BYJU'S EXAM PREP

ESE 2023

Mechanical Engineering

Paper-2 Set-D

Official Questions with Detailed Solutions

ESE 2023 Prelims Paper-2: Major Highlights

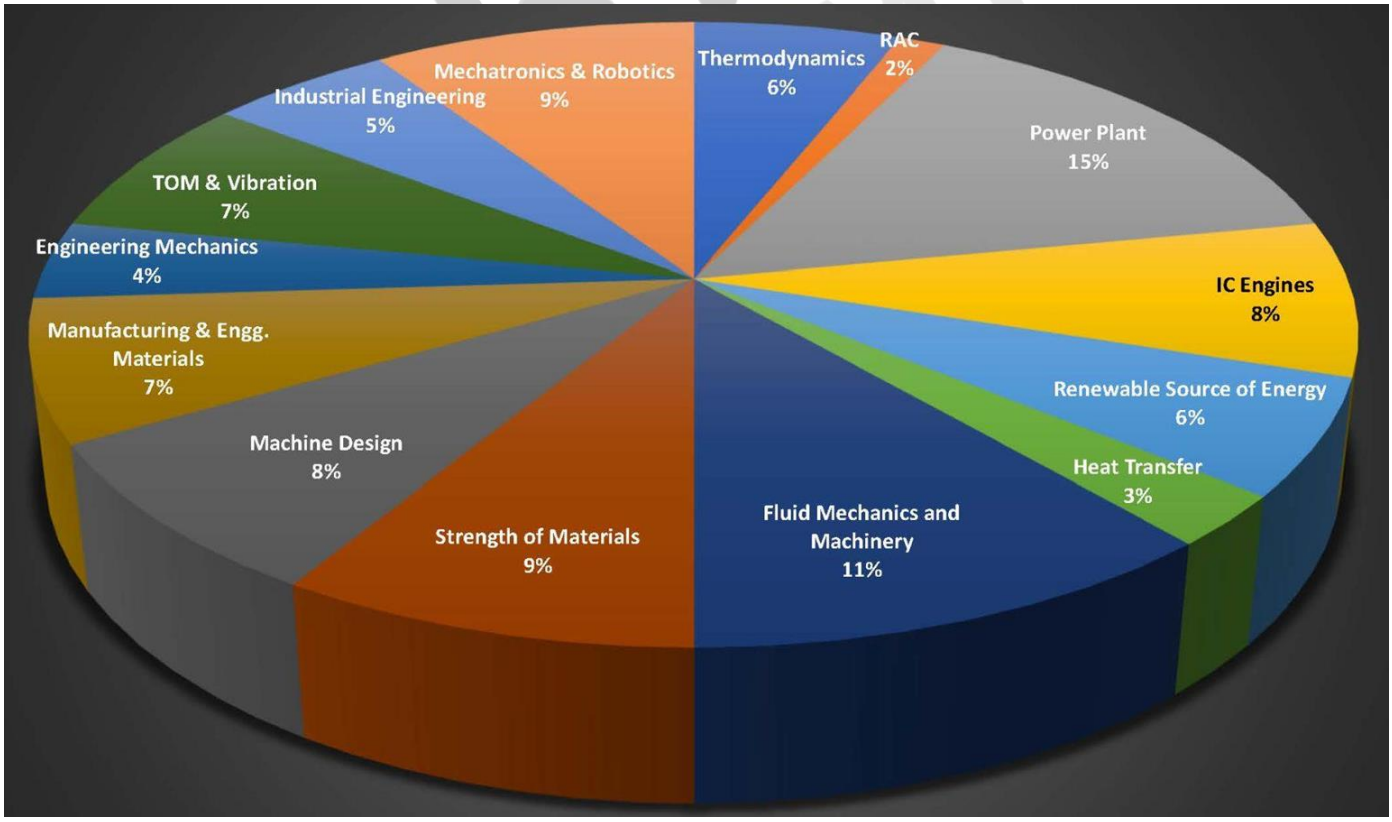
- **Overall Difficulty Level:** Moderate
- **Subject wise difficulty level:** Moderate, Mostly Numerical Question are Calculative
- **Theoretical & Numerical:** Almost Equal weightage
- **Assertion/Reason:** 5 out of 150 Qs.
- **New Qs:** Linked Question Pattern
- Weightage Increases for **Power Plant, IC Engine & SOM.**
- Weightage Decreases for **Manufacturing, Engg. Material, FM & RAC.**

ESE 2023 Prelims Paper-2: Subject-wise Weightage Distribution

S. No.	Subjects	Total Questions	Difficulty Level
1.	Thermodynamics	9	Easy
2.	Refrigeration and Air-Conditioning	2	Easy
3.	Power Plant	22	Difficult
4.	IC Engines	12	Difficult
5.	Renewable Source of Energy	9	Difficult
6.	Heat Transfer	4	Moderate
7.	Fluid Mechanics and Machinery	17	Difficult
8.	Strength of Materials	13	Easy
9.	Machine Design	12	Easy
10.	Manufacturing & Engineering Materials	11	Moderate
11.	Engineering Mechanics	6	Moderate
12.	Theory of Machines & Vibrations	11	Moderate
13.	Industrial Engineering	8	Easy
14.	Mechatronics & Robotics	14	Moderate
	Total	150	Moderate

ESE 2023 Prelims Paper-2: Comparison with Last 3 Years' Data

S. No.	Subjects	2023	2022	2021	2020
1.	Thermodynamics	6	5	12	3
2.	Refrigeration and Air-Conditioning	4	9	6	11
3.	Power Plant	22	14	14	16
4.	IC Engines	11	1	7	6
5.	Heat Transfer	5	12	3	4
6.	Fluid Mechanics and Machinery	18	23	23	21
7.	Engineering Mechanics	5	4	4	5
8.	Strength of Materials	12	10	10	8
9.	Theory of Machines & Vibrations	10	13	13	12
10.	Machine Design	12	11	11	13
11.	Manufacturing & Engineering Materials	17	20	18	17
12.	Industrial Engineering	2	4	5	5
13.	Renewable Source of Energy	11	12	12	13
14.	Mechatronics & Robotics	13	12	12	16
	Total	150	150	150	150



Mechanical Engineering

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

A. $\frac{3}{16}$inch

B. $\frac{5}{16}$inch

C. $\frac{1}{4}$inch

D. $\frac{1}{2}$inch

Ans. B

Sol. Thickness of plate, $t \leq \frac{1}{2}$inch

Minimum leg size, h = 0.707 t

$= 0.707 \times \frac{1}{2}$

$= 0.35 \text{ inch} \approx \frac{5}{16} \text{ inch}$

2. The fatigue strength reduction factor is given by

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

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

C. (endurance limit of a notch-free specimen) x endurance limit of a notched specimen

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

Ans. A

Sol. Fatigue strength reduction factor = $\frac{\text{Endurance limit of a notch free specimen}}{\text{endurance limit of a notched specimen}}$

3. 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. $\frac{\sigma_a}{S'_n} \times \frac{S_u}{\sigma_m} = 1$

B. $\frac{\sigma_a}{S'_n} \times \frac{\sigma_m}{S_u} = 1$

C. $\frac{\sigma_a}{S'_n} \times \frac{\sigma_m}{S_u} = 1$

D. $\frac{\sigma_a}{S'_n} \times \frac{S_u}{\sigma_m} = 1$

Ans. C

Sol. Goodman's equation,

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

4. 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

Sol. During deep drawing, in the flange of blank, there is biaxial tension and compression stresses.

5. 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

Sol. In rolled products, the Plate is generally 5 mm or thicker and is 1.0 or 1.25 m in width and 2.5 m in length.

6. 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

Sol. Liquid colour penetrant testing.

7. 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

Sol. Eddy currents can be used for crack detection, material thickness measurements, coating thickness measurements, conductivity measurements for material identification heat damage detection, heat treatment monitoring etc.

8. 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. A

Sol. Vibration monitoring is used in wind turbines to determine the condition of rotating equipment, including the main bearing gearbox and generator.

The vibration sensors may be place in the axial and radial directions.

Depending on the applicable frequency range,

- The position sensor (low range),
- Velocity sensors (mid-range), or
- Accelerometers is not used for high frequencies.

