ} = \frac{P_{AC}}{\sin 35^\circ} = \frac{P_{AB}}{\sin 110^\circ}$

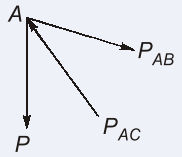
(b) $\frac{P}{\sin 110^\circ} = \frac{P_{AB}}{\sin 110^\circ} = \frac{P_{AC}}{\sin 55^\circ}$

(c) $\frac{P}{\sin 35^\circ} = \frac{P_{AB}}{\sin 35^\circ} = \frac{P_{AC}}{\sin 110^\circ}$

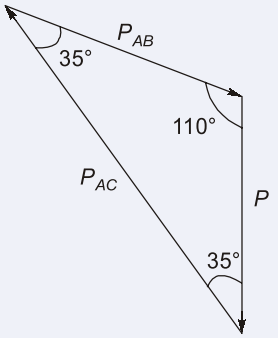
(d) $\frac{P_{AC}}{\sin 55^\circ} = \frac{P_{AB}}{\sin 35^\circ} = \frac{P}{\sin 55^\circ}$

Ans. **(c)**

Considering equilibrium of joint *A*,



Force triangle of the above 3 forces would be



So, according to law of sines,

$$\frac{P}{\sin 35^\circ} = \frac{P_{AB}}{\sin 35^\circ} = \frac{P_{AC}}{\sin 110^\circ}$$

End of Solution

29. Consider the following properties for line loads distributed along a plane curve:
1. The magnitude of the resultant force is equal to the area under the load diagram.
2. The line of action of the resultant force passes through the centroid of the area under the load diagram.
3. The line of action of the resultant force is always vertically upward.

Which of the above properties are correct?

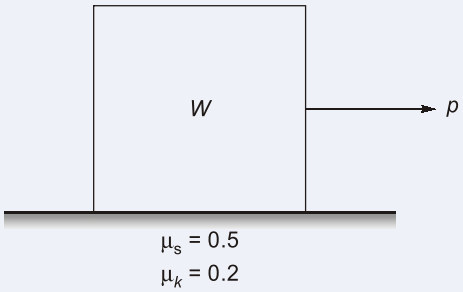
(a) 1 and 2 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans. (a)

Best answer is (a) otherwise statement 1 has also ambiguity.

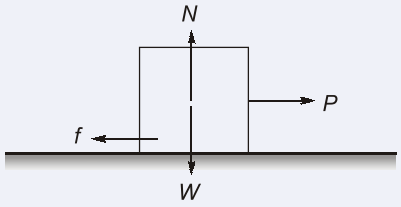
End of Solution

30. The 50-kg block as shown in figure is initially at rest on a horizontal plane. After that P was gradually increased from 0 to 150 N. What is the maximum static friction force?



(a) 490.5 N
(b) 245.25 N
(c) 98.1 N
(d) 25 N

Ans. (b)



Limiting friction force on the block is given by,

$$f_L = \mu_s N = 0.5\,(mg)$$
$$= 0.5 \times 50 \times 9.8 = 245.25 \text{ N}$$

End of Solution

31. What is the minimum leg size for the fillet weld of plate having thickness $\le \frac{1}{2}$ inch?

(a) $\frac{3}{16}$ inch
(b) $\frac{5}{16}$ inch
(c) $\frac{1}{4}$ inch
(d) $\frac{1}{2}$ inch

Ans. **(b)**

Minimum leg size = Minimum throat thickness

$$h = 0.707 \times t = 0.707 \times \frac{1}{2} = 0.3535 \text{ inch}$$

So, $$h = 0.3535 \text{ inch} \approx \frac{5}{16} \text{ inch}$$

End of Solution

32. The fatigue strength reduction factor is given by

(a) $\dfrac{\text{endurance limit of a notch-free specimen}}{\text{endurance limit of a notched specimen}}$

(b) $\dfrac{\text{endurance limit of a notched specimen}}{\text{endurance limit of a notch-free specimen}}$

(c) (endurance limit of a notch-free specimen) × endurance limit of a notched specimen

(d) (endurance limit of a notch-free specimen) + endurance limit of a notched specimen

Ans. **(a)**

Fatigue strength reduction factor (k_f)

$$= \frac{\text{endurance limit of a notch-free specimen}}{\text{endurance limit of a notched specimen}}$$

End of Solution

33. If the estimated actual endurance strength of the material is S_n', the ultimate tensile strength is S_u, the mean stress is σ_m and the alternating stress is σ_a, the equation for the Goodman line is

(a) $\dfrac{\sigma_a}{S_n'} \times \dfrac{S_u}{\sigma_m} = 1$

(b) $\dfrac{\sigma_a}{S_n'} \times \dfrac{\sigma_m}{S_u} = 1$

(c) $\dfrac{\sigma_a}{S_n'} + \dfrac{\sigma_m}{S_u} = 1$

(d) $\dfrac{\sigma_a}{S_n'} + \dfrac{S_u}{\sigma_m} = 1$

Ans. **(c)**

Equation for Goodman line

$$\frac{\sigma_a}{S_n'} + \frac{\sigma_m}{S_u} = 1$$

End of Solution

34. According to the type of stress employed, which one of the following metal forming processes is classified under combined tension and compression type?
(a) Extrusion (b) Rolling
(c) Forging (d) Deep drawing

Ans. (d)

End of Solution

35. In rolled products, which one of the following is generally 5 mm or thicker and is 1.0 or 1.25 m in width and 2.5 m in length?
(a) Foil (b) Slab
(c) Plate (d) Billet

Ans. (c)
Slab generally has more than 10 mm thickness. If slab is rolled then first it will be converted into plate and then into sheet. As more than 5 mm thickness is given so generally we will consider it as plate.

End of Solution

36. Which one of the following is mainly a surface crack detection technique which may be applied to all non-porous materials, but only cracks open to the surface can be detected?
(a) Radiographic Testing (b) Liquid Colour Penetrant Testing
(c) Eddy Current Testing (d) Ultrasonic Testing

Ans. (b)

End of Solution

37. Which one of the following NDT methods can be used for detection of internal voids or measuring the thickness of surface coatings?
(a) Ultrasonic Testing (b) Liquid Colour Penetrant Testing
(c) Eddy Current Testing (d) Acoustic Emissions

Ans. (c)

End of Solution

38. Consider the following statements for vibration monitoring of the wind turbines:
1. Position sensors are used for low frequencies.
2. Velocity sensors are used for medium-range frequencies.
3. Accelerometers are used for high frequencies.
Which of the above statements are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

Ans. (d)
All statements are correct.

End of Solution

39. A data set is said to be incomplete if
(a) it contains both failure data and replacement data.
(b) it does not contain both censored data and replacement data.
(c) it does not contain both failure and censored data.
(d) it contains both failure and censored data.

Ans. (d)
A data is an information provided in correct order. There should not be any error or any rectification or censoring of data.

End of Solution

40. Which one of the following is related to the process data such as the production rate, efficiency, resource consumption?
(a) Technical data
(b) Operational data
(c) Maintenance servicing data
(d) Cost data

Ans. (a)

End of Solution

41. Consider the following common failure mechanisms found in gas turbine blades:
1. Mechanical damage
2. High temperature damage
3. Creep failures
Which of the above failure mechanisms are correct?
(a) 1 and 2 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans. (c)
The damage is basically due to thermal stresses and creep failures.

End of Solution

42. Which one of the following is the excess of available time over the activity time when all jobs start as early as possible?
(a) Free float
(b) Total float
(c) Independent float
(d) Interfering float

Ans. (a)
Free float: How much any activity can be delayed shows that the succeeding activity should not be affected.

End of Solution

43. Which one of the following inventories are stocked in the manufacturing plant as a precaution, in case the semi-finished from one machine does not come to the next machine, and this stock is used to continue a production?

(a) Anticipation inventories
(b) Fluctuation inventories
(c) Decoupling inventories
(d) Lot size inventories

Ans. (c)

Decoupling inventories: Inventories are stocked in the manufacturing plant as a precaution, in case the semi-finished goods from one machine does not come to the next machine.

End of Solution

44. Which one of the following consists of those surface irregularities on the part, which are of considerable wavelength of a periodic character?

(a) Lay
(b) Waviness
(c) Roughness
(d) Flaws

Ans. (b)

Roughness is low wavelength irregularities whereas waviness is high wavelength irrgularities.

End of Solution

45. Consider the following circumstances for a random-order FMS:

1. The part family is small.
2. There are substantial variations in part configurations.
3. The production schedule is subject to change from day-to-day.

Which of the above circumstances are correct?

(a) 1 and 2 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans. (c)

Random order FMS involves large part family.

End of Solution

Directions for the following **three (03)** items: Read the following information and answer the **three** items that follow:

In a spring-controlled governor, the controlling force curve is a straight line. The balls are 450 mm apart when the controlling force is 1450 N and 250 mm when it is 750 N. The mass of each ball is 8 kg.

46. What is the speed at which the governor runs when the balls are 300 mm apart?

(a) 65.1 rpm
(b) 185.5 rpm
(c) 265.1 rpm
(d) 320.5 rpm

Ans. (c)

Given: $F_{C1} = 1450$ N at $r = \frac{450}{2} = 225$ mm

F_{C2} = 750 N at $r = \frac{250}{2} = 125$ mm

Mass of each ball = 8 kg

$F_C = ar - b$

$1450 = a \times 225 - b$ ... (i)

$750 = a \times 125 - b$ ... (ii)

From (i) and (ii)

$a = 7$ N/mm

$b = 125$ N

$$F_{C3} = 7 \times \frac{300}{2} - 125 = 925 \text{ N}$$

$$mr\omega^2 = F_C$$

$$\frac{8 \times 0.3 \times \omega^2}{2} = 925$$

$\omega = 27.76$ rad/s

$N = 265.13$ rpm

End of Solution

47. What is the isochronous speed?

(a) 282.47 rpm (b) 398.42 rpm

(c) 433.33 rpm (d) 598.52 rpm

Ans. (a)

At Isochronism

$b = 0$

$F_C = 7r$

$8 \times r \times \omega^2 = 7 \times r \times 10^3$

$\omega = 29.58$ rad/s

$N = 282.47$ rpm

End of Solution

48. What is the initial tension to be increased to make the governor isochronous?

(a) 75 N (b) 125 N

(c) 285 N (d) 360 N

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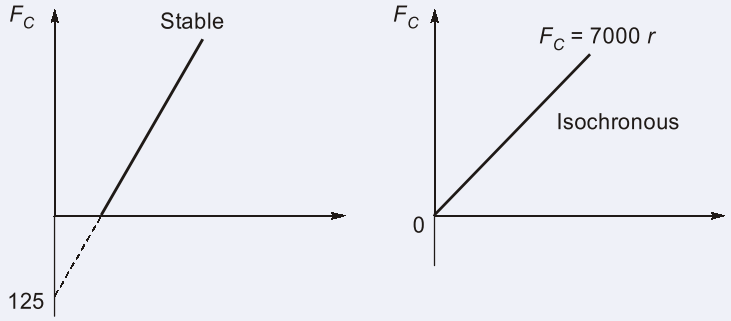
Ans. (b)

Here: From above question data

$a = 7000$, $b = -125$

$F_C = [(7000)r - 125]$



So, initial tension to be increased to make the governor isochorous is equal to 125 N.

