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ESE 2024 Prelims Solutions

Mechanical Engineering

Set-C

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Mechanical Engineering Paper Analysis of ESE 2024 Preliminary Examination

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UPSC ESE Prelims 2024

Mechanical Engineering analysis

by **MADE EASY** faculties

1. Consider the following statements regarding tidal energy:
1. When the sun-earth and moon-earth directions are perpendicular, the solar and lunar tides are out of phase producing net tides of maximum range.
2. Neap tides occur twice per month at times of half-moon.
3. spring tides occur twice per lunar month at times of both full and new moon.
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. **(c)**
When the sun-earth and moon-earth directions are perpendicular, the solar and lunar tides are out of phase producing net tides of minimum range.

End of Solution

2. Consider the following statements regarding phosphoric acid fuel cell:
1. The basic phosphoric acid fuel cell consists of two electrodes of porous conducting material to collect charge.
2. At the negative electrode, hydrogen gas is converted to hydrogen ions.
3. Pure hydrogen or a hydrogen-rich gas is supplied at positive electrode and oxygen or air is supplied at negative electrode.
Which of the above statement are correct?
(a) 1 and 2 only   (b) 1 and 3 only
(c) 2 and 3 only   (d) 1, 2 and 3

Ans. **(a)**
In the basic phosphoric acid fuel cell, pure hydrogen or a hydrogen rich gas is supplied at negative electrode (anode) and oxygen or air is supplied at positive electrode (cathode).

End of Solution

3. Consider the following statements regarding visual perception:
1. Vision is the most important sensory channel for humans.
2. The function of visual perception is to provide visual input to support a robot's learning process.
3. Vision plays a vital role in any machine which intends to perform autonomous motions.
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)**

End of Solution

4. Trajectory is a path
(a) without time constraint   (b) with time constraint
(c) in one-dimensional space   (d) with a motion planning strategy

Ans. **(b)**
Trajectory is a path with time constraint.

End of Solution

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5.   Collision-free path of the trajectory requires
  (a) constrained motion of the work-space
  (b) time constraint
  (c) geometric model of the workspace
  (d) kineto-dynamic chain

Ans.   (c)
  - Collision-free path of the trajectory requires geometric model of the workspace.
  - If there is only a time-invariant obstacle, the existence of a collision-free path only depends on the geometry of the obstacle and the manipulator.
  - However, when a time-varying obstacle exists, the existence of a collision-free path depends not only on the geometry of the obstacle and the manipulator, but also on the manipulator constraints and the dynamic information about the time-varying obstacle.

End of Solution

6.   The purpose of defuzzification is to make a decision based on
  (a) fuzzy output set   (b) fuzzy input set
  (c) Boolean set   (d) motion set

Ans.   (a)
  Defuzzification is the process of converting a fuzzified output into a single crisp value with respect to a fuzzy set. The defuzzified value in FLC (Fuzzy Logic Controller) respresents the action to be taken in controlling the process. The purpose of defuzzification is to make a decision based on fuzzy output set.

End of Solution

7.   Consider the following statements regarding issues in robotics:
  1. A robot's degree of autonomy depends on its ability to perform the ordered sequence of perception, decision-making and action.
  2. Kinematics is the study of motion in relation to force and torque.
  3. Dynamics is the study of motion without consideration of force and torque.
  Which of the above statements is/are correct?
  (a) 1 only   (b) 1 and 2 only
  (c) 2 and 3 only   (d) 1, 2 and 3

Ans.   (a)
  - Kinematics is the study of motion without consideration of cause of motion such as force and torque.
  - Dynamics is the study of motion with consideration of the cause of motion such as force and torque.

End of Solution

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8. Consider the following statements regarding joints:
1. A joint is the connection between two or more links at their nodes.
2. If a joint connects only two links, the entity is also called a kinematic pair.
3. If a one degree of freedom joint imposes a translations motion, it is called a prismatic joint.

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. **(b)**

When a joints connects only two links, the entity is called a pair, but when motion between the links is constrained then it is called a kinematics pair.

End of Solution

9. HARO-1 is
(a) a prototype of robotic animal
(b) a prototype of human-like robot
(c) a prototype of robotic engine
(d) a prototype of robotic bird

Ans. **(b)**

End of Solution

10. Consider the following statements regarding sensing elements:
1. A human sensory system can be divided into five distinct sub-systems.
2. MEMS stands for 'Micro-Electro-Mechanical System'.
3. The walking procedure involves unpredictable movement done by a robot.