9. 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

10. 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

11. 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. D

Sol. Common failure mechanisms found in gas turbine blades are:

1. Mechanical damage
2. High temperature damage
3. Creep failures

12. 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

Sol. **Free float:** Free float represents the amount of time that a schedule activity can be delayed without delaying the early start date of any immediate successor activity within the network path.

13. 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

Sol. Decoupling inventory is the term used when product manufacture set aside extra raw materials or work in progress item for all or some stages in a production line, so that a law stock situation or breakdown at one stage does not stop or slow operations.

Directions (14-16): 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.

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

A. Lay
B. Waviness
C. Roughness
D. Flaws

Ans. B

Sol. Waviness: The surface irregularities of the considerable wavelength of a periodic character are known as waviness or secondary texture.

These irregularities are caused due to misalignment of centres, lack of straightness of guide ways and nm linear feed motion.

15. 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

Sol. A random order FMS:

It is able to handle the substantial variations in part configurations.

A random-order FMS is capable of processing parts that have a higher degree of complexity.

A random order FMS is more appropriate when the part family is large

Production schedule is subjected to change from day to day

16. 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

Sol. Given,

controlling force, $F_1 = 1450$ N

$F_2 = 750$ N

Radii, $r_1 = 225$ mm

$r_2 = 125$ mm

We know

Controlling force, $F = ar + b$

$1450 = 225a + b$ …(i)

$750 = 125a + b$ …(ii)

Equation (i) – (ii)

$700 = 100a$

$a = 7$

$b = -125$

Controlling force $Fc = 7a - 125$

$F_c = 7(300) - 125$

$mr\omega^2 = 1795$

$r = 0.3$ m

$\omega = 28.69$

$N = 265.1$ rpm

17. What is the isochronous speed?

A. 282.47 rpm
B. 398.42 rpm
C. 433.33 rpm
D. 598.52 rpm

Ans. A

Sol. We know that,

isochronous speed, $F_c = ar$

$mr\omega^2 = ar$

$$\omega = \sqrt{\frac{7000}{8}}$$

$N = 282.47$ rpm

18. 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

Ans. B

Sol. Controlling force Fc = 7a – 125

isochronous speed, F_c = 7a

So, for making governor isochronous we need to increase initial tension 125 N

Directions (19-20): 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.

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

A. 125654 Nm B. 195785 Nm

C. 225785 Nm D. 294531 Nm

Ans. D

Sol. Given,

radius of gyration, k = 0.75 m

$C = I\omega\omega_p$

$$= 8000 \times (0.75)^2 \times \left(\frac{2\pi\, 1800}{60}\right)\left(\frac{100 \times 1000}{3600 \times 80}\right)$$

= 294524.31 Nm

20. 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. C

Sol. $C = I\omega\omega_{p_{max}}$

$$\omega_{p_{max}} = \phi \times \frac{2\pi}{t_p}$$

$$= \frac{\pi}{18} \times \frac{2\pi}{20}$$

$= 0.055$ rad/s

$C = I\omega\omega_p$

$$= 8000 \times 0.75^2 \times \frac{180 \times 2\pi}{60} \times 0.055$$

= 46652.65 Nm

21. 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

Sol. Given, diameter D = 100 mm

Pressure, P = 0.5 MPa

Force on piston due to gas pressure

= PA

$= 0.5 \times \frac{\pi}{4} \times 100^2$

= 3927 N

22. 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. C

Sol. Contact stress for spur gears is proportional to pinion diameter (D_P).

23. 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

Sol. $\frac{L_2}{L_1} = \left(\frac{P_1}{P_2}\right)^K$

Where, K = for ball bearing

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

24. 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. C

Sol. For static load analysis,

$\Sigma F_x = 0, \Sigma F_y = 0$

For dynamic load analysis,

$\Sigma F_x = 0, \Sigma F_y = 0$ and $\Sigma M = 0$

25. 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

Sol. We know that,

$$q = \frac{k_f - 1}{k_t - 1}$$

$$\text{Or, } k_f = 1 + q(k_t - 1)$$

26. 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

Sol. For ductile materials,
Maximum shear stress theory and maximum distortion energy theory can be used.

27. 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. C

Sol. Maximum shear stress theory,

$$\boxed{S_{ys} = \frac{S_{yt}}{2}}$$

28. 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

Sol. 1. Torque required to accelerate or decelerate the system
2. Time required to accomplish the speed change

29. 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

Sol. Area of friction surface, A = 20 in^2
Power absorbed, P = 2 hp

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

30. 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

Sol. Clamping force, P = 4000 N

Allowable stress, $\sigma_{per.}$ = 800 N/mm^2

$\therefore A_t = \frac{4000}{800} = 5mm^2$

31. 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. B

Sol. PIC16F84 has several built-in hardware peripherals that can be used to interface with other devices or perform various functions. These peripherals include:

• **Timer/Counter:** The PIC16F84 has an 8-bit timer/counter that can be used for timing and counting purposes.

• **Interrupt Controller:** The interrupt controller allows the PIC16F84 to respond to external events or internal conditions that require immediate attention.

• **Analog-to-Digital Converter (ADC):** The ADC allows the PIC16F84 to convert analog signals from sensors or other sources into digital values that can be processed by the microcontroller.

• **Digital I/O:** The PIC16F84 has 13 I/O pins that can be configured as inputs or outputs to communicate with other devices or sensors.

• **Serial Communication:** The PIC16F84 supports serial communication protocols such as USART and SPI, which allow it to communicate with other devices or microcontrollers.

32. 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. B

Sol. $\text{Resolution } R = \frac{V_{fs}}{2^N - 1}$

Where, V_{Fs} = Full output voltage

N = Number of bit

$R = \frac{12\ V}{2^4 - 1} = \frac{12}{15}$

R = 0.8 V

33. 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

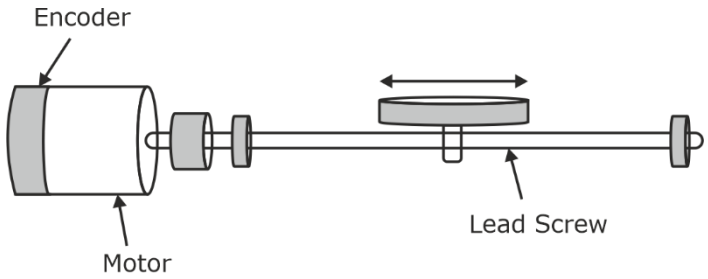
Ans. A

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

• It was discovered by Christian Johann Doppler

• Doppler effect is used to measure speed in RADAR sensors.

34. 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

Sol. Lead of the screw = 2.54 mm/rev
1000 lines on encoder disk
Quadrature mode ⇒ 90° steps
1000 lines in one revolution
Constitutes to 4 × 1000 = 4000 outputs in quadrature mode

$$\text{Resolution} = \frac{2.54 \text{ mm}}{4000} = 0.635 \ \mu\text{m}$$

35. 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

Sol. The hysteresis of the Schmitt trigger in typical circuit for a Hall-effect digital proximity switch is used to reduce the sensitivity of the sensor to noise and false triggering.

36. 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. B

37. 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

Sol. • Transducers which require an external power source for their operation is called a passive transducer.
• The active transducer (Self-generating) operates without using the auxiliary or any external power supply.
• A differential transducer that simultaneously senses two separate sources and provides an output proportional to the difference between them.

38. 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

Sol. Duality principle can be invoked to show that a multi-robot system is controllable if and only if it is observable.

39. 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

Sol. Automated guided vehicles (AGV) systems run on industrial batteries or electricity to perform movement solutions within the manufacturing facility among different workstations.

40. 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

Sol. • A robot singularity is a configuration in which the robot end-effector becomes blocked in certain directions.

• When the Jacobian becomes singular it means determinant matrix is zero.

41. 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 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

Sol. Given l = 1.524 m, b = 0.102 m

h = 0.1524 mm

p = Payload = 444.82 kg

f_{steel} = 787 kg/m^3

E = 206.85 GPs

I = 3×10^{-5} m^4

Robotic link mass = W = 1200 kg m^{-1}

Payload out as concentrated load and robotic link will act as UDL hence, $(\delta)_{payload}$ + $(\delta)_{UDL}$ For the parameters given, the total deflection is

$$\delta_{total} = \frac{PL^3}{3EI} + \frac{WL^3}{8EI} = \frac{(1.524)^3}{(206.85 \times 10^9 \times 3 \times 10^{-5})}\left[\frac{444.82}{3} + \frac{1200}{8}\right] = 170\ \mu m$$

42. 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.