End of Solution

Directions for the following **two (02)** items: Read the following information and answer the **two** items that follow:

The mass of a turbine rotor of a ship is 8000 kg and has a radius of gyration of 0.75 m. It rotates at 1800 rpm clockwise when viewed from the stern.

49. What is the gyroscopic couple if the ship travelling at 100 km/h steers to the left along a curve of 80 m radius?

(a) 125654 Nm (b) 195785 Nm

(c) 225785 Nm (d) 294531 Nm

Ans. (d)

Given: Mass of turbine rotor = 8000 kg,

Radius of gyration, $k = 0.75$ m

Speed, $N = 1800$ rpm

$$\omega = \frac{2\pi \times 1800}{60} = 188.49 \text{ rad/s}$$

Angular velocity of precision, $\omega_p = \frac{V}{R} = \frac{100 \times 5}{80 \times 18} = 0.34$ rad/s

$$C = I\omega\omega_p$$
$$= 8000 \times 0.75^2 \times 188.49 \times 0.34$$
$$= 294515.63 \text{ Nm}$$

End of Solution

50. What is the gyroscopic couple if the ship is pitching and the bow is descending with maximum velocity? (Take the pitching is with simple harmonic motion with periodic time of 20 sec and the total angular movement between extreme positions is 10°)

(a) 25654 Nm (b) 32568 Nm

(c) 46510 Nm (d) 52565 Nm

Ans. (a)

Given; Angular amplitude, $\theta_o = \frac{10°}{2} = 5°$

Time of pitching, $t = 20s$

SHM equation: $\theta = \theta_o \sin\omega t$

$$\omega_p = \frac{d\theta}{dt} = \theta_0\omega_n \cos\omega_n t = 5 \times \frac{\pi}{180} \times \frac{2\pi}{20} \cos\frac{2\pi t}{20}$$

$$= 0.0274 \cos 0.31t$$

$$(\omega_p)_{max} = 0.0274 \text{ rad/s}$$

$$C = I\omega\omega_p$$

$$= 8000 \times 0.75^2 \times 188.49 \times 0.0274$$

$$= 23240.01 \text{ Nm}$$

End of Solution

51. A petrol engine 100 mm in diameter and 120 mm stroke has a connecting rod 250 mm long. The piston has a mass of 1 kg and the speed is 1800 rpm. The gas pressure is 0.5 MPa at 30° from top dead centre during the explosion stroke. What is the force on piston due to gas pressure?

(a) 1927 N (b) 2927 N
(c) 3927 N (d) 4927 N

Ans. (c)

Given: Bore diameter, $d = 100$ mm

$$\text{Crank length, } r = \frac{120}{2} = 60 \text{ mm}$$

Gas pressure, $P = 0.5$ MPa

$$F_{gas} = P \times \frac{\pi}{4} \times d^2 = 0.5 \times \frac{\pi}{4} \times 100^2$$

$$= 3926.99 \text{ N}$$

End of Solution

52. Contact stress for spur gears is proportional to:

(a) Elastic coefficient (C_P) (b) Face width (F)
(c) Pinion diameter (D_P) (d) Geometry factor for bending stress (J)

Ans. (a)

Elastic coefficient (C_P)

End of Solution

53. The relationship between load, P and life, L, for rolling contact bearings can be stated as $\frac{L_2}{L_1}=\left(\frac{P_1}{P_2}\right)^k$. What is the value of k for the roller bearing for this relation?

(a) 2.33 (b) 3.33
(c) 1.25 (d) 2.52

Ans. (b)

$$\frac{L_2}{L_1}=\left(\frac{P_1}{P_2}\right)^k$$

k = For ball bearing

$= \frac{10}{3}$ for roller bearing

End of Solution

54. In static load analysis, the difference between a dynamic loading situation and a static one is
(a) the presence or absence of accelerations
(b) the presence or absence of velocities
(c) the presence or absence of moments
(d) the presence or absence of external forces

Ans. (a)
When acclerations are present, then load will be dynamic and when accelerations are absent, then load will be static.

End of Solution

55. For dynamic loading, we need to modify the theoretical stress-concentration factor to obtain a fatigue stress-concentration factor based on
(a) the factor of safety of the material to obtain a fatigue stress-concentration factor
(b) the nominal stress to obtain a fatigue stress-concentration factor
(c) the stress-concentration factor for nominal stress to obtain a fatigue stress-concentration factor
(d) the notch sensitivity of the material to obtain a fatigue stress-concentration factor

Ans. (d)
To obtain a fatigue stress concentration factor, we used

$$k_f = 1 + 9\,(k_t - 1)$$

End of Solution

56. For the failure of ductile materials under static loading, which of the failure theories is more accurate?
(a) The maximum normal-stress theory
(b) The maximum normal-strain theory
(c) The distortion-energy theory
(d) The total strain-energy theory

Ans. (c)

End of Solution

57. Based on the maximum shear-stress theory, it can be predicted that the relation between the shear yield strength (S_{ys}) and tensile yield strength (S_y) of a ductile material is given by
(a) $S_{ys} = 0.33\ S_y$
(b) $S_{ys} = 0.5\ S_y$
(c) $S_y = 0.5\ S_{ys}$
(d) $S_{ys} = 0.66\ S_y$

Ans. (b)

End of Solution

58. Consider the following parameters involved in the rating of clutches and brakes:
1. Torque required to accelerate or decelerate the system
2. Time required to accomplish the speed change
3. The cycling rate is the number of on/off cycles per unit time.
Which of the above parameters are applicable for the rating of clutches and brakes?
(a) 1 and 2 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans. (a)

End of Solution

59. An annular plate-type brake has the area of the friction surface of 20 in^2 and the frictional power absorbed about 2 hp. The wear rating is
(a) 0.1 hp/in^2
(b) 0.2 hp/in^2
(c) 0.3 hp/in^2
(d) 0.4 hp/in^2

Ans. (a)

$$\text{Wear rating} = \frac{\text{Frictional power absorbed}}{\text{Area of friction surface}}$$

$$= \frac{2}{20} = 0.1\ hp/in^2$$

End of Solution

60. A set of three bolts is to be used to provide a clamping force of 4000 N between two components of a machine. If the allowable stress is 800 N/mm^2, what is the required tensile stress area (A_t) for the bolt?

(a) 0.2 mm^2 (b) 0.5 mm^2
(c) 5 mm^2 (d) 20 mm^2

Ans. (c)

Total clamping force = 4000 N

$$\text{From on one bolt} = \frac{4000}{3}\text{N}$$

So, Using strength critieria

$$\frac{\frac{4000}{3}}{A} \le 800$$

$$A \ge 1.66 \text{ mm}^2$$

End of Solution

61. What is the interplanar spacing when an X-ray beam of wavelength 1.54 Å is directed towards the crystal at an angle of 30° to be atomic plane?

(a) 1.54 Å (b) 3.08 Å
(c) 4.62 Å (d) 6.16 Å

Ans. (a)

Given:Order of reflection, $n = 1$

Angle, $\theta = 30°$

Since, $n\lambda = 2d\sin 30°$

$1.54 = 2d\sin 30°$

$$d = \frac{1.54}{2\times\left(\frac{1}{2}\right)} = 1.54\text{Å}$$

End of Solution

62. Which of the following is/are main ingredients of Portland cement?

(a) Sodium silicate only (b) Tri-calcium phosphate only
(c) Bi-calcium phosphate only (d) Dicalcium silicate and Tri-calcium silicate

Ans. (d)

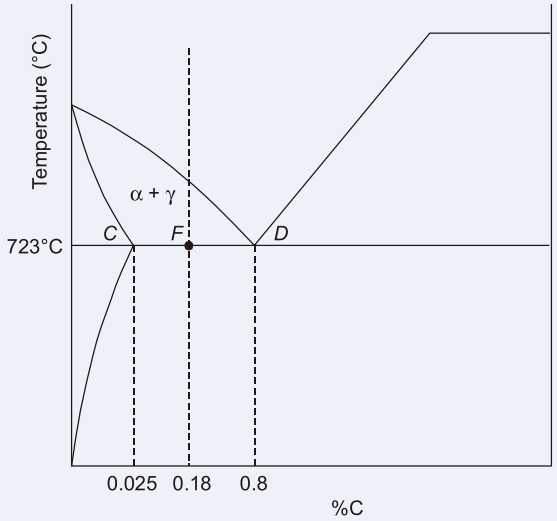
Portland cement consists of tri and dicalcium silicate, tricalcium aluminate, tetracalcium alumino ferrite and calcium sulphate as gypsum.

End of Solution

63. What is the fraction of Proeutectoid ferrite in 0.18 percent steel assuming that eutectoid reaction takes place at 0.8 percent carbon?

(a) 0.3 (b) 0.5
(c) 0.8 (d) 0.9

Ans. (c)



$$\text{Fraction of proeutectoid ferrite} = \frac{FD}{CD} = \frac{0.8 - 0.18}{0.8 - 0.025}$$

$$= \frac{0.62}{0.775} = 0.8$$

End of Solution

64. Oxidation loss on the copper surface is 0.05 mm in 15 h. How much will be the loss in 225 h?

(a) 0.194 mm (b) 0.394 mm
(c) 0.594 mm (d) 0.794 mm

Ans. (a)

Copper follows parabolic law of corrosion

$$X = A_P \times \sqrt{t}$$

where, A_P = constant; t = time; X = thickness of oxidation film

In 15 hr: $X_1 = 0.05 = A_P\sqrt{15}$ ... (i)

In 225 hr: $X_2 = A_P\sqrt{225}$ ... (ii)

(ii) divided by (i)

$$\frac{X_2}{0.05} = \sqrt{\frac{225}{15}} = \sqrt{15}$$

$$X_2 = 0.194 \text{ mm}$$

End of Solution

65. What is the thermal shock resistance R of a steel body with
$\alpha = 12 \times 10^{-6}/°C$, $K = 80$ W/mK,
$\sigma_{ut} = 650$ N/mm^2, $E_t = 200000$ N/mm^2?
(Where α is the coefficient of thermal expansion, K is thermal conductivity, σ_{ut} is the ultimate tensile strength of the material, E_t is the Young's modulus of the material in tension)

(a) 10.549×10^3 W/m
(b) 21.667×10^3 W/m
(c) 32.856×10^3 W/m
(d) 41.256×10^3 W/m

Ans. (b)

Given: $\alpha = 12 \times 10^{-6}/°C$

$k = 80$ W/mK

$\sigma_{ut} = 650$ N/m^2, $E_t = 2 \times 10^5$ N/mm^2

Thermal shock resistance $(R) = \dfrac{k \times \sigma_{ut}}{\alpha \times E_t}$

$$R = \frac{80 \times 650}{12 \times 10^{-6} \times 2 \times 10^5} = 21.667 \times 10^3 \text{ W/m}$$

End of Solution

66. Which one of the following stainless steels is used in automobile exhaust components, valves and combustion chamber?

(a) Ferritic stainless steel
(b) Martensitic stainless steel
(c) Austenitic stainless steel
(d) Invar steel

Ans. (a)

Vehicle exhaust systems perform the essential function of removing harmful exhaust fumes such as CO_2, NO, HC, P, SO_2 and Pb from vehicle engines. The materials used in the exhaust system must be resistant to high-temperature oxidation, thermomechanical vibration, external salt corrosion, and internal acid/base corrosion. Ferritic stainless steel are the best choice considering all aspects of the exhaust or flue gases emitted due to fuel combustion such as petrol, diesel or fuel oil. The desired end goal is high strength at high temperatures, plus greater resistance to oxidation and corrosion while meeting the relevant social and economic targets.