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)**

The walking procedure involves predicatable movement done by a robot.

End of Solution

11. The physical quantities related to touch are measured by
(a) Simple sensors
(b) Reflective sensors
(c) Tactile sensors
(d) Touch sensors

Ans. **(c)**

A tactile sensor is a device that measures the forces in response to the physical interaction with the environment.

End of Solution

12. Consider the following statements regarding joint-space control
1. The motion performed by a robot is the input motion of its mechanism.
2. The control scheme at the lowest level of a robot's motion control system is called joint-space control

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3. A robot is a machine which is skilled at executing motions.

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.   **(c)**

The motion performed by a robot is the output motion of its mechanism.

End of Solution

13.   Autonomy is describes

(a) an automated system's degree of independence

(b) an automated system's degree of freedom

(c) an automated behaviour

(d) an automated action

Ans.   **(a)**

End of Solution

14.   Consider the following statements regarding monocular vision:

1. The monocular vision system takes images as input, and produces geometrical measurement as output.

2. A monocular vision system is normally composed of a single electronic camera, an image digitizer and computing hardware

3. The electrical signals, picked up by the imaging sensor of the camera, will be converted into an analogue image.

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)**

End of Solution

15.   The function of parallel splitter motion is to

(a) duplicate the input motion into multiple output motions.

(b) duplicate the split input motion into multiple parallel input motions.

(c) duplicate the split input motion into multiple random input motions

(d) duplicate the multiple random input motions into single input motion.

Ans.   **(a)**

The function of parallel splitter of motion is to duplicate the input motion into multiple output motions.

End of Solution

16. In which one of the following casting processes, thin slabs are produced from molten metal?
(a) Gravity die casting
(b) Centrifugal casting
(c) Plaster casting
(d) Strip casting

Ans. **(d)**
Strip casting, slab casting and continuous casting is used to produce thin slabs from molten metal.

End of Solution

17. Consider the following statements regarding forging:
1. In incremental forging process, a tool forges a blank into a shape in several small steps.
2. In isothermal forging process, the process heats the dies to the same temperature as that of the hot workpiece.
3. In rotary swaging process, a solid rod is subjected to radial impact forces by a set of reciprocating dies of the machine.
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)**
Incremental forging: (Also called as Cogging or Drawing out or Drawing Down)
In this, stock is reduced at one end only. It is used to produce blooms and slabs from cast ingot.
Isothermal forging: It is hot forging operation in which workpiece is maintained at or near its starting elevated temperature during deformation, usually by heating the forging dies to the same elevated temperature.
Isothermal forging is more expensive than conventional forging and is usually reserved for difficult to forge metals such as titanium and super alloys and for complex part shapes.
To avoid oxidation sometimes it is carried out in vacuum.
Rotary swaging: Swaging and radial forging processes are used to reduce the diameter of a tube or solid rod. In swaging, dies are rotating.
In radial forging, work piece is rotating.

End of Solution

18. Which one of the following instruments is commonly used for measuring the thickness and inside or outside dimensions of parts?
(a) Micrometer
(b) Anvil
(c) Sine bar
(d) Surface plate

Ans. **(a)**
Micrometer can be used to measure thickness and inside or outside dimension of part.
For Internal dimension, inside or internal micrometer is used which consist of a head assembly and a set of rods of different lengths to measure various inside dimensions.
Depth micrometer is similar to an inside micrometer but adopted to measure hole depth.

End of Solution

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19. The technique that creates a three- dimensional image of the part by utilizing an optical system is called
- (a) thermal inspection
- (b) eddy current inspection
- (c) holography
- (d) radiography

Ans. **(c)**

Holography is a technique that enables a wave front to be recorded and later reconstructed. It is the best method of generating 3-D images.

End of Solution

20. The welding flame with excess oxygen is known as
- (a) oxidizing flame
- (b) carburizing flame
- (c) reducing flame
- (d) neutral flame

Ans. **(a)**

End of Solution

21. Consider the following statements regarding solar energy:
1. The sun radiates energy uniformly in all directions in the form of electromagnetic waves.
2. The output of the sun is 2.8×10^{23} kW.
3. The energy reaching the earth is 1.1×10^{12} kWh/year.