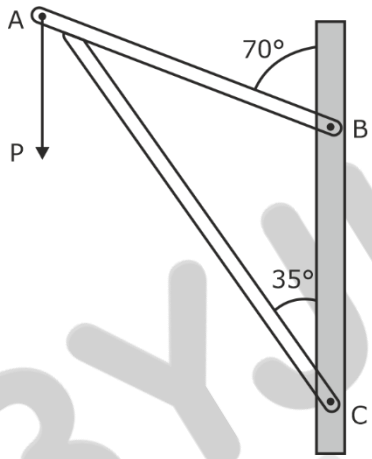
Which of the above statements is/are correct?

A. 1 only
B. 2 only
C. Both 1 and 2
D. Neither 1 nor 2

Ans. C

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

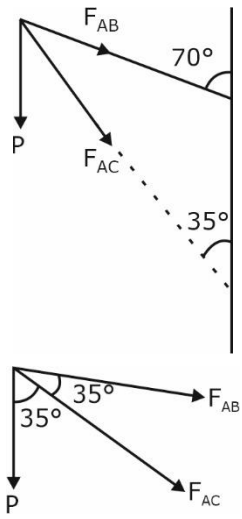
43. In the frame as shown in figure, an external force P is applied at joint A. Which one of the equations is correct by using law of sines?



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

Sol.



$$\frac{P}{\sin 35} = \frac{F_{AC}}{\sin 110} = \frac{F_{AB}}{\sin 35}$$

44. 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.

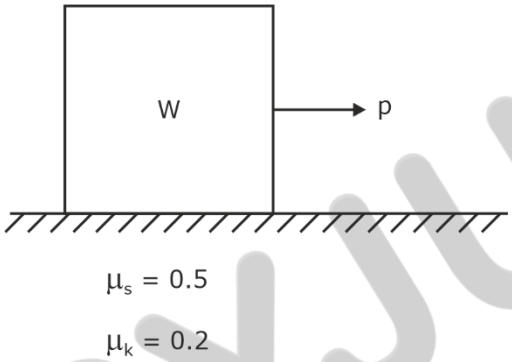
Which of the above properties are correct?

A. 1 and 2 only
B. 1 and 3 only
C. 2 and 3 only
D. 1, 2 and 3

Ans. A

Sol. 1 and 2 statements are correct.

45. 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

Sol. Maximum static friction force

$F_{max} = \mu_s \times N$ (N = mg)

$= 0.5 \times (50 \times 9.81)$

$= 245.25$ N

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

A. 1.54 Å
B. 3.08 Å
C. 4.62 Å
D. 6.16 Å

Ans. A

Sol. Given data:

Wavelength $\lambda = 1.54$ Å

Crystal at angle $\theta = 30°$

Applying Bragg's equation

$n\lambda = 2d \sin\theta$ (assume n = 1)

$1 \times 1.54 = 2 \times d \times \sin 30$

$d = 1.54$ Å

47. 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

Sol. The important ingredients present in port land cement are tricalcium silicate (51%), dicalcium silicate (26%) and tricalcium aluminate (11%).

48. 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

Sol. Fraction of proeutectoid ferrite in steel

$$W = \frac{0.8 - 0.18}{0.8 - 0.002} = \frac{0.62}{0.78}$$

$W = 0.794 \simeq 0.8$

49. Oxidation loss on the copper surface is 0.05 mm is 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

Sol. Oxidation loss on copper surface (X1) = 0.05 mm

Time (T_1) = 15 h

Losses in 225 h = ?

$$X_2 = X_1 \times \sqrt{\frac{T_2}{T_1}}$$

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

$X_2 = 0.1936 \simeq 0.194$ mm

50. What is the thermal shock resistance R of a steel body with

$\alpha = 12 \times 10^{-6}$/°C, K = 80 W/m,

σ_{ut} = 650 N/mm^2, E_t = 200,000 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

Sol. Given

$\alpha = 12 \times 10^{-6}$/°C

K = 80 W/mk

σ_{ut} = 650 N/m^2

E = 200.000 N/m^2

Thermal shock resistance

$$R = \frac{K\sigma}{\alpha E} = \frac{80 \times 650}{12 \times 10^{-6} \times 200000}$$

$= 21.667 \times 10^3$ W/m

51. 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. C

Sol. Austenitic stainless steel is used in automobile exhaust components, values and combustion chambers.

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

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 creep-resistant alloys. are best

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

Sol. Vitallium is an alloy of 65% cobalt, 30% chromium, 5% molybdenum and other substances.
Vitallium is not a vanadium-based super alloy.
So, statement 2 is not correct.

53. Plain carbon steels in which carbon percentage is less than 0.8 wt% are called

A. Hypoeutectoid steels
B. Eutectoid steels
C. Proeutectoid steels
D. Austenite steels

Ans. A

Sol. Hypo-eutectoid steel:
Plane carbon steels in which carbon percentage is less than 0.8% are called hypo-eutectoid steel.

54. 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

Sol. Gibb's phase rule: $P + F = C + N$
Where, P = number of phases of material
F = number of degree of freedom
C = number of component of a system
N = number of non compositional variables

55. 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

Sol. Given data,
m = 120 kg
v = 15 km/h = 4.166 m/s
D = 0.9 m
R_N = 100 N, μ = 0.05

Let x distance travelled (in meters) by the bicycle before it comes to rest.

We know that tangential braking force acting at the point of contact of the brake wheel.

$F_t = \mu \times R_N = 0.05 \times 100 = 5$ N

$\Rightarrow F_t \times x = 5 \times x = 5x$ N-m

Kinetic energy of the bicycle $= \frac{mv^2}{2} = \frac{120 \times (4.16)^2}{2} = 1038.33$

Work done against friction must be equal to kinetic energy of the bicycle.

$5x = 1038.33$

$x = 207.66 \simeq 208.3$ m

56. 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. C

Sol. $N_1 = 360$ rpm

$T_1 = 18$

$N_2 = 120$ rpm

$\frac{N_1}{N_2} = \frac{T_2}{T_1}$

$\frac{360}{170} = \frac{T_2}{18}$

$T_2 = 54$

57. 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

Sol. Globoidal can has either a convex or a concave surface.

58. 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

Sol. $\omega_n = \sqrt{\frac{k}{m}}$

$= \sqrt{\frac{350}{0.35}} = \sqrt{1000}$

= 31.62 rad/s

59. 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. C

Sol. Energy method makes use of fact that the maximum kinetic energy in a vibratory system is equal to the maximum potential energy in a free longitudinal vibration system.

60. 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

Sol. $V_{max} = r\omega$

$= \frac{25}{1000} \times \frac{2\pi \times 240}{60}$

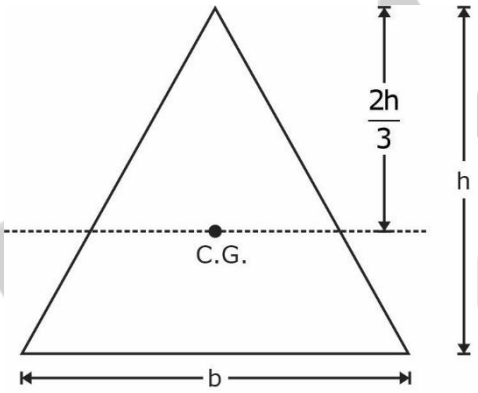
= 0.628 m/s

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

A. $bh^2/12$
B. $bh^2/24$
C. $bh^3/12$
D. $bh^3/24$

Ans. B

Sol.



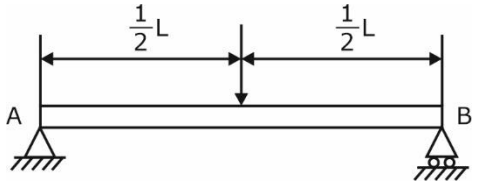
Area moment of inertia about C.G.