End of Solution

67. Consider the following statements regarding super alloys for high temperature applications:

1. In iron-nickel super alloys, the composition is 15 percent Cr, 20-40 percent Ni, remainder is iron, and the two alloys, discalloy and **incoloy** are nickel-based alloys.
2. Vitallium is a vanadium-based super alloy.
3. Nickel-based alloys are best creep-resistant alloys.

Which of the above statements are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans. (c)

Fe-Ni super alloys are used in engine casings, blades, discs that need low thermal expansion and composition given statement is correct. Similarly, Ni based superalloys are used for creep resistance applications. Hence, statement '3' is correct. Vitallium is a cobalt based super alloy having 65% Co-30% Cr and 5% Mo. Thus, statement '2' is incorrect.

End of Solution

68. Plain carbon steels in which carbon percentage is less than 0.8 wt% are caled

(a) Hypoeutectoid steels
(b) Eutectoid steels
(c) Proeutectoid steels
(d) Austenite steels

Ans. (a)

End of Solution

69. Which one of the following is a Gibbs phase rule? (where P is the number of phase's presents, F is the number of degrees of freedom, C is the number of components and N is the number of non-compositional variables)

(a) P + F = C + N
(b) P – F = C + N
(c) P + F = C – N
(d) P + N = C + F

Ans. (a)

End of Solution

70. A bicycle and rider of mass 120 kg are travelling at a speed of 15 km/h on a level road. The rider applies brake to the rear wheel that is 0.9 m in diameter. The pressure applied on the brake is 100 N and coefficient of friction between the brake and the cycle rim is 0.05. Assume that no other resistance is acting on the bicycle. How far does the bicycle travel before it comes to rest?

(a) 85.36 m
(b) 107.36 m
(c) 208.33 m
(d) 307.36 m

Ans. (c)

Frictional force acting on the cycle rim,

$$f = \mu N = 0.05 \times 100 = 5 \text{ N}$$

Deceleration of the bicycle,

$$a = \frac{f}{M} = -\frac{5}{120} = -0.0416 \text{ m/s}^2$$

Using 3rd equation of kinematics,

$$v^2 = u^2 + 2as$$

$$a = \left(15 \times \frac{5}{18}\right)^2 - 2 \times 0.0416s$$

$$s = \frac{17.36}{0.0832} = 208.65 \text{ m}$$

End of Solution

71. The reduction of speed from 360 rpm to 120 rpm is desired by the use of a chain drive. The driving sprocket has 18 teeth. What is the number of teeth on the driven sprocket?
(a) 34 (b) 44
(c) 54 (d) 64

Ans. (b)

Given: Speed of driving sprocket, $N_1 = 360$ rpm
Speed of driven sprocket, $N_2 = 120$ rpm
Teeth on driving sprocket, $T_1 = 18$

$$N_1T_1 = N_2T_2$$
$$360 \times 18 = 120 \times T_2$$
$$T_2 = 54$$

End of Solution

72. Which one of the following types of cams has either a convex or a concave surface?
(a) Conjugate cam (b) Spherical cam
(c) Globoidal cam (d) Spiral cam

Ans. (c)

End of Solution

73. A spring-mass system consists of a spring of stiffness 350 N/m. The mass is 0.35 kg. The mass is displaced 20 mm beyond the equilibrium position and released. The damping coefficient is 14 N.s/m. What is the undamped natural frequency for the system?
(a) 15.62 rad/s (b) 31.62 rad/s
(c) 61.62 rad/s (d) 81.62 rad/s

Ans. (b)

Given: Stiffness of spring, $k = 350$ N/m
Mass, $m = 0.35$ kg

Undamped natural frequency, $\omega_n = \sqrt{\frac{350}{0.35}} = 31.62$ rad/s

End of Solution

74. Which one of the following methods/ principles makes use of the fact that the maximum kinetic energy in a vibrating system is equal to the maximum potential energy in a free longitudinal vibrations system?
(a) Equilibrium method (b) Rayleigh's method
(c) Energy method (d) D'Alembert's principle

Ans. (b)

End of Solution

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75. The distance between two parallel shafts connected by Oldham's coupling is 25 mm. The driving shaft revolves at 240 rpm. What is the maximum velocity of sliding?

(a) 0.628 m/s (b) 0.725 m/s
(c) 0.859 m/s (d) 0.926 m/s

Ans. **(a)**

Given: Speed of driving shaft, $N = 240$ rpm

Distance between shafts, $d = 25$ mm

$$(V_{max})_{sliding} = \omega d$$

$$= \frac{2\pi \times 240}{60} \times 0.025 = 0.628 \text{ m/s}$$

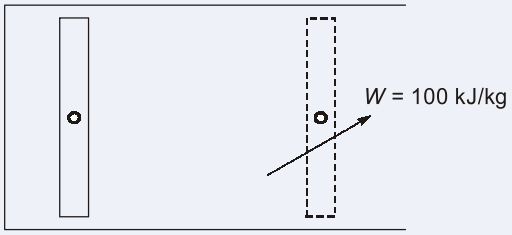
End of Solution

76. In the cylinder of an air motor, the compressed air has a specific internal energy of 420 kJ/kg at the beginning of the expansion and a specific internal energy of 200 kJ/kg after expansion. What is the heat flow to or from the cylinder when the work done by the air during the expansion is 100 kJ/kg?

(a) –120 kJ/kg (b) +200 kJ/kg
(c) –80 kJ/kg (d) +100 kJ/kg

Ans. **(a)**

Given: $u_1 = 400$ kJ/kg, $u_2 = 200$ kJ/kg



From first law, $Q = \Delta u + W$

$Q = (200 - 420) + 100 = -120$ kJ/kg

End of Solution

77. In the turbine of a gas turbine unit the gases flow through the turbine at 17 kg/s and the power developed by the turbine is 14000 kW. The specific enthalpies of the gases at inlet and outlet are 1200 kJ/kg and 360 kJ/kg respectively, and the velocities of the gases at inlet and outlet 60 m/s and 150 m/s respectively. What is the rate at which heat is rejected from the turbine?

(a) –89.5 kW (b) 96.2 kW
(c) –121.5 kW (d) 119.3 kW

Ans. **(d)**

Given: mass flow rate, $\dot{m} = 17$ kg/s

Power developed, $P = 14000$ kW

Enthalpy at inlet, $h_i = 1200$ kJ/kg

Enthalpy at outlet, $h_e = 360$ kJ/kg
Velocity at inlet, $V_i = 60$ m/s
Velocity at exit, $V_e = 60$ m/s

Using SFEE,

$$\dot{m}\left[h_i - h_e + \frac{V_i^2}{2000} + \frac{V_e^2}{2000}\right] - P = -Q$$

$$17\left[1200 - 360 + \frac{60^2}{2000} + \frac{150^2}{2000}\right] - 14000 = -Q$$

$$Q = -119.35 \text{ kW}$$

End of Solution

78. A certain perfect gas of mass 0.01 kg occupies a volume of 0.003 m^3 at a pressure of 7 bar and a temperature of 131°C. The gas is allowed to expand until the pressure is 1 bar and the final volume is 0.02 m^3. What is the molar mass of the gas? (Take universal gas constant as 8314.5 J/K. kmol)

(a) 8 kg/kmol (b) 10 kg/kmol
(c) 12 kg/kmol (d) 16 kg/kmol

Ans. (d)

Given: Mass of gas, $m = 0.01$ kg
Volume, $V = 0.003$ m^3
Initial pressure, $P_1 = 7$ bar
Initial temperature, $T = 131°C$

Universal gas constant, $\bar{R} = 8314.5$ J/K kmol

$$PV = RT$$

$$7 \times 10^5 \times 0.003 = \frac{0.01}{M} \times 8314.5 \times (273 + 131)$$

$$M = 15.99 \text{ kg/kmol}$$

End of Solution

79. What is the highest possible theoretical efficiency of a heat engine operating with a hot reservoir of furnace gases at 2000°C when the cooling water available is at 10°C?

(a) 47.37% (b) 57.37%
(c) 77.54% (d) 87.54%

Ans. (d)

Given: Temperature of hot reservoir, $T_H = 2273$ K
Temperature of cooling water, $T_L = 283$ K

$$\eta = 1 - \frac{283}{2273} = 0.8754$$

End of Solution

80. What is the compression ratio of the Otto cycle for a petrol engine with a cylinder bore of 50 mm, a stroke of 75 mm, and clearance volume of 21.3 cm^3?

(a) 4.9 (b) 5.9

(c) 6.9 (d) 7.9

Ans. (d)

Given: Bore diameter, d = 50 mm

Stroke length, l = 75 mm

Clearance volume, V_c = 21.3 cm^3

$$\text{Swept volume, } V_s = \frac{\pi}{4} \times 5^2 \times 7.5 = 147.26 \text{ cm}^3$$

$$r = 1 + \frac{147.26}{21.3} = 7.91$$

End of Solution

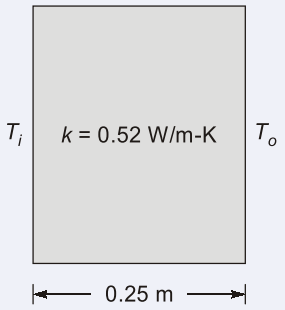
81. The inner surface of a plane brick wall is at 40°C, the outer surface is at 20°C, the wall is 250 mm thick and the thermal conductivity of the brick is 0.52 W/mK. What is the rate of heat transfer per unit area of wall surface?

(a) 24.9 W/m^2 (b) 34.9 W/m^2

(c) 41.6 W/m^2 (d) 51.6 W/m^2

Ans. (c)

Given: T_i = 40°C, T_o = 20°C, L = 250 mm = 0.25 m, k = 0.52 W/m-K



$$q = \frac{\Delta T}{R_{th}} = \frac{\Delta T}{\frac{L}{kA}} = \frac{kA\Delta T}{L}$$

$$\therefore \quad \frac{q}{A} = q'' = \frac{(\Delta T)k}{L} = \frac{(40-20)\times 0.52}{0.25}$$

$$\therefore \quad q'' = 41.6 \text{ W/m}^2$$

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follows:

Hot water at 98°C flows through a 2-in schedule 40 horizontal steel pipe,

ID = 0.0525 m, OD = 0.06033 m [k = 54 W/m°C] and is exposed to atmospheric air at 20°C. The water velocity is 25 cm/s.