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)**

End of Solution

22. Consider the following statements regarding measurement of solar radiation:
1. Pyranometer cannot measure diffuse radiation.
2. Pyrheliometer is an instrument that measures beam radiation.
3. A sunshine recorder measures the sunshine hours in a day.

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. **(c)**

A pyranometer is designed to measure global radiation usually on a horizontal surface, but can also be used on an inclined surface, when shaded from beam radiation by using a shading ring, a pyranometer measures diffused radiation.

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23. Consider the following statements:
1. The sum of beam and diffuse radiation is referred to as global radiation.
2. Diffuse radiation does not have a unique direction.
3. Solar radiation propagating in a straight line and received at the earth surface without change of direction is called direct radiation.
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)
- The total radiation at any location on the surface of the earth is the sum of beam radiation and diffused radiation and is known as global radiation.
- Solar radiation scattered by aerosols, dust and molecules is known as diffused radiation. It does not have a unique direction.
- Solar radiation propagating in a straight line and received at the earth surface without change of direction i.e. in line with the sun is called beam or direct radiation.

End of Solution

24. Consider the following statements regarding depletion of solar radiation:
1. Nitrogen gas absorbs the X-rays and extreme ultraviolet radiations.
2. Dust particles and air molecules absorb a part of solar radiant energy irrespective of wavelength
3. Ozone cannot absorb ultraviolet radiation.
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)
Ozone absorbs ultraviolet radiation.

End of Solution

25. Consider the following statements :
1. Solar radiation incident on the outer atmosphere of the earth is known as extra radiation.
2. Solar radiation that reaches the earth surface after passing through the earth's atmosphere is known as terrestrial radiation.
3. The term 'solar insolation' is defined as solar radiation energy received on a given surface area in a given time.
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)

End of Solution

26. Consider the following statements regarding solar collectors:

1. Collector efficiency is defined as the ratio of the energy actually absorbed and transferred to heat- transporting fluid by the collector to the energy incident on the collector.
2. Concentration ratio is defined as the ratio of the area of the receiver to the area of aperture of the system.
3. Temperature range is the range of temperature to which the heat- transporting fluid is heated up by the collector.

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. **(b)**

Concentration ratio is defined as the ratio of area of aperture of the system to the area of the reciever.

End of Solution

27. Consider the following statements:

1. The concentration ratio achieved from compound parabolic concentrator collector is in the range of 3-7.
2. The concentration ratio in the range of 70-80 may be achieved from cylindrical parabolic concentrator collector.
3. A concentration ratio of 10-30 may be achieved from linear Fresnel lens collector which yields temperatures between 150°C and 300 °C.

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. **(b)**

The concentration ratio in the range of 5-30 may be achieved from cylindrical parabolic concentrator collector.

End of Solution

28. Consider the following statements regarding solar greenhouse :

1. If natural means are adopted to collect, store and distribute the energy inside, it is known as active greenhouse.
2. In cold countries, winter 'greenhouses' provide supplementary heat to maintain adequate temperature during cold months when solar insolation is low.
3. Greenhouses for arid zone are designed to conserve water resources.

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. **(c)**

When natural means are adopted to collect, store and distribute the energy inside, it is known as passive greenhouse.

End of Solution

29. Consider the following statements regarding wind energy :
1. The rate of change of wind speed with height is called wind shear.
2. The layer of air from ground to gradient height is known as planetary boundary layer.
3. In the surface layer, the mean wind speed with height can be represented by Prandtl logarithmic law model.
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)**

30. Consider the following regarding biomass energy:
1. Charcoal is obtained by biomization process of woody biomass to achieve higher energy enthalpy per unit mass.
2. Biodiesel is simple to use, biodegradable and non-toxic.
3. The raw vegetable oil is upgraded as biodiesel through a chemical process called trans-esterification
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. **(c)**
Charcoal is obtained by carbonization process of woody biomass to achieve higher energy enthalpy per unit mass.

31. Consider the following statements regarding cooling towers in thermal power plants:
1. In a natural draught cooling tower, the cold water is allowed to fall over louvers.
2. In an atmospheric type cooling tower, the hot water from the condenser is pumped to the troughs and nozzles situated near the bottom.
3. In forced draught cooling towers, draught fans are installed at the bottom of towers.
4. Mechanical draught cooling towers may be forced draught cooling towers or induced draught cooling towers.
Which of the above statements are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 3 and 4 only
(d) 1 and 3 only

Ans. **(c)**
• In a natural draught cooling tower the hot water is allowed to fall over louvers.
• In an atmospheric type cooling tower, the hot water from the condenser is pumped to the troughs and nozzles situated near the top.
• In forced draught cooling towers, draught fans are installed at the bottom of towers.
• Mechanical draught cooling towers may be forced draught cooling towers or induced draught cooling towers.