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

Section modulus (z) = $\frac{I}{y_{max}}$

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

62. 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

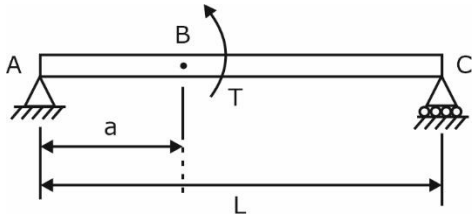
Sol. Given simply supported beam is symmetric. So, reaction force at A and B

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

Maximum bending moment, $M_{max} = \frac{P}{2} \times \frac{L}{2}$

$$= \frac{PL}{4}$$

63. 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. $\frac{T}{L}$

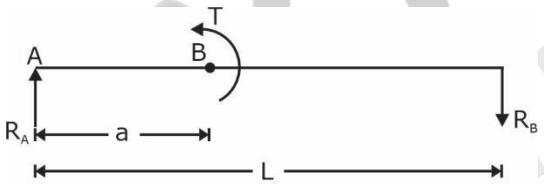
B. $\frac{Ta}{4}$

C. $\frac{TL^2}{2}$

D. $\frac{TL}{4}$

Ans. A

Sol.



$\Sigma F_y = 0$

$R_A = R_B$

$\Sigma M_A = 0$

$T = R_B \times L$

$$R_B = \frac{T}{L}$$

There is constant shear force throughout beam.

$$S_f = R_B = \frac{T}{L}$$

64. 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

Sol. Total elongation = $\frac{P_{extra} \times L}{AE}$

$$= \frac{120 \times 30}{15 \times 0.75 \times 200 \times 10^3}$$

$= 1.6 \times 10^{-3}$ m

= 1.6 mm

65. 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. A and C

Sol. Modulus of Rigidity: It is the ratio of shear stress and shear strain within the proportional limit. It is also called as shear modulus.

66. 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

Sol. **For tapered bar**

Elongation, $\Delta L_{TB} = \frac{4PL}{\pi d_1 d_2 E}$

$$\Delta L_{TB} = \frac{4PL}{\pi(d+a)(d-a)E}$$

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

For uniform bar

Elongation, $\Delta L_{UB} = \frac{4PL}{\pi d^2 E}$

$$\% \text{ Error in elongation} = \frac{\Delta L_{TB} - \Delta L_{UB}}{\Delta L_{TB}} \times 100$$

$$= \frac{\frac{4PL}{\pi\left(d^2-a^2\right)E} - \frac{4PL}{\pi d^2 E}}{\frac{4PL}{\pi\left(d^2-a^2\right)}} \times 100$$

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

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

67. 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

Sol. Torsional equation for solid circular shaft

$$\tau = \frac{16T}{\pi d^3}$$

$$50 \times 10^6 = \frac{16 \times T}{\pi \times (0.2)^3}$$

T = 78539.8 N-m

T = 78.54 kN-m

68. 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

Sol. **Thin cylinder**

Longitudinal stress, $\sigma_L = \frac{Pd}{4t}$

Hoop stress, $\sigma_h = \frac{Pd}{2t}$

$\sigma_h \geq \sigma_L$ So design is done in the basis of hoop stress.

$\sigma_h \leq \sigma_{allowable}$

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

$$t \geq \frac{Pd}{2f_a}$$

69. 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 homogenous 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

Sol. Assumption for Lami's problem in the thick shells

Plane sections of the cylinder, perpendicular to the longitudinal axis, remain plane under the pressure.

The material of the shell is homogenous and isotropic.

70. **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 destiny.

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.

Ans. A

Sol. • Fluid motion produced due to change in density resulting from the temperature gradients is called free convection.

• 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 destiny.

71. **Statement I:** Heat is defined as the form of energy that is transferred between the system and surrounding due to the temperature difference between him.

Statement II: The temperature difference is the driving for or potential for heat transfer.

Ans. A

Sol. Heat is defined as the form of energy that is transferred between the system and surrounding due to the temperature difference between him.

The temperature difference is the driving for or potential for heat transfer.

72. **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.

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.

Ans. B

Sol.

- The simple air standard cycle analysis cannot predict the variation of thermal efficiency with mixture strength since air is assumed to be working medium.
- Fuel air cycle analysis suggests that the thermal analysis will denote as the mixture supplied to an engine is enriched.

Both statements are correct but Statement II is NOT the correct explanation of Statement I

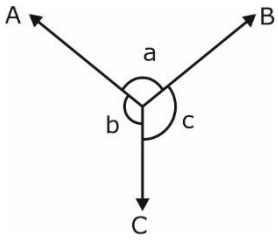
73. **Statement I:** When three concurrent forces are in equilibrium then each force is inversely proportional to the sine of the angle between the remaining two forces.

Statement II: The algebraic sum of moments of all forces about any point is equal to the moment of their resultant about that point.

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.

Ans. D

Sol.



Concurrent forces of the same magnitude are in equilibrium.
The concurrent forces always passing through a comma point.
According to Lami theorem

$$\text{Constant} = \frac{A}{\sin c} = \frac{B}{\sin b} = \frac{C}{\sin a}$$

So, $A \propto \sin c$

Statement I is in correct.

74. **Statement I:** When a material is subjected to a tensile strain, there is a simultaneous shortening dimensions of the cross-sectional 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.
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.

Ans. B

Sol. When a material is subjected to a tensile strain, there is a simultaneous shortening dimensions of the cross-sectional perpendicular to the direction of the tensile strain.
The ratio of the shortening strain to the tensile strain is called Poisson's ratio.
Statement 2 is not correct explanation of statement 1 but Statement 1 is correct explanation of statement 2.

75. **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.
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.

Ans. D

Sol. Toughness is the ability of a material to absorb applied energy without fracture.
Failure term may represent the yield failure, necking or fracture etc.

76. 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

Sol. Given,
Cubic, capacity of engine, V = 245 CC
Over square ratio = 1.1

Thus, $\frac{D}{L} = 1.1$

Where, D is bore & L is the stroke

Swept volume $V = \frac{\pi}{4}D^2L$

$245 = \frac{\pi}{4}1.1^2L^3$

$L^3 = 257.80$

$L = 6.36\,cm$

77. 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

Sol. Given,
Brake power, BP = 42.5 kW
Mechanical efficiency η_1 = 85%
We know,

$\eta_{mech} = \frac{B.P}{I.P} = \frac{B.P}{B.P + F.P}$

Where F.P is friction power

$\eta_I = \frac{B.P}{B.P + F.P}$

$0.85 = \frac{42.5}{42.5 + F.P}$

$F.P = 7.5\,kW$

At 60% load i.e. B.P is 60% of the initial given value,
$BP_2 = 0.6 \times 42.5 = 25.5$
Again, mechanical efficiency

$\eta = \frac{B.P}{I.P} = \frac{25.5}{FP + BP}$

$\eta = \frac{25.5}{7.5 + 25.5} = 77.3\%$

78. 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

Sol. Given,

Torque T = 8 N-m,

Speed, N = 1800 rpm,

Indicated power, I.P = 1.8 kW

Brake power, B.P = T × ω

$= T \times \frac{2\pi N}{60} = 8 \times \frac{2\pi \times 1800}{60}$

= 1.507 kW

Friction power F.P = I.P – B.P

= 1.80 – 1.507

F.P = 0.293 kW

$\text{Ratio} = \frac{F.P}{B.P} \times 100 = \frac{0.293}{1.507} \times 100$

= 19.36%

79. 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

Sol. Given,

Calorific value CV = 4400 kJ/kg

Specific gravity of gasoline = 0.75,

Volume, Flow rate of gasoline, V_f = 8 lit/hr

Indicated power I_P = 25 kW

Mass flow rate $\dot{m}_f = \rho \dot{v}_f$

$= 0.75 \times 1000 \times \frac{8 \times 10^{-3}}{3600}$

= 0.00167 kg/sec

Indicated thermal efficiency

$\eta_{ith} = \frac{\text{Indicated power}}{\text{Heat added per second}}$

$\eta_{ith} = \frac{25}{44000 \times 0.00167}$

η_{ith} = 34.1%

Directions (80-81): Read the following information and answer the two items that follow:

The bore and stroke 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.