The properties of water at 98°C are

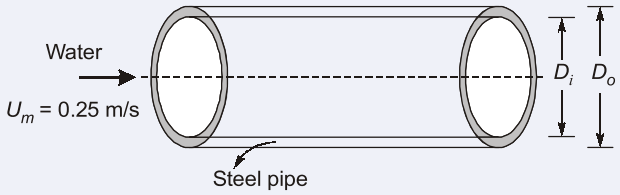
ρ = 960 kg/m^3, μ = 2.82 × 10^{-4} kg/m.s, k = 0.68 W/m°C, Pr = 1.76, Nu = 151.4

82. What is the Reynolds number?

(a) 31340 (b) 44680

(c) 48450 (d) 51230

Ans. (b)



Inner diameter, D_i = 0.0525 m

Outer diameter, D_o = 0.06033 m

ρ = 960 kg/m^3, μ = 2.82 × 10^{-4} kg/m-s, K = 0.68 W/m-°C

Pr = 1.76, Nu = 151.4

$$\text{Reynolds number, Re} = \frac{\rho U_m D_h}{\mu};\ D_h = \text{Hydraullic mean diameter [Here : } D_h = D_i]$$

$$\text{Re} = \frac{960 \times 0.25 \times 0.0525}{2.82 \times 10^{-4}}$$

Re = 44680.85

Alternative

As per given data,

$$\text{Reynolds number} = \frac{\rho V D}{\mu}$$

$$\text{Reynolds number} = \frac{960 \times 0.25 \times 0.0525}{2.82 \times 10^{-4}}$$

Reynolds number = 44680

End of Solution

83. What is the convective heat transfer coefficient at inlet?

(a) 1961 W/m^2°C (b) 1961 W/m^{2}K

(c) 1348 W/m^2°C (d) 1348 W/m^{2}K

Ans. **(b)**

Nusselt number, Nu = 151.4

$$\frac{hD_i}{k} = 151.4$$

$$h = \frac{151.4 \times 0.68}{0.0525}$$

$$h = 1961 \text{ W/m}^2\text{°C}$$

End of Solution

84. Consider the following statements regarding methods of compounding in steam engines:

1. Tandem type compounding of steam engines has the in-line cylinders having pistons mounted on the same piston rod which is further having crosshead and connecting rod providing power output at crankshaft.
2. Woolf compound engine is a cross-type compounding having two cylinders having pistons at 270° phase difference i.e., at some position one cylinder may have piston at inner dead centre and other cylinder has piston at outer dead centre.
3. Receiver compound engine is also a cross compound engine having two cylinders with out of phase pistons and receiver in between.

Which of the above statements are correct?

(a) 1 and 2 only (b) 2 and 3 only

(c) 1 and 3 only (d) 1, 2 and 3

Ans. **(c)**

Methods of compounding in steam engines

(i) Tandem compound engines

(ii) Woolf compound engines

(iii) Receiver compound engines

Woolf compound engine is a cross type compounding having two cylinders have piston on 180° stage difference that is at several positions. One cylinder might have piston at inner dead centre with other cylinder have piston at outer dead centre. So, statement II is wrong.

End of Solution

85. Water at the rate of 68 kg/min is heated from 35 to 75°C by oil having a specific heat of 1.9 kJ/kg°C. The fluids are used in a counter flow double-pipe heat exchanger, and the oil enters the exchanger at 110°C and leaves at 75°C. The overall heat-transfer coefficient is 320 W/m^2°C. What is the total heat transfer? [Take specific heat of water as 4180 J/kgK]

(a) 78.3 kW (b) 189.5 kW

(c) 241.3 kW (d) 280.6 kW

Ans. (b)

Given :

$$\text{Mass of water } (\dot{m}_c) = 68 \text{ kg/min} = \frac{68}{60}\text{kg/s}$$

Inlet temperature of water;

$$(T_c)_i = 35°C$$

Outlet temperature of water;

$$(T_c)_o = 75°C$$

Specific heat of oil; $c_{ph} = 1.9$ kJ/kg°C
$= 1900$ J/kg-°C

Inlet temperature of oil;

$$(T_h)_i = 110°C$$

Outlet temperature of oil;

$$(T_h)_o = 75°C$$

Overall heat-transfer coefficient;

$$U = 320 \text{ W/m}^2\text{-°C}$$

Specific heat of water;

$$c_{pc} = 4180 \text{ J/kg-K}$$

Heat transfer rate:

$$q = \dot{m}_h c_{ph}\left(T_{h_i} - T_{h_o}\right) = \dot{m}_c c_{pc}\left(T_{c_o} - T_{c_i}\right)$$

$$q = \dot{m}_c c_{pc}\left(T_{c_o} - T_{c_i}\right)$$

$$q = \frac{68}{60} \times 4180 \times (75 - 35)$$

$$q = 189.493 \times 10^3 \text{ W}$$

$$q = 189.5 \text{ kW}$$

End of Solution

86. What is the specific volume of steam at 17672 kPa and 712 K considering it as a perfect gas? [Take critical pressure = 22.09 MPa, critical temperature = 647.3 K, $R_{steam} = 0.4615$ kJ/kg.K]

(a) 0.0186 m^3/kg (b) 0.0986 m^3/kg
(c) 0.2146 m^3/kg (d) 0.3146 m^3/kg

Ans. (a)

Given : $P = 17672$ kPA
$T = 712$ K
$R = 0.4615$ kJ/kg.K

Using ideal gas equation,

$$Pv = RT$$

$$v = \frac{RT}{P} = \frac{0.4615 \times 712}{17672}$$

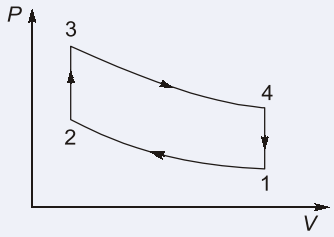
$$v = 0.01859 \text{ m}^3/\text{kg}$$

End of Solution

87. Which type of gas power cycle has limitation of isochoric heat addition and rejection in piston cylinder arrangement?

(a) Carnot cycle
(b) Otto cycle
(c) Diesel cycle
(d) Dual cycle

Ans. (b)



End of Solution

88. Consider the following statements regarding slip and twinning in imperfection in solids:

1. In slip, orientations of the crystal above and below the slip plane will change drastically after deformation, but twinning results in an orientation difference across the twin plane.
2. Slip occurs in discrete multiples of atomic spacing, but in twinning, the atom movements are much less than an atomic distance.
3. Twins can be formed within a time as short as a few microseconds, while for slip there is a delay time of several milliseconds before a slip band is formed.

Which of the above statements are correct?

(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans. (d)

End of Solution

89. Which of the following materials are used for turbine blades in an aircraft engine?

(a) Nickel-based super alloys
(b) Magnesium-Zinc super alloys
(c) Copper-Nickel super alloys
(d) Copper-Tungsten super alloys

Ans. (a)

Turbine blades are made out of Ni-based superalloys, as they possess good high temperature resistance and creep resistance for use in jet engines.

End of Solution

90. Which of the following steels are used for propeller hubs, welded steel propeller blades, engine bolts and nuts, coil springs and valve springs?
(a) Chrome-Vanadium steels
(b) Nickel-Chrome steels
(c) Molybdenum-Nickel steels
(d) Vanadium-Nickel steels

Ans. (b)
Propeller hubs, welded steel propeller blades, engine bolts, nuts, coil springs, valve springs are made of stainless / Ni-Cr steel.

End of Solution

91. Waves are created by the progressive transfer of energy from the wind as it blows over the surface of the water. Once created, waves can travel large distances without much reduction in energy. The energy in a wave is
(a) directly proportional to the height
(b) directly proportional to the height squared
(c) indirectly proportional to the height
(d) indirectly proportional to the height squared

Ans. (b)
Total energy per unit surface area in a wave

$$E = E_P + E_K$$

$$E = \frac{1}{4}\rho g a^2 + \frac{1}{4}\rho g a^2$$

$$= \frac{1}{2}\rho g a^2 \text{ J/m}^2$$ [where 'a' is the height of crest]

So, energy is directly proportional to the square of the height.

End of Solution

92. A fuel cell converts chemical energy of a fuel into electricity
(a) indirectly, with conversion from fuel → heat → electricity
(b) directly, with no intermediate combustion cycle
(c) directly, with conversion from fuel → heat → work → electricity
(d) indirectly, with conversion from fuel → work → electricity

Ans. (b)

End of Solution

93. The efficiency of conversion from chemical energy to electricity by a fuel cell may
(a) theoretically be 100%
(b) practically be 50%
(c) theoretically be 50%
(d) practically be 75%

Ans. (b)

End of Solution

94. A spherical water drop of 1 mm in diameter splits up in air into 64 smaller drops of equal size. The surface tension coefficient of water in air = 0.073 N/m. What is the work required in splitting up the drop?

(a) 0.12×10^{-3} J (b) 0.36×10^{-3} J

(c) 0.69×10^{-6} J (d) 0.89×10^{-3} J

Ans. (c)

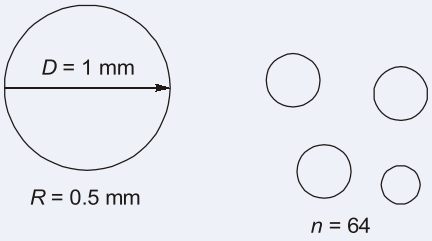
Workdone in splitting the drop is given by,

$$W = \sigma \times 4\pi R^2 [n^{1/3} - 1]$$

$$W = 0.073 \times 4\pi \times (0.5 \times 10\text{–}3)^2[(64)^{1/3} - 1]$$

$$W = 0.69 \times 10^{-6} \text{ J}$$

Alternatively,



$$\text{W.D.} = (\text{Change in surface area})\sigma$$

$$= 0.073\left[n4\pi r^2 - 4\pi R^2\right]$$

$$= 0.073\left[n \times \frac{4\pi R^2}{n^{2/3}} - 4\pi R^2\right]; \qquad r = \frac{R}{n^{1/3}}$$

$$= 0.073\left[4\pi R^2 n^{1/3} - 4\pi R^2\right]$$

$$= 0.0734\pi R^2\left[n^{1/3} - 1\right]$$

$$= 0.073 \times 4\pi\left(0.5 \times 10^{-3}\right)^2\left[(64)^{1/3} - 1\right]$$

$$= 0.69 \times 10^{-6}\text{J}$$

End of Solution

95. What is the intensity of pressure in the ocean at a depth of 1500 m, assuming salt water is incompressible with a specific weight of 10050 N/m^3?