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32. Consider the following statements regarding steam condensers
1. Power plant cycle improves in efficiency as the turbine exhaust pressure drops with steam condenser
2. The use of condenser decreases the size of boiler installation.
3. The vacuum obtainable in a condenser is governed by the inlet water temperature which in turn varies with the amount of condensing water used per kg of steam and its initial temperature.

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)**
- As the turbine exhaust pressure drops, we can obtain work turbine output and thus efficiency of power plant improves.
- As we decrease condenser pressure, the net work output will increase, so the steam flow required will be less, thus it will result in smaller size of boiler.
- The vacuum obtainable in a condenser is governed by the inlet water temperature which in turn varies with the amount of condensing water used per kg of steam and its initial temperature.

End of Solution

33. Multi-cylinder turbines which have their rotors mounted on one and the same shaft and coupled to a single generator are known as
(a) single-shaft turbines
(b) topping turbines
(c) multi-axial turbines
(d) back pressure turbines

Ans. **(a)**
Multi-cylinder turbines which have their rotors mounted on one and the same shaft and coupled to a generator are known as single-shaft turbines. It is also known as tendem compounding turbines.

End of Solution

34. Consider the following features for a gas turbine plant:
1. Intercooling
2. Regeneration
3. Reheat

Which of the above features in a gas turbine cycle increase the specific output and thermal efficiency of the plant?
(a) 1, 2 and 3
(b) 1 and 2 only
(c) 2 and 3 only
(d) 1 and 3 only

Ans. **(a)**
- Intercooling and reheating in gas turbine results in decreasing work input to the compressor and increasing work output to the turbine. Thus, it will result in increase in net specific output.

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- Whereas regeneration in gas turbine, increases the mean temperature of heat addition and decreases mean temperature of heat rejection. Thus regeneration increases the efficiency of gas turbine plant.
- The combined effect of intercooling, regeneration and reheating results in increase the specific output and thermal efficiency of the gas turbine cycle.

End of Solution

35. Consider the following statements regarding combustion of fuels:
1. Carbon combines with oxygen to form carbon monoxide.
2. Hydrogen burns with oxygen to give water as the product.
3. When methane burns in the presence of oxygen, the combustion products are carbon dioxide and water vapours.
Which of the above statements are correct?
(a) 1 and 3 only
(b) 1 and 2 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans. **(c)**

- $$C + O_2 \rightarrow CO_2$$

- $$C + \frac{1}{2}O_2 \rightarrow CO \quad \text{[It will occur only when there is insufficient supply of air]}$$

- $$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$$

- $$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

End of Solution

36. Consider the following statements :
1. Air contains 23% of oxygen and 77% of nitrogen by volume.
2. The main constituents of natural gas are methane and ethane.
3. Coal gas mainly consists of hydrogen, carbon monoxide and hydrocarbons.
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. **(c)**

Air contains 21% of oxygen and 79% if nitrogen by volume.

End of Solution

37. Consider the following statements regarding properties of good coal:
1. It should have low ash content and high calorific value.
2. It should have large percentage of sulphur (more than 25%).
3. It should have high grindability index.
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

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Ans. **(b)**

Desirable properties of coal:
- It should have high energy content or calorific value.
- It should contain low sulphur content, as burning coal produces SO_2 as an air pollutant which causes acid rain.
- It should have low ash content.
- It should have high grindability index.
- It should have good burning characteristics.
- Excellent weatherability.
- It should have high ash softening temperature which lower the risk of slagging.