80. 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

Sol. Given,

Bore, D = 80 mm

Stroke, L = 110 mm

Torque, T = 23.5 Nm

We know

$P_{mep} \times \dot{V}s = \text{Power}$

$$P_{mep} \times \frac{\pi}{4} D^2 L \times \frac{N}{60} \times \frac{1}{2} \times k = T \times \omega$$

Where k is number of cylinder, here (k = 1)

& P_{mep} is mean effective pressure)

$$P_{mep} \times \frac{\pi}{4} D^2 L \times \frac{N}{60} \times \frac{1}{2} \times 1 = T \times 2\pi \frac{N}{60}$$

$$P_{mep} = \frac{16T}{D^2 L}$$

$$P_{mep} = \frac{16 \times 23.5}{80^2 \times 110} \times 10^9$$

= 5.34 bar

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

A. 3.26 bar B. 4.46 bar

C. 5.78 bar D. 6.46 bar

Ans. C

Sol. Given,

Brake power = 4 kW,

Speed, N = 1500 rpm

We know,

$P_{mep} \times Vs$ = brake power

$$P_{mep} \times \frac{\pi}{4} D^2 L \times \frac{N}{60} \times \frac{1}{2} = 4 \times 10^3$$

$$P_{mep} \times \frac{\pi}{4} \times \frac{80^2 \times 110}{10^9} \times \frac{1500}{60} \times \frac{1}{2} = 4 \times 10^3$$

P_{mep} = 5.78 bar

82. 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

Sol. $(COP) = \frac{-16 + 273}{27 + 16} = 5.97$

$$\frac{Q}{W} = 5.97$$

$$W = \frac{500}{5.97}$$

W = 83.66 kJ/min

Directions (83-84): Read the following information and answer the two items that follow:

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.

83. What is the 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

Sol. Given,

cylinder diameter, D= 12 cm

bore-stroke ratio = 1.2

spring constant, k=20 × 10^3 kN/m^2

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

L = 1.2 × 12 = 14.4

$\ell = \frac{L}{2} = \frac{14.4}{2} = 7.2$ cm

$P_m = \frac{30}{7.2} \times 20 \times 10^3 = 8.33 \times 10^5\ N/m^2$

84. 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

Sol. We know that,

I.P = P_{mep} × Vs

$$I.P = \frac{P_m \times \frac{\pi}{4} \times (0.12)^2 \times (0.144) \times 4 \times 2000}{120}$$

$= 22.6$ kW

85. A double-acting reciprocating pump has indicator diagram with area cm2 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 driven a double acting reciprocating pump?

A. 33.45 kW B. 44.36 kW

C. 663.35 kW D. 88.36 kW

Ans. D

Sol. Given,

Indicator diagram area, a = 40 cm^2

l = 8 cm

Bore dia, d = 15 cm

Stroke length, L = 20 cm

N = 100 rpm

Spring constant, K = 1.5 × 10 kPa/m

Mean effective pressure

$$P_m = \frac{a}{l} \times K = \frac{40}{8} \times \frac{1.5 \times 10^8}{100}$$

$P_m = 7.5 \times 10^6$ Pa

Indicated power = $2P_m$ LAN (2 is taken because double acting pump is given)

$$= 2 \times 7.5 \times 10^6 \times 0.2 \times \frac{\pi}{4} \times (0.15)^2 \times \frac{100}{60}$$

= 88.36 kW

Directions (86-87): Read the following information and answer the two items that follow:

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.

86. 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

Sol. Given,

Relative humidity, φ = 60% at 30°C

P_{VS} = 0.0425 bar

We know that,

$$\phi = \frac{P_V}{P_{VS}}$$

$$\text{or } 0.6 = \frac{P_V}{0.0425}$$

or P_V = 0.0255 bar

$\therefore P_a = P_t - P_V = 1.013 - 0.0255$

= 0.9875 bar

87. 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

Sol. Humidity ratio,

$$\omega = 0.622 \frac{P_V}{P_t - P_V}$$

$$= \frac{0.622 \times 0.0255}{1.013 - 0.0255} = 0.01606 \text{ kg/kg of dry air}$$

Directions (88-89): Read the following information and answer the two items that follow:

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.

88. What is the Jet speed ratio?

A. 0.2798
B. 0.4798
C. 0.6798
D. 0.8798

Ans. B

Sol. Given,

Power, P = 4 MW

Speed, N = 375 rpm

Head at nozzle = 200 m of water

Velocity coefficient, K_N = 0.98

Diameter, D = 1.5 m

Jet speed ratio, $\phi = \frac{u}{v_1}$

$$\phi = \frac{u}{C_v\sqrt{2gH}}$$

$$= \frac{\pi \times 1.5 \times 375}{60 \times 0.98\sqrt{2 \times 9.81 \times 200}}$$

= 0.4798

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

A. 62.55% B. 76.46%

C. 86.66% D. 92.46%

Ans. C

Sol. $u = \frac{\pi DN}{60} = \frac{\pi \times 1.5 \times 375}{60} = 29.45$ m/s

$v_1 = 0.98\sqrt{2gH} = 0.98\sqrt{2 \times 9.81 \times 200} = 61.39$ m/s

Runner efficiency of turbine

$$\eta_h = \frac{2u(v_1 - u)(1 + k\cos\beta_2)}{v_1^2}$$

$$\eta_h = \frac{2 \times 29.45(61.39 - 29.45)(1 + 0.85 \times 0.866)}{(61.39)^2}$$

$\eta_h = 0.8666$

90. The following data refers to an axial flow compressor:

β_1 = 60°, turning angle = 30°, degree of reaction 50%, speed 36000 rpm, mean diameter = 140 mm, inlet pressure = 2 bar and inlet temperature = 57°C. What is the 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

Sol. $u = \frac{\pi DN}{60} = 263.89$ m/s

91. In an impulse steam turbine, steam 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. *

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

A. $(G_1 - G_2)/G_1$ B. $(G_1 + G_2)/G_1$

C. $G_1/(G_1 - G_2)$ D. $G_1/(G_1 + G_2)$

Where G_1 = quantity of ash entering an ash collector per unit time (kg/s)

G_2 = Quantity of uncollected as passing through the collector per unit time (kg/s)

Ans. A

Sol. Degree of collection $(\eta) = \frac{G_1 - G_2}{G_1}$

Directions (93-96): Read the following information and answer the four items that follow:

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.

93. 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

Sol. Given,

P_{atm} = 765 mm of Hg

P_{vaccum} = 720 mm of Hg

P_{abs} = 765 – 720 = 45 mm of Hg

P_{vaccum} at 760 mm = ?

$45 = 760 - P_{vaccum}$

or $P_{vaccum} = 760 - 45$

= 715 mm of Hg

94. What is the under-cooling efficiency?

A. 45.36 B. 53.31

C. 84.36 D. 99.31

Ans. B

Sol. Given,

Mean temperature of condensation, T_m = 34°C;

Inlet temperature of cooling water, T_{ci} = 15°C;

Hot well temperature, T_h = 29°C;

We know that,

Uncooling efficiency,

$$\eta_{cooling} = \frac{T_h - T_{ci}}{T_{mean} - T_{ci}}$$

$$= \frac{25-15}{34-15} = 52.63\%$$

95. What is the under cooling of condenser?

A. 2°C
B. 3°C
C. 4°C
D. 5°C

Ans. D

Sol. Given,

Mean temperature of condensation = 34°C

Hot well temperature = 29°C

Undercooling of condenser = 34 – 29 = 5°C

96. What is the condenser pressure?

A. 0.03 bar
B. 0.04 bar
C. 0.05 bar
D. 0.06 bar

Ans. D

Sol. Given,

Barometer = 765 mm of mercury

Vacuum = 720 mm of mercury

condenser Pressure, P_m = 765 – 720 = 45 mm

condenser Pressure, $P_m = \frac{145}{760} \times 1.013 = 0.0599 \text{ bar} = 0.06 \text{ bar}$

97. 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

Sol. 1. Pyranometer is used to measure global (direct and diffuse) solar radiation on a surface usually horizontal, but can also be used inclined surface.

2. It is designed to respond to radiation of all wavelength and hence measure accurately the total power in the incident spectrum.