(a) 15.08 MN/m^2 gauge (b) 25.08 MN/m^2 gauge

(c) 32.06 MN/m^2 gauge (d) 42.06 MN/m^2 gauge

Ans. (a)

The intensity of pressure is given by,

$$P = \rho gh = 10050 \times 1500$$

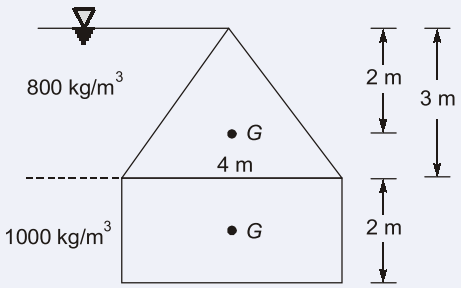
$$= 15.08 \text{ MN/m}^2$$

End of Solution

96. Oil of specific gravity 0.800 acts on a vertical triangular area whose apex is in the oil surface. The triangle is isosceles 3 m high and 4 m wide. A vertical rectangular area 2 m high is attached to the 4 m base of the triangle and is acted upon by water. What is the magnitude of the resultant hydrostatic force on the entire area? (Consider acceleration due to gravity as 9.81 m/s^2)

(a) 184 kN (b) 361 kN
(c) 421 kN (d) 520 kN

Ans. (b)



$S = 0.800$

$\rho = 800 \text{ kg/m}^3$

$\theta = 90°$

$F = [(\text{Given pressure at } C.G. \text{ of triangle}) \times \text{Area}] + [(\text{Given pressure at } C.G. \text{ of rectangle}) \times \text{Area}]$

$$F = \left[(800 \times 9.81 \times 2) \times \frac{1}{2} \times 4 \times 3\right] + \left[(800 \times 9.81 \times 3) + (1000 \times 9.81 \times 1) \times (2 \times 4)\right]$$

$F = 94.176 + 266.832 = 361.008 \text{ kN}$

End of Solution

97. A jet propelled boat with an absolute velocity of 8.7 m/s is moving upstream in a river. The stream is flowing with a velocity of 2.3 m/s. A jet of water is ejected astern at a relative velocity of 18 m/s. If the flow in jet is 1.4 m^3/s, what is the efficiency of the propulsion device?

(a) 38.5% (b) 48.5%
(c) 58.5% (d) 68.5%

Ans. (*)

Efficiency of propulsion is given by,

$$\eta = \frac{2u}{V + 2u}$$

where, u is velocity of boat and V is absolute velocity of Jet.

On substituting the given values, none of the options are matching.

End of Solution

98. Air flow through a duct, and the Pitot-static tube measuring the velocity is attached to a differential manometer containing water. The deflection of the manometer is 100 mm, assuming the density of air is constant and equals to 1.22 kg/m^3, and that the coefficient of the tube is 0.98. What is the air velocity? [Consider acceleration due to gravity as 9.81 m/s^2]

(a) 19.3 m/s (b) 29.3 m/s
(c) 39.3 m/s (d) 49.3 m/s

Ans. (c)

Air velocity in Pitot tube,

$$h = x\left[\frac{\rho_m}{\rho} - 1\right] = 100\left[\frac{1000}{1.22} - 1\right]$$

$$= 81.86 \text{ m}$$

$$\therefore \quad V = C_V \times \sqrt{2gh}$$

$$V = 0.98 \times \sqrt{2 \times 9.81 \times 81.86}$$

$$V = 39.3 \text{ m/s}$$

Alternatively,

$$h = x\left[\frac{\rho_m}{\rho} - 1\right]$$

$$V = C_V \times \sqrt{2gh}$$

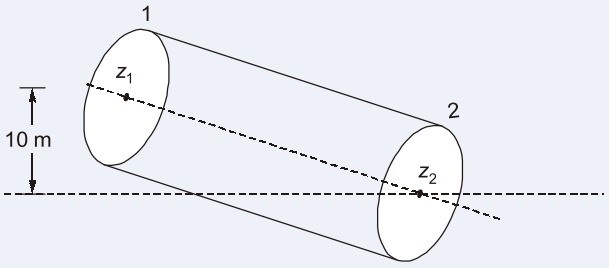
$$V = 39.3 \text{ m/s}$$

End of Solution

99. Water flows in a circular pipe. At one section, the diameter is 0.3 m, the static pressure is 260 kPa gauge, the velocity is 3 m/s and the elevation is 10 m above ground level. The elevation at a section downstream is 0 m, and the pipe diameter is 0.15 m. Frictional effects may be neglected. Assume density of water to be 999 kg/m^3. What is the gauge pressure at the downstream section?
[Consider acceleration due to gravity as 9.81 m/s^2]

(a) 180.25 kPa gauge (b) 290.57 kPa gauge
(c) 320.25 kPa gauge (d) 380.57 kPa gauge

Ans. (b)



Given: $d_1 = 0.3$ m; $d_2 = 0.15$ m
$P_1 = 260$ kPa; $V_1 = 3$ m/s

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Using equation of continuity,

$$A_1V_1 = A_2V_2$$

$$\frac{\pi}{4}\times(0.3)^2\times 3 = \frac{\pi}{4}\times(0.15)^2\times V_2$$

$$V_2 = 12 \text{ m/s}$$

Applying Bernoulli's equation between (1) and (2),

$$\frac{P_1}{\rho g}+\frac{V_1^2}{2g}+z_1 = \frac{P_2}{\rho g}+\frac{V_2^2}{2g}+\cancel{z_2}^{\,0}$$

$$\frac{260\times 10^3}{9810}+\frac{(3)^2}{2\times 9.81}+10 = \frac{P_2}{9810}+\frac{(12)^2}{2\times 9.81}$$

$$\therefore \quad P_2 = 290.57 \text{ kPa}$$

End of Solution

100. Water at 20°C is flowing between a two-dimensional channel in which the top and bottom walls are 1.5 mm apart. If the average velocity is 2 m/s, what is the maximum velocity?

(a) 1 m/s (b) 1.5 m/s
(c) 2 m/s (d) 3 m/s

Ans. (d)

$$\text{Maximum velocity, } V_{max} = \frac{3}{2}V_{avg}$$

$$V_{max} = 1.5 \times 2$$
$$V_{max} = 3 \text{ m/s}$$

End of Solution

101. Air moves over a 10 m long flat plate. The transition from laminar to turbulent flow takes place between Reynolds numbers of 2.5×10^6 and 3.6×10^6. The free stream velocity is 30 m/s and $\nu = 1.5 \times 10^{-5}$ m^2/s. What is the maximum distance from the front edge of the plate along which one expects laminar flow in the boundary layer?

(a) 0.9 m (b) 1.2 m
(c) 1.5 m (d) 1.8 m

Ans. (b)

$$L = 10 \text{ m}, \; U_\infty = 30 \text{ m/s}, \; \nu = 1.5 \times 10^{-5} \text{ m}^2/\text{s}$$

$$\text{Reynolds number} = \frac{U_\infty \cdot x}{\nu}$$

$$2.5 \times 10^6 = \frac{30\times x}{1.5\times 10^{-5}}$$

$$\therefore \quad x = 1.25 \text{ m}$$

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follows:

Air (ρ = 1.23 kg/m^3 and ν = 1.5 × 10^5 m^2/s) is flowing over a flat plate. The free stream speed is 15 m/s at a distance of 1 m from the leading edge.

102. What is the boundary layer thickness for completely laminar flow?

(a) 5.48 mm (b) 7.21 mm

(c) 2.83 mm (d) 8.35 mm

Ans. **(c)**

$$\rho = 1.23 \text{ kg/m}^3$$

$$\nu = 1.5 \times 10^{-5} \text{ m}^2/\text{s}$$

$$U_\infty = 15 \text{ m/s at } x = 1 \text{ m}$$

Reynold's number,

$$3.2 \times 10^5 = \frac{15 \times x}{1.5 \times 10^{-5}}$$

$$\Rightarrow \quad x = 0.32 \text{ m}$$

$$\therefore \quad \delta = \frac{5x}{\sqrt{Re_x}} = \frac{5 \times 0.32}{\sqrt{3.2 \times 10^5}} = 2.83 \text{ mm}$$

End of Solution

103. What is the wall shear stress for completely laminar flow?

(a) 0.101 N/m^2 (b) 1.201 N/m^2

(c) 2.301 N/m^2 (d) 3.401 N/m^2

Ans. **(a)**

For laminar flow,

$$C_{f_x} = \frac{0.664}{\sqrt{Re_x}} = \frac{0.664}{\sqrt{3.2 \times 10^5}}$$

$$C_{f_x} = \frac{0.664}{565.68} = 1.17 \times 10^{-3}$$

$$\therefore \text{ Wall shear stress, } \tau_w = C_{f_x} \times \rho \times \frac{V^2}{2}$$

$$= 1.17 \times 10^{-3} \times 1.23 \times \frac{15^2}{2}$$

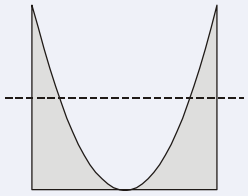
$$= 0.162 \text{ N/m}^2$$

End of Solution

104. A hollow cylinder of 0.6 m diameter, open at the top, contains some liquid and spins about its vertical axis, producing a forced vortex motion. What is the height of the vessel so that the liquid just reaches the top of the vessel and begins to uncover the base at 100 rpm? [Consider acceleration due to gravity as 9.81 m/s^2]

(a) 3.203 m (b) 2.303 m
(c) 1.403 m (d) 0.503 m

Ans. (d)



$$\text{Angular velocity, } \omega = \frac{2\pi N}{60} = \frac{2\pi \times 100}{60}$$

$$\omega = 10.47 \text{ rad/sec}$$

$$\text{Height of parabola, } z = \frac{\omega^2 R^2}{2g} = \frac{10.47^2 \times 0.3^2}{2 \times 9.81}$$

$$z = 0.503 \text{ m}$$

End of Solution

105. The velocity of air at the outer edge of a tornado, where the pressure is 750 mm of Hg and diameter 30 meters, is 12 m/s. Consider the density of air to be constant and equal to 1.2 kg/m^3 (specific gravity of mercury = 13.6). What is the velocity of air at a radius of 2 meters from its axis?

(a) 60 m/s (b) 70 m/s
(c) 80 m/s (d) 90 m/s

Ans. (d)

$$V_1 r_1 = V_2 r_2$$
$$12 \times 15 = 2 \times V_2$$
$$V_2 = 90 \text{ m/s}$$

End of Solution

106. In an impulse steam turbine, steam is accelerated through a nozzle from rest. It enters the nozzle at 9.8 bar dry and saturated. The height of the blade is 10 cm and the nozzle angle is 15°. Mean blade velocity is 144 m/s. The blade velocity ratio is 0.48 and blade velocity coefficient is 0.97. What is the isentropic heat drop?