End of Solution

38. Which one of the following interpersonal roles the manager is expected to train, counsel, mentor and encourage for high employee performance?
(a) Figurehead role
(b) Leader role
(c) Liaison role
(d) Monitor role

Ans. **(b)**

End of Solution

39. Which one of the following approaches includes application of statistics, optimization models, information models and computer simulations?
(a) Quantitative approach
(b) Qualitative approach
(c) Contingency approach
(d) Behavioural approach

Ans. **(a)**

End of Solution

40. Consider the following statements regarding purpose of the micromotion study:
1. It is to study the nature and path of movements for accomplishing the elements of an operation.
2. It is to impart training to the operators economy regarding motion economy principles so that unnecessary motion or movement by the operators may be avoided.
3. It is to find the most efficient way of accomplishing the elements.
Which of the above statements are correct?
(a) 2 only
(b) 1 and 3 only
(c) 2 and 3 only
(d) 1, 2 and 3

Ans. **(d)**

End of Solution

41. Consider the following statements regarding computer-aided manufacturing:
1. Inventory control is concerned with managing and controlling the physical operations in the factory.
2. Manufacturing control is concerned with the demand fulfilment and also to reduce the inventory to eliminate the wastage and extra money investment.

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3. Shop floor control is concerned with the problem of monitoring the progress of processing, assembling, and inspection of the products in the factory.
Which of the above statements are correct?
(a) 1 and 2 only
(b) 1 and 3 only
(c) 3 only
(d) 1, 2 and 3

Ans. **(c)**
Inventory control is concerned with the demand fulfillment while manufacturing control is concerned with managing and controlling the physical operations in the factory.

End of Solution

42. Which of the following is/are not included in flexible manufacturing system workstation facilities?
(a) Machining centres
(b) Inspection stations
(c) Milling modules
(d) Welding workspace

Ans. **(d)**

End of Solution

43. Consider the following statements regarding pure project
1. The project manager has full authority over the project.
2. Team members report to one boss.
3. It has longest communication chains.
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)**
Since team members report to one boss only, the communication chains becomes the shortest.

End of Solution

44. Consider the following statements regarding costs associated with project:
1. Direct costs increase with time.
2. Direct costs are normal costs that can be assigned directly to a specific work package or project activity.
3. Crashing activities increase direct costs.
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. **(c)**
Direct costs decrease with time.

End of Solution

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45. Consider the following statements regarding redundancy :

1. Warm redundancy is also known as hot redundancy.
2. Active redundancy is also known as lightly loaded redundancy.
3. Passive redundancy is also known as standby redundancy.

Which of the above statements are correct?

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

Ans. **(b)**

Active redundancy: It is also known as parallel or hot redundancy. In this case, redundant components are subjected from the beginning of the same load as operation elements.

Passive redundancy: It is also known as standby or cold or unloaded redundancy. Redundant components are subjected to no load until one of the operating components fails.

Warm redundancy: It is also known as lightly loaded redundancy. Redundant components are subjected to a lower load until one of the operating components fails.

End of Solution

46. Consider the following statements regarding low-cycle and high-cycle fatigue:

1. Any fatigue failure, when the number of stress cycles is less than 1000, is called low-cycle fatigue.
2. Any fatigue failure, when the number of stress cycles is more than 1000, is called high-cycle fatigue.
3. The high-cycle fatigue involves plastic yielding at localized areas of the components.

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)**

- Any fatigue failure, when the number of stress cycles is less than 1000, is called low-cycle fatigue.
- Any fatigue failure, when the number of stress cycles is more than 1000, is called high-cycle fatigue.
- Fatigue failure occurs in three steps:
  (i) Crack initiation
  (ii) Crack propagation
  (iii) Fracture

End of Solution

47. Consider the following statements regarding joints :

1. Bolted joint is the example of permanent joint.
2. Cotter joint is the example of separable joint.
3. In hand riveting, a die is placed on the protruding end of the shank and blows are applied by a hammer.

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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. **(c)**

- Bolted joint is an example of temporary joint.
- Cotter joint is the example of separable joint.
- In hand riveting, a die is placed on the protruding end of the shank and blows are applied by a hammer.

End of Solution

48. Consider the following statements regarding transmission shaft:
1. Countershaft is a secondary shaft, which is driven by the main shaft and from which the power is supplied to a machine component.
2. Spindle consists of a number of shafts, which are connected in axial direction by means of couplings.
3. Jackshaft is an auxiliary shaft between two shafts that are used in transmission of power.

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. **(b)**

- Countershaft is a secondary shaft, which is driven by the main shaft and from which the power is supplied to a machine component.
- Jackshaft is an auxiliary shaft between two shafts that are used in transmission of power.