3. When shaded from beam radiation by using a shading ring it measures diffused radiation.

Only 1 is correct.

98. 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

Sol. The fraction of solar radiation that is reflected back to space is called albedo.

Different parts of the earth have different albedos for example, ocean surfaces and rain forest have low albedos which means that they reflect only a small portion of the sun’s energy, Deserts, ice and clouds however have high albedos.

99. 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

Sol. Given,

I_t = 6 kW/m^2 (per clear day)

70% sunshine in a day.

Area = 1.2 m × 2.5 m = 3 m^2

τ = 90%

I = I_t × A × τ × percentage sunshine × Number of days in January

= 6 × 3 × 0.9 × 0.7 × 31

I = 351 kWh

100. 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

101. 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 between the temperature difference between the mean temperature of the heat-removal fluid in the collector, T_m, transmittance-absorptance product (τα) and the surrounding air temperature, T_a, follows:

A. F[(τα)G_c + U(T_m − T_a)]
B. F[(τα)G_c − U(T_m + T_a)]
C. F[(τα)G_c − U(T_m − T_a)]
D. F[(τα)G_c + U(T_a − T_m)]

Ans. C and D

Sol. The maximum useful heat transfer can be expressed as.

$$\left(\dot{Q}_u\right)_{max} = A_C\left((\tau\alpha)G_C - U\left(T_m - T_a\right)\right)$$

Occurs when whole collector is at the inlet fluid temperature.

The actual useful energy gain is found by multiplying the collector heat removal factor (FR) by the maximum useful energy gain

$$\dot{Q} = FA_c\left(\tau\alpha G_c - U\left(T_m - T_a\right)\right)$$

$$\frac{\dot{Q}}{A} = F\left[\tau\alpha G_C - U\left(T_m - T_C\right)\right]$$

102. 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

Sol. V = 5 m^3

C = 4.19 kJ/kg °C

T_f = 26°C

T_i = 18°C

$$Q_{useful} = m_\omega C_{p\omega}\left(T_{f,o} - T_{f,i}\right)$$

Q_{useful} = 5 × 10^3 × 4.19 × (26 − 18)

Q_{useful} = 167.6 × 10^3 kJ

103. 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

Sol. Environmental factors:
i) Dry bulb temperature of air (DBT)
ii) Relative humidity
iii) Radiation
Physiological factor:
→ Amount of clothing.

104. What is the approximate value of the energy output for a 0.5 kW PV system for Amarillo, Taxes, 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. A

Sol. Energy output in January
= Average power output/day/m^2 × Area × Number of days × Number of module × E_S × E_C
= 4.9 × 1.65 × 31 × 2 × 0.7 × 0.17
= 59.65 kWh

105. What is the annular 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

Sol. $$\text{Capacity factor} = \frac{\text{Actual output}}{\text{Maximum possible output}}$$

$$0.4 = \frac{\text{AEP}}{\text{Maximum possible output}}$$

For a wind turbine maximum possible output
= Capacity × 87260 hr/gr

$$= 3 \times 8760 \frac{\text{MWh}}{\text{yr}}$$

AEP = 0.4 × 3 × 8760
AEP = 10512 MWh/yr

106. During a trial on single acting single stage compression the following observations 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

Sol. Given,

Free air delivery, V_a = 15 m³/hr,

Speed of rotation= 500 rpm

Bore, D= 10 cm

volumetric efficiency $\eta_{vol.} = \frac{V_a}{V_s} \Rightarrow \frac{\frac{15}{3600}}{\frac{\pi}{4}(1)^2 \times (0.08) \times \frac{500}{60}}$

$\eta_{vol} = 79.64\%$

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/m³ 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%.

107. 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

Sol. Propulsive efficiency.

$\eta_p = \frac{2V_a}{V_a + V_j} = 0.56$

$\frac{2 \times 50 \times \frac{5}{18}}{V_j + 900 \times \frac{5}{18}} = 0.56$

$\frac{500}{V_j + 250} = 0.56$

892.86 = V_j + 250

V_j = 642.85 m/s

$V_j - V_a$ = 642.85 – 250 = 392.85 m/s

108. What is the volume flow rate?

A. 86.6 m³/s

B. 102.6 m³/s

C. 115.4 m³/s

D. 131.8 m³/s

Ans. C

Sol. Given,

Drag power = 6800 kW

absolute velocity of jet = absolute velocity of jet

$P = \dot{m} \times V_{abs}$

$6800 = \dot{m} \times 392.86$

$\dot{m}. = 17.5$ kg/s

$\therefore$ Volume flow rate $= \frac{\dot{m}}{f}$

$= \frac{17.3}{0.15}$

= 115.4 m³/s

109. 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

Sol. Given,

blade velocity coefficient, k= 0.85

nozzle angle, α =30°.

maximum possible blade efficiency, $\eta_{max} = \left(\frac{1+k}{2}\right)\cos^2\alpha$

$= \left(\frac{1+0.85}{2}\right)\cos^2 30$

$= \frac{1.85}{2} \times \frac{3}{4} = 69.37\%$

110. 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. D

Sol. 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.

111. 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

Sol. Pressure compounded → Rateau turbine
Velocity compounded → Curtis turbine

112. 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

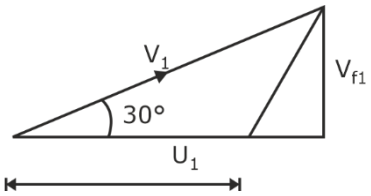
Ans. D

Sol. Given,

Mean blade speed, U = 180 m/s

Blade speed to steam velocity ratio = 0.8

Outlet angle of fixed blade, θ = 30°



$\frac{U}{V} = 0.8$,

$V = \frac{180}{0.8}$

$V_{f1} = V_1 \sin 30°$

$= \frac{180}{0.8} \times \frac{1}{2} = 112.5$ m/s

Directions (113-114): Read the following information and answer the **two** items that follow:

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)

113. 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

Sol. Given,

Vacuum reading = 69 cm

Barometer reading = 76 cm

Absolute pressure = ρgh

$= 13600 \times 9.81 (76 - 69) \times 10^{-2}$

= 9.33 kPa

114. 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

Sol. Total absolute pressure $P = P_a + P_s$

Partial pressure of air $P_a = P - P_s$

= 9.33 – 4.246

= 5.08 kPa

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

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

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.

115. What is the work ratio?

A. 0.677 B. 0.799

C. 0.845 D. 0.997

Ans. D

Sol. Given,

Steam enthalpy entering turbine, h_1 = 2802.3 kJ/kg

Steam enthalpy leaving turbine, h_2 = 1862.03 kJ/kg

Pump work W_p = 3 kJ/kg

$$\text{Work ratio} = \frac{W_{net}}{W_{turbine}} = 1 - \frac{W_P}{W_T}$$

$$= 1 - \frac{3}{(2802.3 - 1862.03)} = 0.997$$

116. 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

Sol.

Specific steam consumption

$$SFC = \frac{3600}{W_{net}}$$

$$= \frac{3600}{W_T - W_C}$$

$$= \frac{3600}{2802.3 - 1862.04} = 3.83 \text{ kg/kwh}$$

117. 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

Sol. Given,

Generator efficiency, η_g = 0.97,

Mechanical efficiency, η_m = 0.95

Boiler efficiency, η_{boiler} = 0.92

Cycle efficiency, $\eta_{absolute}$ = 0.42

Overall efficiency, η_o = 0.33

We know that

$\eta_o = \eta_p \times \eta_c \times \eta_g \times \eta_{avx}$

$0.33 = 0.92 \times 0.42 \times 0.97 \times \eta_{avx}$

$\eta_{avx} = 0.927$

Percentage consume = (1 – 0.92) × 100 = 7.32%

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

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

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/m³.