(a) 28.4 kJ/kg (b) 38.4 kJ/kg
(c) 48.9 kJ/kg (d) 58.9 kJ/kg

Ans. (c)

Given:

Mean blade velocity, $u = 144$ m/s

$$\text{Blade velocity ratio} = \frac{u}{V} = 0.48$$

$$\Rightarrow \quad V = \frac{144}{0.48} = 300 \text{ m/s}$$

$$\text{Actual enthalpy drop} = \frac{V^2}{2000} = \frac{300^2}{2000} = 45 \text{ kJ/kg}$$

$$\text{Nozzle efficiency} = \frac{\text{Actual enthalpy drop}}{\text{Isentropic enthalpy drop}} \quad \ldots(i)$$

In this question nozzle efficiency is missing,
Taking nozzle efficiency $\eta = 0.92$
From (i)

$$\text{Isentropic enthalpy drop} = \frac{45}{0.92} = 48.91 \text{ kJ/kg}$$

End of Solution

107. The principal characteristic of an ash collector is the degree of collection (η) which is given in terms of quantity by

(a) $\dfrac{(G_1 - G_2)}{G_1}$ (b) $\dfrac{(G_1 + G_2)}{G_1}$

(c) $\dfrac{G_1}{(G_1 - G_2)}$ (d) $\dfrac{G_1}{(G_1 + G_2)}$

where G_1 = Quantity of ash entering an ash collector per unit time (kg/s)
G_2 = Quantity of uncollected ash passing through the collector per unit time (kg/s)

Ans. **(a)**

$(G_1 - G_2)$ = Quantity of ash collected
G_1 = Quantity of ash entering
∴ Degree of collection,

$$\eta = \frac{(G_1 - G_2)}{G_1}$$

End of Solution

Directions for the following **four (04)** items:
Read the following information and answer the **four** items that follows:
In a condenser test, the following observations were made:
Vacuum = 720 mm of mercury;
Barometer = 765 mm of mercury;
Mean temperature of condensation = 34°C;
Hot well temperature = 29°C;
Inlet temperature of cooling water = 15°C;
Outlet temperature of cooling water = 25°C;
Absolute pressure of steam at 34°C is 0.0533 bar.
Take 760 mm of Hg = 1.013 bar.

108. What is the vacuum corrected to standard barometer of 760 mm?

(a) 348 mm of Hg (b) 424 mm of Hg
(c) 715 mm of Hg (d) 804 mm of Hg

Ans. **(c)**

Given :Vacuum pressure = 720 mm of Hg
Barometric pressure = 765 mm of Hg
∴ Vacuum corrected to standard barometer of 760 mm = 760 – (765 – 720)
= 715 mm of Hg

End of Solution

109. What is the under cooling efficiency?

(a) 45.36 (b) 53.31
(c) 84.36 (d) 99.31

Ans. **(d)**

Under cooling efficiency,

$$\eta_V = \frac{\text{Actual vacuum}}{\text{Barometric pressure} - \text{Absolute pressure of steam}}$$

$$= \frac{720}{765 - 39.99} \qquad (\because \ 0.0533 \text{ bar} = 39.99 \text{ mm of Hg})$$

$$= 0.9931 = 99.31\%$$

End of Solution

110. What is the under cooling of condenser?

(a) 2°C (b) 3°C
(c) 4°C (d) 5°C

Ans. **(d)**

Under cooling of condenser = Mean temperature of condensation – Hot well temperature
= (34 – 29)°C = 5°C

End of Solution

111. What is the condenser pressure?

(a) 0.03 bar (b) 0.04 bar
(c) 0.05 bar (d) 0.06 bar

Ans. **(d)**

Absolute pressure, P_{abs} = (765 – 720)
= 45 mm of Hg
Absolute pressure inside the condenser = 45 mm of Hg
∴ 45 mm of Hg = 0.06 bar

End of Solution

112. Consider the following statements related to Pyranometer:

1. Pyranometer is used to measure global (direct and diffuse) solar radiation on a surface.
2. This instrument cannot be used to measure the diffuse radiation by blocking out the direct radiation with a shadow band.

Which of the above statements is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

Ans. (a)

End of Solution

113. Most of the reflection occurs from clouds, with a small proportion from the Earth's surface. This reflectance is called

(a) Scattering (b) Greenhouse effect
(c) Albedo (d) Climate change

Ans. (c)

End of Solution

114. What is the amount of solar heat that comes through a south-facing window (single pane) for January (70% sunshine)? (Consider vertical window, dimensions of 1.2 m × 2.5 m, single pane, transmission = 90%, area = 3 m^2 and insolation for January is 6 kWh/m^2 per clear day)

(a) 300 kWh (b) 351 kWh
(c) 400 kWh (d) 451 kWh

Ans. (b)

Solar energy coming through window for a day in January

$$= \left(\frac{6kWhr}{m^2} \times 0.70\right) \times 3m^2 \times 0.9$$

$$= 11.34 \text{ kWhr}$$

For January month = 11.34 × 31 = 351.54 kWh

End of Solution

115. The temperature difference between absorber plate and outdoor air is –10°C, and then the flat-plate collector efficiency is higher for

(a) one pane (b) two panes
(c) three panes (d) more than three panes

Ans. (a)

End of Solution

116. The Hottel-Whillier-Bliss, equation, expresses the useful heat collected, Q, per unit area, in terms of two operating variables, the incident solar radiation normal to the collector plate, G_C, and the temperature difference between the mean temperature of the heat-removal fluid in the collector, T_m, transmittance-absorptance product ($\tau\alpha$) and the surrounding air temperature, T_a, as follows:

(a) $F[(\tau\alpha)G_C + U(T_m - T_a)]$ (b) $F[(\tau\alpha)G_C - U(T_m + T_a)]$

(c) $F[(\tau\alpha)G_C - U(T_m - T_a)]$ (d) $F[(\tau\alpha)G_C + U(T_a - T_m)]$

Ans. (c)

End of Solution

117. What is the heat stored in 5 m^3 of water, if specific heat is 4.19 kJ/(kg°C), temperature final = 26°C, temperature initial = 18°C?

(a) 67.6×10^3 kJ (b) 147.6×10^3 kJ

(c) 167.6×10^3 kJ (d) 47.6×10^3 kJ

Ans. (c)

Given, Volume of water, $V = 5\ m^3$

Specific heat, $c = 4.19$ kJ/kg°C

Final temperature, $T_f = 26°C$

Initial temperature, $T_i = 18°C$

Mass of water,

$m = \rho V$ where, density of water, $\rho = 1000\ kg/m^3$

$\therefore$ $m = 1000 \times 5 = 5000$ kg

Thus, heat stored is

$Q = mc\Delta T$

$= 5000 \times 4.19 \times (26 - 18)$

$= 167600\ kJ = 167.6 \times 10^3\ kJ$

End of Solution

118. Thermal comfort depends on environmental and physiological factors. Which one of the following is representing the physiological factor?

(a) Air temperature (dry bulb) (b) Relative humidity

(c) Radiation (d) Amount of clothing (insulation)

Ans. (d)

Amount of clothing (insulation)

End of Solution

119. What is the approximate value of the energy output for a 0.5 kW PV system for Amarillo, Texas, for the month of January if the system is as follows : BP solar, crystalline silicon, 225-W module, 1.65 m × 1 m, area = 1.65 m^2, array of two modules tilted at latitude? [Consider the Amarillo data; January average day = 4.9 kWh/m^2/day, E_s = 70%, E_C = 17%]

(a) 60 kWh (b) 50 kWh

(c) 40 kWh (d) 30 kWh

Ans. (d)

$$\text{Energy output} = E_S E_C \text{ (energy output per day)} \times \text{Area} \times \text{Number of days}$$
$$= 0.7 \times 0.17 \times 4.9 \times 1.65 \times 31$$
$$= 29.82 \text{ kWh}$$
$$\simeq 30 \text{ kWh}$$

End of Solution

120. What is the annual energy production (AEP) for a 3-MW wind turbine in a class 4 wind regime? (Take class 4 in a good wind regime, Capacity Factor = 40%)

(a) 8512 MWh/yr (b) 9512 MWh/yr
(c) 10512 MWh/yr (d) 11512 MWh/yr

Ans. (c)

$$\text{AEP} = 3MJ/s \times \frac{3600s}{hour} \times \left(24 \times 365 \frac{hour}{year}\right) \times 0.40$$

$$\text{AEP} = 37843200 \frac{MJ}{year} = 37843200 \times \frac{MJ}{s} \times \frac{s}{year}$$

$$= 37843200MW \times \frac{3600^{-1} hr}{year}$$

$$= \frac{37843200}{3600} \frac{MW\text{-}hr}{\text{year}} = 10512 \frac{MW\text{-}hr}{\text{year}}$$

End of Solution

121. During a trial on single acting single stage compression the following obervations are made:

Dimensions of cylinder : 10 cm bore and 8 cm stroke,

Speed of rotation : 500 rpm,

Barometer reading : 76 cm Hg

Atmospheric temperature : 27°C

Delivery air temperature = 130°C,

Free air delivery = 15 m^3/hr

Spring balance of dynamometer type (electric motor) reading : 10 kg

Radius of arm of spring balance : 30 cm

Take mechanical efficiency = 0.90.

What is the volumetric efficiency of the compressor?

(a) 38.49% (b) 52.56%
(c) 63.84% (d) 79.62%

Ans. (d)

Actual volume entered = Free air delivered

$$= \frac{15}{3600}\ m^3/s$$

Theoretical swept volume,

$$V_s = \frac{\pi}{4} \times (0.1)^2 \times (0.08) \times \frac{500}{60}$$

$$= 5.235 \times 10^{-3}\ m^3/s$$

$$\text{Volumetric efficiency, } \eta = \frac{15/3600}{5.235 \times 10^{-3}} = 0.796$$

$$= 79.6\%$$

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follow:

A jet aeroplane flies at a speed of 900 km/h. The density of air at this altitude is 0.15 kg/m^3 and drag on plane is 6800 kW. Consider jet plane to have 2 jets and engine working on turbo-prop system with propulsive efficiency of 56%.

122. What is the absolute velocity of jet?

(a) 115.4 m/s (b) 250.4 m/s

(c) 392.86 m/s (d) 480.46 m/s

Ans. (c)

Given : $V_a = 900\ km/h = 250\ m/s$

Propulsive efficiency; $\eta = 0.56$

$$\eta = \frac{2V_a}{V_j + V_a}$$

$$\Rightarrow \quad 0.56 = \frac{2 \times 250}{V_j + 250}$$

$$\therefore \quad V_j = 642.85\ m/s$$

Absolute velocity of jet;

$$V_j - V_a = 642.85 - 250$$

$$= 392.86\ m/s$$

End of Solution

123. What is the volume flow rate?

(a) 86.6 m^3/s (b) 102.6 m^3/s

(c) 115.4 m^3/s (d) 131.8 m^3/s

Ans. (c)

As calculated in the above queston

$$V_j - V_a = 392.86$$

$\therefore$ Thrust $= \dot{m} \times (V_j - V_a)$

$6800 = \dot{m} \times (392.86)$ (Here thrust is take as 6800 N)

$\dot{m} = 17.31$ kg

$\therefore$ Volume flow rate $= \frac{\dot{m}}{\rho} = \frac{17.31}{0.15} = 115.4\ m^3/s$

End of Solution

124. A single stage impulse turbine has equal blade angles and nozzle angle of 30°. What is the maximum possible blade efficiency, if the blade velocity coefficient is 0.85?