End of Solution

49. A pair of spur gears consists of a 20 teeth pinion meshing with a 120 teeth gear. The module is 4 mm. What is the centre distance?
(a) 210 mm   (b) 280 mm
(c) 310 mm   (d) 325 mm

Ans. **(b)**

Given: $T_P = 20$, $T_G = 120$, $m = 4$ mm

$$\text{Center distance} = R_P + R_G = \frac{D_P}{2} + \frac{D_G}{2} = \frac{mT_P + mT_G}{2}$$

$$= \frac{4 \times 20 + 4 \times 120}{2} = 280 \text{ mm}$$

End of Solution

50. In a particular application, the expected life for 90% of the bearings is 8000 h. What is the rated bearing life when the shaft rotates at 1450 r.p.m.?
(a) 607 million revolutions   (b) 641 million revolutions
(c) 696 million revolutions   (d) 712 million revolutions

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Ans. (c)

$$L_{90} = 8000 \text{ hrs}$$
$$= 8000 \times 60 \times 1450 \text{ revolutions}$$
$$= 696 \times 10^6 \text{ revolutions}$$

End of Solution

51. Consider the following statements:
1. Zero film bearing is a bearing which operates without any lubricant.
2. Thin film lubrication describes a condition of lubrication, where two surfaces of the bearing in relative motion are completely separated by a film of fluid.
3. Hydrodynamic lubrication is defined as a system of lubrication in which the load-supporting fluid film is created by the shape and relative motion of the sliding surfaces.
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. (b)
- Zero film bearing is a bearing which operates without any lubricant.
- Thin film lubrication describes a condition of lubrication, where two surfaces of the bearing in relative motion are completely separated by a film of fluid.
- Thin film lubrication describes a condition of lubrication, where there is metal to metal contact between the shaft and the bearing.

End of Solution

52. Consider the following statements regarding lubricant :
1. Molybdenum disulphide is semi-solid lubricant
2. It is used to protect bearing from corrosion.
3. It is used to reduce wear.
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. (c)
- Molybdenum disulphide is solid lubricant.
- It is used to protect bearing from corrosion.
- It is used to reduce wear.

End of Solution

53. A solid cast iron disc, 1130.97 kg mass, is used as a flywheel. The radius of gyration of the solid disc is 0.3535 m about its axis of rotation. It is rotating at an angular speed of 36.65 rad/s and brought to rest by means of a brake. The energy absorbed by the brake is
(a) 61 kJ
(b) 76 kJ
(c) 94 kJ
(d) 107 kJ

Ans. **(c)**

Given: m = 1130.97 kg, R_g = 0.3535 m, ω = 36.65 rad/s

Mass moment of ratio, $I = mR_g^2$ = 1130.97 × (0.3535)^2 = 141.3285 kg-m^2

Energy absorbed, $E = \dfrac{1}{2}I\omega^2 = \dfrac{1}{2}\times(141.3285)\times(36.65)^2$

$= 94917.81$ J $= 94.91781$ kJ

$\simeq 94$ kJ

End of Solution

54. Consider the following statements regarding functions of flywheel :
1. It stores and releases energy when needed during the work cycle.
2. It increases the power capacity of the electric motor or engine.
3. It reduces the amplitude of speed fluctuations.
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. **(b)**

Functions of flywheel:
- It stores and releases energy when needed during the work cycle.
- It reduces the amplitude of speed fluctuations.

End of Solution

55. Consider the following statements:
1. The governor controls the mean speed of the engine by varying the fuel supply to the engine.
2. The flywheel has no influence on the mean speed of the engine.
3. A flywheel may be used if the cyclic fluctuations of energy output are negligible.
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)**

- The governor controls the mean speed of the engine by varying the fuel supply to the engine.
- The flywheel has no influence on the mean speed of the engine.

End of Solution

56. The yearly duration curve of a certain power plant can be considered as a straight line from 350 MW to 80 MW. Power is supplied with one generating unit of 250 MW capacity and two units of 150 MW capacity each. What is the utilization factor?
(a) 0.436
(b) 0.536
(c) 0.636
(d) 0.736

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Ans. **(c)**

$$\text{Utilization factor} = \frac{\text{Maximum demand on the power station}}{\text{Rated capacity of the power station}}$$

$$= \frac{350}{250 \times 1 + 150 \times 2} = \frac{350}{550}$$

$$= 0.636$$

End of Solution

57. Which one of the following is Dulong's formula for the calculation of the calorific value of the solid or liquid fuels from their chemical composition? (Where H, O and S are hydrogen, oxygen and sulphur in percentage respectively in 100 kg of fuel)