118. 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

Sol. Given,

Draught = 20 mm of water

$P_s = \rho gh \Rightarrow 1000 \times 0.02 \times 9.8 \Rightarrow 196\ N/m^2$

$P_k = \frac{V^2}{2g} \Rightarrow \frac{10 \times 10}{2 \times g}$

$P_k = P_a g h_k \Rightarrow \frac{1.176 \times 10 \times 10}{2 \times 2} \times 2 = 58.8\,N/m^2$

Total $P_t = P_s + P_k = 196 + 58.8 = 254.8\ N/m^2$

119. 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

Sol. Volume of air to be handled, $v = \frac{m}{\rho} = \frac{\frac{2500}{3600} \times 10}{1.176} = 9.45\,m^3/s$

120. 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

Sol. Total pressure head =254.8 N/m^2

power required $= \frac{P_t \times V}{\eta} = \frac{254.8 \times 9.45}{1 \times 1000}$

= 2.41 kW

121. 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

Sol. Given,

u_1 = 420 kJ/kg

u_2 = 200 kJ/kg

δW = 100 kJ/kg

$\Delta Q = \Delta U + \Delta W$

$\Delta Q = (200 - 420) + 100$

$\Delta Q = -220 + 100$

$\Delta Q = -120$ kJ/kg

122. 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

Sol. Given,

$\dot{m}$ = 17 kg/s

$\dot{W}_{out} = 14000\,kW$.

h_1 = 1200 kJ/kg

h_2 = 360 kJ/kg

C_1 = 60 m/s

C_2 = 150 m/s

From SFEE

$$\dot{m}\left(h_1+\frac{C_1^2}{2000}+gz_1\right)+\dot{Q}=\dot{m}\left(h_2+\frac{C_2^2}{2000}+gz_2\right)+\dot{W}_{cv}$$

$\Delta PE = 0$

$$17\left(1200+\frac{60^2}{2000}\right)+\dot{Q}=17\left[360+\frac{150^2}{2000}+0\right]+14000$$

$$\dot{Q}=17\left[-840+\frac{150^2-60^2}{2000}\right]+14000$$

$\dot{Q} = -119.35$ kW

$\dot{Q}_{rj} = 119.35$ kW

123. 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

Sol. m = 0.01 kg

V_1 = 0.003 m^3

P_1 = 7 bar

T_1 = 131°C = 131 + 273 = 404 k

P_2 = 1 bar

V_2 = 0.02 m^3

$\bar{R} = 8314.5$ J/K.mol.

$P_1V_1 = n\bar{R}T_1$

$7 \times 10^5 \times 3 \times 10^3 = n \times 8314.5 \times 404$

$n = 6.2517 \times 10^{-4}$ kmol

$$\text{Molar mass of gas} = \frac{m}{n} = \frac{0.01kg}{6.2517\times10^{-4}\,kmol}$$

= 16 kg/kmol

124. 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

Sol. Given,

T_H = 2000°C = 2000 + 273 = 2273 k

T_C = 10°C = 10 + 273 = 283 k

$$\eta_{max} = 1 - \frac{T_{min}}{T_{max}} \Rightarrow 1 - \frac{283}{2273}$$

$$\eta_{max} = 0.87549$$

$$\eta_{max} = 87.54\%$$

125. 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 a clearance volume of 21.3 cm^3?

A. 4.9
B. 5.9
C. 6.9
D. 7.9

Ans. D

Sol. Given,

Cylinder Bore, D = 50 mm

Stroke, L = 75 mm

Clearance volume, V_C = 21.3 cm^3

Compression ratio, $r = 1 + \frac{V_S}{V_C}$

$$= 1 + \frac{\left(\frac{\pi}{4} D^2 L\right)}{V_C}$$

$$= 1 + \frac{\frac{\pi}{4}(50)^2 \times 75 \times 10^{-3}}{21.3}$$

= 7.9

126. 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/m K. 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

Sol. Rate of heat transfer, $Q = \frac{T_i - T_o}{\left(\frac{L}{kA}\right)}$

or $\frac{Q}{A} = \frac{40 - 20}{\left(\frac{0.25}{0.52}\right)} = 41.6\ W/m^2$

Directions (127-128): Read the following information and answer the two items that follow:

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

$\rho = 960\ kg/m^3$

$\mu = 2.82 \times 10^{-4}$ kg/.s,

k = 0.68 W/m.°C,

Pr = 1.76

Nu = 151.4

127. What is the Reynolds number?

A. 31340 B. 44680

C. 48450 D. 51230

Ans. B

Sol. Reynold's number $= \frac{\rho VD}{\mu} = \frac{960 \times 0.25 \times 0.0525}{2.82 \times 10^{-4}}$

= 44680

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

A. 1961 $W/m^2°C$ B. 1961 W/m^2K

C. 1348 $W/m^2°C$ D. 1348 W/m^2K

Ans. A

Sol. $Nu = \frac{hD}{k}$

$151.4 = \frac{h \times 0.0525}{0.68} \Rightarrow h = 1961\ W/m^2°C$

129. 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

Sol. 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.

Receiver compound engine is also a cross compound engine having two cylinders with out of phase pistons and receiver in between.

130. Water at the rate of 68 kg/min is heated from 35°C 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/m²°C. What is the total heat transfer?

(Take specific heat of water as 4180 J/kg.K)

A. 78.3 kW
B. 189.5 kW
C. 241.3 kW
D. 280.6 kW

Ans. B

Sol. Given,

Mass flow rate of water, $\dot{m}_C = 68$ kg/min

Inlet temperature of water, T_{Ci} = 35°C

Outlet temperature of water, T_{Co} = 75°C

Inlet temperature of oil, T_{hi} = 110°C

Outlet temperature of oil, T_{ho} = 75°C

Overall heat transfer coefficient, U = 320 W/m²°C

$$Q = \dot{m}_c C_{P,C}\left(T_{Co} - T_{Ci}\right)$$

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

= 189.5 kW

131. What is the specific volume of steam at 17676 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 m³/kg
B. 0.0986 m³/kg
C. 0.2146 m³/kg
D. 0.3146 m³/kg

Ans. A

Sol. Given,

P = 17672 kPa

T = 712 k

P_{cr} = 22.07 MPa

T_{cr} = 647.3 k

R_{steam} = 0.4615 kJ/kg.K

$$\text{Specific volume} = \frac{R_{steam}.T}{P}$$

$$= \frac{0.4615 \times 713}{17.672}$$

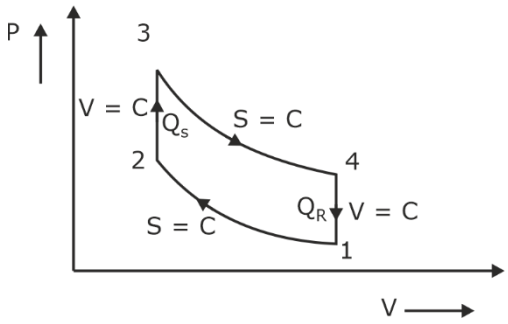
$$= 0.0186 \text{ m}^2/\text{kg}$$

132. 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

Sol. Constant volume heat addition, V = C (Isochoric)
Constant volume heat rejection, V = C (Isochoric)
Otto cycle



133. 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. A

Sol. Statements 1 and 2 are correct.

134. 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

Sol. Turbine blades are made using nickel-based super-alloys, which are capable of withstand the phenomenal stresses and temperatures, they need to operate under within the jet engine.

135. 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

Sol. Nickel-chrome steels.

136. 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

Sol. $P = \left(\frac{\rho g^2}{8\pi}\right) a^2 T$

a = amplitude, m
T = period, s

137. 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

Sol. A fuel cell is an electro chemical energy conversion device that continually converts chemical energy of fuel directly into electrical energy.

Fuel cell does not require intermediate combustion cycle.

138. The efficiency of conversion from chemical energy to electricity by a fuel cell may

A. theoretically be 110%

B. practically be 50%

C. theoretically be 50%

D. practically be 75%

Ans. B

Sol. In a fuel cell as conversion of chemical energy of fuel into electrical energy takes place directly without intermediate thermal stage, the efficiency of conversion is better and net limited by carnot efficiency of thermal stage. The efficiency of particle fuel cell may be around 50%.