(a) 33.46% (b) 45.63%

(c) 55.46% (d) 69.37%

Ans. **(d)**

Given: $\alpha = 30°;\ K = 0.85$

$\therefore$ $\eta_{max} = \frac{\cos^2 \alpha (1+K)}{2} = \frac{\cos^2 30 (1+0.85)}{2} = 0.6937$

$\therefore$ $\eta_{max} = 69.37\%$

End of Solution

125. Consider the following statements:

1. Impulse turbine stage has pressure drop occurring in moving blades only.
2. Reaction turbine stage has pressure drop occurring in both fixed as well as moving blades.
3. Reaction turbines have complete admission of steam or steam being admitted all around the rotor through fixed blade ring.

Which of the above statements are correct?

(a) 1 and 2 only (b) 2 and 3 only

(c) 1 and 3 only (d) 1, 2 and 3

Ans. **(b)**

In impulse turbine stage, the pressure drop takes place in the nozzle only so there is no pressure drop in the moving blades.

End of Solution

126. Which type of steam turbine is also known as Curtis turbine?

(a) Pressure compounded impulse turbine.

(b) Velocity compounded impulse turbine.

(c) Pressure-velocity compounded impulse turbine.

(d) Cross-flow compound turbine.

Ans. **(b)**

Velocity compounded impulse turbine is also known as curtis turbine.

End of Solution

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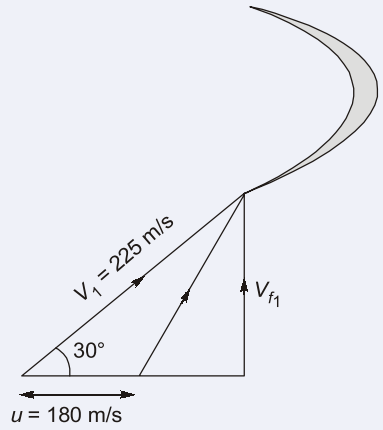
127. A reaction turbine has mean blade speed of 180 m/s, blade speed to steam velocity ratio of 0.8, outlet angles of fixed and moving blades as 30° and 35°, specific volume at outlet of fixed blade as 0.5 m^3 and at moving blade outlet as 0.6 m^3. Areas at exit of fixed blade and moving blades are same. Consider the efficiency of blades as 90% when considered as nozzles and $K^2 = 0.88$, where K is blade velocity coefficient. What is the axial velocity component at the inlet?

(a) 92.5 m/s (b) 98.5 m/s
(c) 101.2 m/s (d) 112.5 m/s

Ans. (d)



$$\frac{u}{V_1} = 0.8$$

$$\Rightarrow \quad \frac{180}{V_1} = 0.8$$

$$\Rightarrow \quad V_1 = \frac{180}{0.8} = 225 \text{ m/s}$$

Axial velocity component at the inlet;

$$V_{f_1} = V_1 \sin 30°$$
$$= 112.5 \text{ m/s}$$

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follows:

In a surface condenser operating with steam turbine, the vacuum near inlet of air pump is 69 cm of Hg when barometer reading is 76 cm of Hg. Temperature at inlet of vacuum pump is 30°C. Air leakage occurs at the rate of 60 kg/hr. [Take 1 cm of Hg = 1333.22 Pa]

128. What is the absolute pressure at inlet to air pump?

(a) 4.33 kPa (b) 5.33 kPa
(c) 6.33 kPa (d) 9.33 kPa

Ans. (d)

Barometric pressure, P_a = 76 cm of Hg

Vacuum pressure, P_{vac} = 69 cm of Hg

Absolute pressure; $P_{abs} = P_a - P_{vac}$

$= (76 - 69)$ cm of Hg

$= 7$ cm of Hg

$$= \frac{7 \times 1333.22}{1000} = 9.33 \text{ kPa}$$

End of Solution

129. What is the partial pressure of air if saturation pressure at 30°C is taken as 4.246 kPa?

(a) 3.08 kPa (b) 4.08 kPa

(c) 5.08 kPa (d) 6.08 kPa

Ans. (c)

Given:

Saturation pressure of air at 30°C; P_s = 4.246 kPa

Total pressure, $P = P_a + P_s$

$= 9.33 - 4.246$

$= 5.08$ kPa

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follows:

A simple Rankine cycle works between the boiler pressure of 3 MPa and condenser pressure of 4 kPa. The steam is dry saturated before the throttling in the turbine. From the steam tables at 3 MPa (30 bar) and saturated vapour condition, take enthalpy of steam entering into turbine as 2802.3 kJ/kg and enthalpy of steam leaving the turbine as 1862.04 kJ/kg. Consider pump work as 3 kJ/kg.

130. What is the work ratio?

(a) 0.677 (b) 0.799

(c) 0.845 (d) 0.997

Ans. (d)

Given:

Boiler pressure; P_b = 3 MPa

Condenser pressure; P_c = 4 kPa

Enthalpy at turbine inlet; h_1 = 2802.3 kJ/kg

Enthalpy at turbine exit; h_2 = 1862.04 kJ/kg

Pump work, W_P = 3 kJ/kg

$\therefore$ $W_{net} = W_T - W_P$

$= (2802.3 - 1862.04) - 3$

$= 937.26$

$$\text{Work ratio; } r_w = \frac{W_{net}}{W_T} = \frac{937.26}{940.26} = 0.997$$

End of Solution

131. What is the specific steam consumption?

(a) 2.83 kg/kWh (b) 3.83 kg/kWh

(c) 4.83 kg/kWh (d) 5.83 kg/kWh

Ans. **(b)**

Specific steam consumption;

$$\text{SSC} = \frac{3600}{W_{net}} = \frac{3600}{937.26}$$

$$= 3.83 \text{ kg/kWh}$$

End of Solution

132. In a power plant, the efficiencies of the electric generator, turbine (mechanical), boiler, cycle and the overall plant are 0.97, 0.95, 0.92, 0.42 and 0.33 respectively. What percentage of the total electricity generated is consumed in running the auxiliaries?

(a) 3.56% (b) 4.67%

(c) 5.67% (d) 7.32%

Ans. **(d)**

Overall efficiency, $\eta_0 = \eta_{boiler} \times \eta_{cycle} \times \eta_{mech} \times \eta_{aux}$

$\Rightarrow$ $0.33 = 0.95 \times 0.92 \times 0.42 \times \eta_{aux}$

$\therefore$ $\eta_{aux} = 92.6\%$

$\therefore$ Percentage of total electricity generated which is consumed in running the auxiliaries

$= (100 - 92.6)\%$

$= 7.32\%$

End of Solution

Directions for the following **three (03)** items:

Read the following information and answer the **three** items that follows:

A forced draught fan supplies air at 10 m/s against a draught of 20 mm of water across the fuel bed. 2500 kg/h of coal is consumed and 16 kg of air is supplied per kg of coal burned to run the fan. The temperature of the flue gas and the ambient air may be taken as 600 K and 300 K respectively. Take density of air as 1.176 kg/m^3.

133. What is the total pressure head to be produced by the fan?

(a) 176.50 N/m^2 (b) 255.00 N/m^2

(c) 310.05 N/m^2 (d) 412.00 N/m^2

Ans. **(b)**

Given:

Draught across fuel bed = 20 mm of H_2O

$= 20g\ N/m^2$

$$\text{Draught velocity head} = \frac{V^2}{2g} = \frac{100}{2g}$$

$$= \frac{100}{2\times 9.81} = 5.1\,m$$

Pressure; $P = \rho gh$

$= 1.176 \times g \times 5.1 = 5.59g$

$\therefore$ Total draught $= (20 + 5.59)g$

$= 255\ N/m^2$

End of Solution

134. What is the volume of air to be handled?

(a) 2.46 m^3/s (b) 4.79 m^3/s

(c) 8.29 m^3/s (d) 9.45 m^3/s

Ans. **(d)**

Volume of air to be handled,

$$V = \frac{m}{\rho} = \frac{(2500\times 16)}{1.176\times 3600}$$

$= 9.45\ m^3/s$

End of Solution

135. What is the power required to run the forced draught fan?

(a) 2.41 kW (b) 3.47 kW

(c) 4.36 kW (d) 5.33 kW

Ans. **(a)**

Power required to run the forced draught fan;

$$P = \frac{255\times 9.45}{1000\times \eta}$$

Assuming efficiency, $\eta = 100\%$

$\therefore$ $$P = \frac{255\times 9.45}{1000} = 2.41\,kW$$

End of Solution

136. The cubic capacity of a four-stroke over-square spark-ignition engine is 245 cc. The over-square ratio is 1.1. The clearance volume is 27.2 cc. What is the stroke length of the engine?

(a) 4.36 cm (b) 5.36 cm

(c) 6.36 cm (d) 7.36 cm

Ans. (c)

Given:

Cubic capacity, $V_T = 245\ cm^3$

Over square ratio, $\frac{d}{l} = 1.1$

Clearance volume, $V_C = 27.2\ cm^3$

Swept volume, $V_s = 245 - 27.2 = 217.8\ cm^3$

$$\frac{\pi}{4}d^2l = 217.8$$

$$\frac{\pi}{4} \times 1.1^2 \times l^3 = 217.8$$

$$l = 6.12\ cm$$

End of Solution

137. A 42.5 kW engine has a mechanical efficiency of 85%. If the frictional power is assumed to be constant with load, what is the mechanical efficiency at 60% of the load?

(a) 44.2% (b) 40.0%

(c) 66.3% (d) 77.3%

Ans. (d)

Given: $\eta_m = 0.85$

Let BP = x

FP = y

@ 100% load

$$\eta_m = \frac{BP}{BP + FP}$$

$$0.85 = \frac{x}{x + y},$$

$$x = 5.67\ y$$

$$x = 42.5\ kW$$

$$y = 7.495\ kW$$

So, $$\eta_m = \frac{0.6x}{0.+6x+y} = \frac{0.6 \times 42.5}{0.6 \times 42.5 + 4.795} = 0.7728$$

End of Solution

138. A single-cylinder engine running at 1800 rpm develops a torque of 8 N-m. The indicated power of the engine is 1.8 kW. What is the loss due to friction power as the percentage of brake power?