(a) $HCV = \frac{1}{100}\left[13800 + 144000\left\{H - \frac{O}{8}\right\} + 7270S\right] kJ/kg$

(b) $HCV = \frac{1}{100}\left[23800 + 144000\left\{H - \frac{O}{8}\right\} + 8270S\right] kJ/kg$

(c) $HCV = \frac{1}{100}\left[33800 + 144000\left\{H - \frac{O}{8}\right\} + 9270S\right] kJ/kg$

(d) One of these

Ans. **(a)**

End of Solution

58. Consider the following regarding steam turbines:
1. In reaction turbine, the steam expands in the stationary nozzles and attains high velocity.
2. In impulse turbine, the steam enters the fast moving blades on the rotor from stationary nozzles; if the steam is superheated before allowing it to expand, the Rankine cycle efficiency may be increased
3. In impulse turbine, the resulting high velocity steam impinges against the blades which alter the direction of steam jet thus changing the momentum of jet and causing impulsive force on the blades.
4. In steam turbine, the steam consumption does not increase with increase in years of service.

Which of the above statements are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 3 and 4 only
(d) 1 and 4

Ans. **(b)**
- In reaction turbine, the steam expands in the fixed blades and moving blades and attains high velocity.
- In steam turbine, the steam consumption increases with the increase in years of service.

End of Solution

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59. The overall thermal efficiency of a 40 MW turbo alternator is 30%. If the load factor of the power station is 50% and the coal burnt has a calorific value of 6800 kcal, what is the energy produced per day?
(a) 44×10^4 kWh
(b) 48×10^4 kWh
(c) 34×10^4 kWh
(d) 38×10^4 kWh

Ans. **(b)**

$$\text{Load factor} = \frac{\text{Average demand}}{\text{Maximum demand}}$$

$\therefore$ Average demand = Energy produced per day

$= $ Load factor $\times$ Maximum demand

$= 0.50 \times 40 \times 10^3 \times 24$

$= 48 \times 10^4$ kWh

End of Solution

60. Consider the following statements regarding steam power plants :

1. An increase in the initial pressure of steam raises the thermal efficiency.

2. The thermal efficiency will be dropped by raising the initial temperature of the steam without changing the pressure.

3. Intermediate reheating of steam improves the thermal efficiency of the plant.

4. An increase in the initial pressure of steam improves the thermal efficiency of steam power plant and also wetness fraction of such steam decreases at the end of expansion.

Which of the above statements are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 3 and 4 only
(d) 1 and 3

Ans. **(*)**
- As an increase in the initial pressure of steam, results in increase in mean temperature of heat addition, thus increases the thermal efficiency.
- At same pressure, raising the temperature of steam results in increase in mean temperature of heat addition, thus increases the thermal efficiency.
- Intermediate reheating of steam can increase or decrease the thermal efficiency. As thermal efficiency in intermediate reheating is directly proportional to mean temperature of heat addition.
- An increase in the initial pressure of steam improves the thermal efficiency of steam power plant and increases the wetness fraction or decreases dryness fraction of steam at the end of expansion.

End of Solution

61. A turbine develops 9000 kW when running at a speed of 150 r.p.m. and under a head of 30 m. What is the specific speed of the turbine?
(a) 202 rpm
(b) 152 rpm
(c) 189 rpm
(d) 217 rpm

Ans. **(a)**

Given: $P = 9000$ kW, $N = 150$ rpm, $H = 30$ m

Specific speed of turbine is given as

$$N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{150 \times \sqrt{9000}}{(30)^{5/4}} = 202.68 \text{ rpm}$$

$$\simeq 202 \text{ rpm}$$

End of Solution

62. Consider the following regarding unit quantities:
1. Unit specific speed is defined as the speed of a turbine working under unit head.
2. Unit discharge is defined as the discharge passing through a turbine, which is working under a unit head.
3. Unit power is defined as the power developed by a turbine working under unit speed.
   Which of the above statements is/are correct?
   (a) 1 and 3 only
   (b) 2 and 3 only
   (c) 2 only
   (d) 3 only

Ans. **(c)**
- Unit discharge is defined as the discharge passing through a turbine, which is working under a unit head.
- Unit power is defined as the power developed by a turbine working under unit head and gives maximum efficiency.