139. A spherical water drop 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

Sol. A spherical drop splits up in air into 64 smaller drops Hence,

$V_1 = V_2$

$$\frac{4}{3} \times \pi \times (0.5)^3 = 64 \times \frac{4}{3} \pi (r^3)$$

$r = 0.125$ mm

Work required = $\sigma \Delta A$

$= 0.073 \times [64 \times 4\pi \times (0.125)^2 - 4\pi \times (0.5)^2]$

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

140. 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

Sol. Given,

$h = 1500$ m

$\gamma = \rho g = 10050$ N/m^2

Pressure at a depth of 1500 m is

$P = \gamma h$

$= 10050 \times 1500$

$= 15.075 \times 10^6$ N/m^2

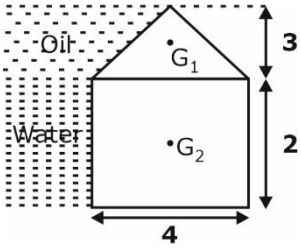
$= 15.075$ MN/m^2

141. 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

Sol.



Hydrostatic force at triangular section

$$F_1 = \rho_0 g\left(\frac{1}{2}\times 3\times 4\right)\times\left(\frac{2}{3}\times 2\right)$$

= 94.176 kN

Hydrostatic force at rectangular section

$$F_2 = (\rho_0 g\times 3 + \rho_w g\times 1)\times(2\times 4)$$

= 27.2 g = 266.83 kN

Total hydrostatic force

= F_1 + F_2

= 94.176 + 266.83

= 361 kN

142. 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%

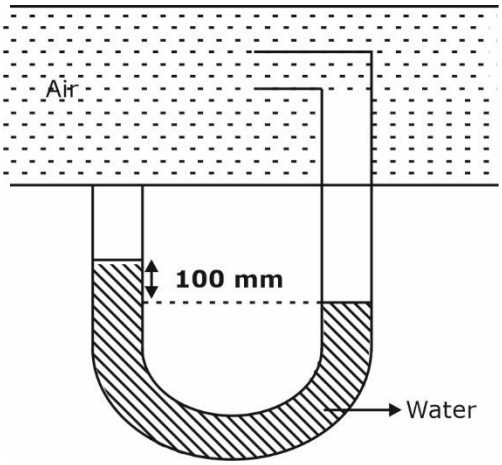
Ans. *

143. Air flows 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

Sol.



Given,

Deflection in manometer

x = 100 mm

Air velocity

$$V = C_V\sqrt{2gx\left(\frac{s_m}{s_f}-1\right)}$$

$$= 0.98\sqrt{2\times 9.81\times 0.1\times\left(\frac{1000}{1.22}-1\right)}$$

= 39.27 m/s

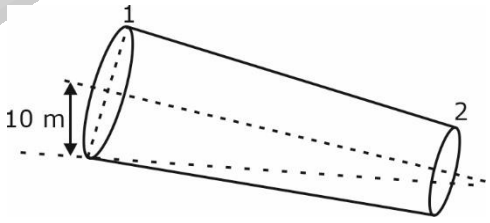
144. Water flows in a circular pipe. At one section, the diameter is 0.3 m, the static pressure is 260 kPa gauge, the velocity is 3 m/s and the elevation is 10 m above ground level. The elevation at a section downstream is 0 m, and the pipe diameter is 0.15 m. Frictional effects may be neglected. Assume 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

Sol.



Applying Bernauli equation at 1 and 2 section

$$\frac{p_1}{\rho g}+\frac{v_1^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{v_2^2}{2g}+z_2$$

$$\frac{260\times 10^3}{999\times 9.81}+\frac{3^2}{2\times 9.81}+10=\frac{p_2}{999\times 9.81}+\frac{v_2^2}{2g\times 9.81}$$

Continuity equation

$m_1 = m_2$

$\because$ density is same ($\rho_1 = \rho_2$)

$A_1v_1 = A_2v_2$

$\frac{\pi}{4} \times (0.3)^2 \times 3 = \frac{\pi}{4} \times (0.15)^2 \times v_2$

v_2 = 12 m/s

$$26.53 + 0.458 + 10 = \frac{p_2}{999 \times 9.81} + \frac{12^2}{2 \times 9.81}$$

p_2 = 290561 Pa = 290.57 kPa

145. 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 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

Sol. Water is flowing between two fixed plate (2-D channel) average velocity, V = 2 m/s

Maximum velocity, $U_{max} = \frac{3}{2} \times V$

$= \frac{3}{2} \times 2 = 3$ m/s

146. 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

Sol. Given,

Critical Reynold number = 2.5×10^6

$\nu = 1.5 \times 10^{-5}$

V = 30 m/s

$$Re = \frac{VL}{\nu}$$

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

L = 1.25 m

Directions (147-148): Read the following information and answer the two items that follow:

Air (ρ = 1.23 kg/m^3 and $\nu = 1.5 \times 10^5$ 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.

147. 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. *

Sol. Incorrect Data

148. 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. *

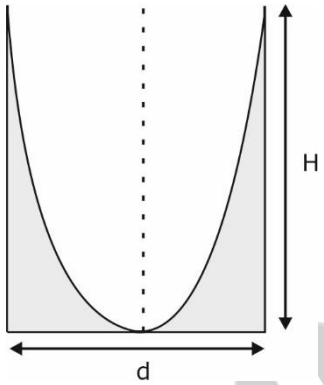
Sol. Incorrect Data

149. 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

Sol.



Given,

Hollow cylinder diameter = 0.6 m

$$H = \frac{\omega^2 R^2}{2g}$$

$$H = \frac{\left(\frac{2\pi \times 100}{60}\right)^2 \times (0.3)^2}{2 \times 9.81}$$

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

150. 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

Sol. Considering tornado as free vortex motion

vr = constant

$v_1r_1 = v_2r_2$

$12 \times 15 = v_2 \times 2$

$v_2 = 90$ m/s

Answer Key

Set-D

Q. No.	Answer	Q. No.	Answer	Q. No.	Answer	Q. No.	Answer
1.	B	**26.**	C	**51.**	C	**76.**	C
2.	A	**27.**	B	**52.**	C	**77.**	D
3.	C	**28.**	A	**53.**	A	**78.**	B
4.	D	**29.**	A	**54.**	A	**79.**	C
5.	C	**30.**	C	**55.**	C	**80.**	D
6.	B	**31.**	C	**56.**	C	**81.**	C
7.	C	**32.**	B	**57.**	C	**82.**	D
8.	A	**33.**	A	**58.**	B	**83.**	D
9.	D	**34.**	D	**59.**	C	**84.**	A
10.	A	**35.**	C	**60.**	A	**85.**	D
11.	D	**36.**	B	**61.**	B	**86.**	D
12.	A	**37.**	B	**62.**	D	**87.**	B
13.	C	**38.**	B	**63.**	A	**88.**	B
14.	B	**39.**	C	**64.**	D	**89.**	C
15.	C	**40.**	C	**65.**	A, C	**90.**	B
16.	B	**41.**	A	**66.**	D	**91.**	*
17.	A	**42.**	C	**67.**	B	**92.**	A
18.	B	**43.**	C	**68.**	D	**93.**	C
19.	D	**44.**	A	**69.**	C	**94.**	B
20.	C	**45.**	B	**70.**	A	**95.**	D
21.	C	**46.**	A	**71.**	A	**96.**	D
22.	C	**47.**	D	**72.**	B	**97.**	A
23.	B	**48.**	C	**73.**	D	**98.**	C
24.	C	**49.**	A	**74.**	B	**99.**	B
25.	D	**50.**	B	**75.**	B	**100.**	A

Q. No.	Answer	Q. No.	Answer
101.	C, D	**126.**	C
102.	C	**127.**	B
103.	D	**128.**	A, B
104.	A	**129.**	C
105.	C	**130.**	B
106.	D	**131.**	A
107.	C	**132.**	B
108.	C	**133.**	D
109.	D	**134.**	A
110.	D	**135.**	B
111.	B	**136.**	B
112.	D	**137.**	B
113.	D	**138.**	B
114.	C	**139.**	C
115.	D	**140.**	A
116.	B	**141.**	B
117.	D	**142.**	*
118.	B	**143.**	C
119.	D	**144.**	B
120.	A	**145.**	D
121.	A	**146.**	B
122.	D	**147.**	*
123.	D	**148.**	*
124.	D	**149.**	D
125	D	**150.**	D

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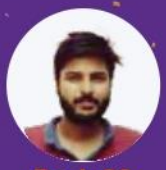

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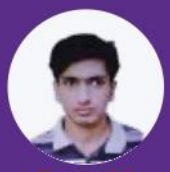
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