(a) 9.36% (b) 19.36%

(c) 29.36% (d) 39.36%

Ans. (b)

$$\text{Brake power, } P = T\omega$$

$$= \frac{8}{1000} \times 2\pi \times \frac{1800}{60} = 1.51 \text{ kW}$$

$$\text{Friction power} = 1.8 - 1.51 = 0.29 \text{ kW}$$

$$\therefore \quad \frac{\text{Friction power}}{\text{Brake power}} = \frac{0.29}{1.51} = 0.1921$$

End of Solution

139. A gasoline engine working on Otto cycle consumes 8 litres of gasoline per hour and develops 25 kW. The specific gravity of gasoline is 0.75 and its calorific value is 44000 kJ/kg. What is the indicated thermal efficiency of the engine?

(a) 14.1% (b) 24.1%

(c) 34.1% (d) 44.1%

Ans. (c)

$$\eta_{ith} = \frac{IP}{\dot{m}_f \times CV} \quad \ldots (i)$$

$$\dot{m}_f = \dot{V}_f \times \rho_f = \frac{8}{3600} \times 0.75$$

From (i)

$$\eta_{ith} = \frac{25 \times 3600}{8 \times 0.75 \times 44000} = 0.3409$$

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follows:

The bore and stoke of a water-cooled, vertical, single-cylinder, and four-stroke diesel engine are 80 mm and 110 mm respectively and the torque is 23.5 Nm.

140. What is the brake mean effective pressure of the engine?

(a) 1.01 bar (b) 2.01 bar

(c) 3.26 bar (d) 5.34 bar

Ans. (d)

Given :

Diameter of bore, $d = 80$ mm

Stroke length, $l = 110$ mm

Torque, $T = 23.5$ Nm

$$T\omega = P_m \times \frac{\pi}{4} d^2 \times l \times \frac{N}{2}$$

$$23.5 \times 2\pi \times N = P_m \times \frac{\pi}{4} \times 0.08^2 \times 0.11 \times \frac{N}{2}$$

$$P_m = 5.34 \times 10^5 \text{ Pa} = 5.34 \text{ bar}$$

End of Solution

141. What is the mean effective pressure if its rating is 4 kW at 1500 rpm?

(a) 3.26 bar (b) 4.26 bar

(c) 5.78 bar (d) 6.46 bar

Ans. (c)

$$4 \times 10^3 = p_m \times \frac{\pi}{4} \times 0.08^2 \times 0.11 \times \frac{1500}{2 \times 60}$$

$$p_m = 5.78 \times 10^5 \text{ Pa}$$

End of Solution

142. A refrigerator operating on reversed Carnot cycle extracts 500 kJ/min heat from a refrigerated space being maintained at –16°C and rejects heat to the atmosphere at 27°C. What is the work input required to run the refrigerator?

(a) 42.46 kJ/min (b) 55.24 kJ/min

(c) 66.36 kJ/min (d) 83.66 kJ/min

Ans. (d)

Given :

Refrigeration effect, $R_E = 500$ kJ/min

Temperature of refrigerated space, $T_L = 273 - 16 = 257$ K

Temperature of atmosphere, $T_H = 273 + 27 = 300$ K

$$\text{COP} = \frac{R_E}{W} = \frac{T_L}{T_H - T_L}$$

$$\frac{500}{W} = \frac{257}{300 - 257}$$

$$W = 83.66 \text{ kJ/min}$$

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follows:

A four-cylinder diesel engine of 4-stroke type has stroke to bore-stroke ratio as 1.2 and the cylinder diameter is 12 cm. Based on the indicator card, the area of 30 cm^2 and length as half of stroke is given. The indicator spring constant is given as 20×10^3 kN/m^2 and engine is running at 2000 rpm.

143. What is mean effective pressure of the engine?

(a) 2.33×10^5 N/m^2 (b) 4.33×10^5 N/m^2

(c) 6.33×10^5 N/m^2 (d) 8.33×10^5 N/m^2

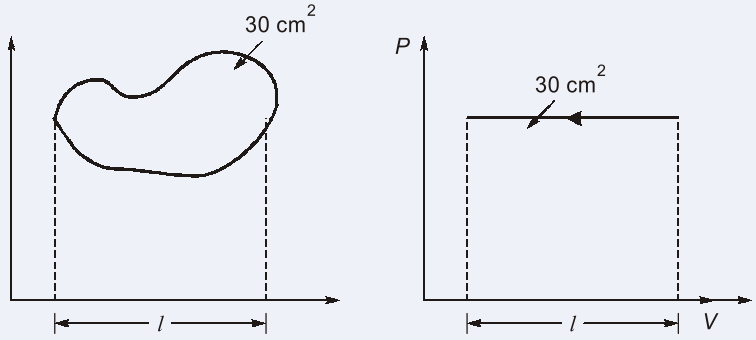
Ans. (d)

Given: $\frac{L}{D} = 1.2$, $D = 12$ cm, Area of indicator diagram = 30 cm^2

$$\frac{L}{D} = 1.2$$

Length of indicator diagram (l) = $\frac{L}{2} = 7.2$ cm

$\Rightarrow$ $L = 14.4$ cm



$h \times l = 30$ cm^2

$h = 4.16$ cm

M.e.p = $h \times k = 4.16 \times 10^{-2} \times 20 \times 10^3$

$= 833.33$ kN/m^2

$= 8.33 \times 10^5$ N/m^2

End of Solution

144. What is the indicated power for one cylinder?

(a) 22.6 kW (b) 38.4 kW

(c) 41.2 kW (d) 54.5 kW

Ans. (a)

$$\text{I.P.} = \frac{PlanK}{60n}$$

$$\frac{IP}{k} = \frac{Plan}{60n}$$

$$= \frac{833.33 \times 0.144 \times \frac{\pi}{4} \times (0.12)^2 \times 2000}{60 \times 2}$$

$= 22.618$ kW

End of Solution

145. A double-acting reciprocating pump has indicator diagram with area 40 cm^2 and length 8 cm. The bore diameter and stroke of the pump are 15 cm and 20 cm respectively. The pump motor runs at 100 rpm and the indicator spring constant is given as 1.5×10^8 Pa/m. What is the power required to drive a double acting reciprocating pump?

(a) 33.45 kW (b) 44.36 kW

(c) 66.34 kW (d) 88.36 kW

Ans. (d)

$$\text{Height } (h) = \frac{\text{Area of indicator diagram}}{\text{Length of indicator diagram}} = \frac{40}{8}$$

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$$h = 5 \text{ cm} = 5 \times 10^{-2} \text{ m}$$
$$P_{mep} = h \times \text{Spring constant}$$
$$= 5 \times 10^{-2} \times 1.5 \times 10^{8} \text{ Pa/m}$$
$$= 7500 \text{ kPa}$$
$$\text{Power} = \frac{P_{mep} \times L \times A \times N \times K}{60}$$
$$= \frac{7500 \times 0.2 \times \frac{\pi}{4} \times (0.15)^2 \times 100 \times 2}{60}$$
$$\simeq 88.357 \text{ kW}$$

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follows:

For the atmospheric air at room temperature of 30°C and relative humidity of 60%, the saturation pressure at 30°C is given as 0.0425 bar.

146. What is the partial pressure of air?

(a) 0.4255 bar (b) 0.6755 bar
(c) 0.7895 bar (d) 0.9875 bar

Ans. (d)

Given, relative humdity, $\phi = 60\%$

Saturation pressure, $P_s = 0.0425$ bar

$$P_v = \phi P_s = 0.6 \times 0.0425 = 0.0255 \text{ bar}$$
$$P_a = 1.01 - 0.0255 = 0.9845 \text{ bar}$$

End of Solution

147. What is the humidity ratio?

(a) 0.1606 kg/kg of dry air (b) 0.01606 kg/kg of dry air
(c) 0.2606 kg/kg of dry air (d) 0.02606 kg/kg of dry air

Ans. (b)

$$\text{Humidity ratio, } \omega = 0.622 \times \frac{P_v}{P_b - P_v}$$
$$= 0.622 \times \frac{0.0255}{1.01 - 0.0255}$$
$$= 0.0161$$

End of Solution

Directions for the following **two (02)** items:

Read the following information and answer the **two** items that follows:

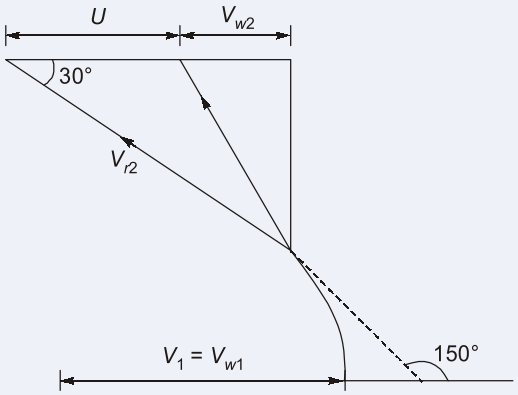
A Pelton turbine is driven by two jets, generating 4.0 MW at 375 rev/min. The effective head at the nozzles is 200 m of water and the nozzle velocity coefficient, K_N = 0.98. The axes of the jets are tangent to a circle 1.5 m in diameter. The relative velocity of the flow across the buckets is decreased by 15 percent and the water is deflected through an angle of 150° neglecting bearing and windage losses.

148. What is the Jet speed ratio?

(a) 0.2798 (b) 0.4798

(c) 0.6798 (d) 0.8798

Ans. (b)



Given: Power = 4.40 MW, N = 375 rpm

Runner diameter (D) = 1.5 m

k_N = 0.98

$\frac{V_{r2}}{V_{r1}}$ = 0.85, H = 200 m

$$u = \frac{\pi DN}{60} = \frac{\pi \times 1.5 \times 375}{60} = 29.452 \text{ m/s}$$

$$V_1 = k_N\sqrt{2gH} = 0.98\sqrt{2 \times 9.81 \times 200} = 61.357 \text{ m/s}$$

$$\text{Jet speed ratio} = \frac{u}{V_1} = \frac{29.452}{61.357} = 0.48$$

End of Solution

149. What is the runner efficiency of the Pelton turbine?

(a) 62.55% (b) 76.46%

(c) 86.66% (d) 92.46%

Ans. (c)

$$\text{Runner efficiency } (\eta) = \frac{(V_1 - u)(1 + k\cos\theta) \times 2 \times u}{V_1^2}$$

$$= \frac{(61.357 - 29.452)(1 + 0.85\cos(30°)) \times 2 \times 29.452}{61.357^2}$$

$$b = 0.8666 = 86.66\%$$

End of Solution

150. The following data refers to an axial flow compressor:
β_1 = 60°, turning angle = 30°, degree reaction 50%, speed 36000 rpm, mean diameter = 140 mm, inlet pressure = 2 bar and inlet temperature = 57°C. What is blade mean speed?

(a) 140.36 m/s (b) 263.89 m/s
(c) 313.85 m/s (d) 413.85 m/s

Ans. (b)

Given : Mean diameter;

$$D_m = 140 \text{ mm}$$

$$N = 36000 \text{ rpm}$$

$$u = \frac{\pi \times D_m \times N}{60}$$

$$= \frac{\pi \times 140 \times 36000}{1000 \times 60} = 263.89 \text{ m/s}$$

End of Solution

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