End of Solution

63. Consider regarding the following characteristic curves of hydraulic turbines:
1. Main characteristic curves are obtained by maintaining a constant speed and a constant gate opening on a turbine.
2. Operating characteristic curves are obtained by maintaining a constant head on a turbine.
3. Constant efficiency curves are known as Muschel curves.
   Which of the above statements is/are correct?
   (a) 1 and 2 only
   (b) 2 and 3 only
   (c) 2 only
   (d) 3 only

Ans. **(d)**
- Main characteristic curve or constant head curve are obtained by maintaining a constant head and a constant gate opening on a turbine.
- Operating characteristic curves or constant speed curves are obtained by maintaining a constant speed by changing the load on the turbine.

End of Solution

64. Consider the following statements regarding centrifugal pumps :
1. The rotating part of a centrifugal pump is called runner.
2. Volute casing is spiral type in which area of flow increases gradually.
3. In vortex casing, a vortex chamber is introducing between the casing and impeller.
4. Foot valve is fitted at the lower end of suction pipe.

Which of the above statements are correct?
(a) 1, 2 and 3 only
(b) 2, 3 and 4 only
(c) 1, 3 and 4 only
(d) 1, 2, 3 and 4

Ans. **(b)**
- In case of centrifugal pumps, the rotating part is called impeller.
- In case of turbine, the rotating part is called runner.
- Volute casing is spiral type in which area of flow increases gradually.
- In vortex casing, a vortex chamber is introducing between the casing and impeller.
- Foot valve is fitted at the lower end of suction pipe.

End of Solution

65. Consider the following statements :
1. The horizontal distance between the centre line of the pump and the water surface in the tank to which water is delivered is known as delivery head
2. The sum of suction head and delivery head is known as static head.
3. The manometric head is defined as the head against which centrifugal pump has to work.

Which of the above statements are correct?
(a) 1 and 3 only
(b) 2 and 3 only
(c) 1 only
(d) 2 only

Ans. **(b)**
- The vertical distance between the centreline of the pump and the water surface in the tank to which water is delivered is known as delivery head.
- The sum of suction head and delivery head is known as static head.
- The manometric head is defined as the head against which centrifugal pump has to work.

End of Solution

66. Consider the following statements regarding efficiencies of a centrifugal pump:
1. The ratio of the manometric head to the head imparted by the impeller to the water is known as manometric efficiency.
2. The ratio of the power available at the impeller to the power at the shaft of the centrifugal pump is known as overall efficiency.
3. The ratio of the power output of the pump to the power input to the pump is known as mechanical efficiency.

Which of the above statements is/are correct?
(a) 1 and 3 only
(b) 2 and 3 only
(c) 1 only
(d) 3 only

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Ans. **(c)**
- The ratio of the manometric head to the head imparted by the impeller to the water is known as manometric efficiency.
- The ratio of the power available at the impeller to the power at the shaft of the centrifugal pump is known as mechanical efficiency.
- The ratio of the power output of the pump to the power input to the pump is known as overall efficiency.

End of Solution

67. The outlet velocity of flow and outlet velocity of whirl of an impeller of a centrifugal pump are 5 m/s and 12 m/s respectively. What is the resultant velocity at outlet?
(a) 17 m/s　　　　　　　　　　　(b) 7 m/s
(c) 11 m/s　　　　　　　　　　　(d) 13 m/s

Ans. **(d)**
Given: $V_{F2} = 5$ m/s, $V_{w2} = 12$ m/s
At the outlet of an impeller,

$$V_2 = \sqrt{V_{w2}^2 + V_{F2}^2} = \sqrt{12^2 + 5^2} = \sqrt{13^2} = 13\,\text{m/s}$$

End of Solution

68. Consider the following statements regarding steam nozzles:
1. Nozzle efficiency is defined as the ratio of the actual enthalpy drop to the isentropic enthalpy drop between the same pressures.
2. Velocity coefficient is defined as the ratio of the actual exit velocity to the exit velocity when the flow is isentropic between the same pressures.
3. Velocity coefficient is the square root of nozzle efficiency.
Which of the above statements are correct?
(a) 1 and 3 only　　　　　　　　(b) 2 and 3 only
(c) 1 and 2 only　　　　　　　　(d) 1, 2 and 3

Ans. **(d)**

- Nozzle efficiency = $\dfrac{\text{Actual enthalpy drop}}{\text{Isentropic enthalpy drop}} = \dfrac{h_1 - h_2}{h_1 - h_{2s}}$

$$= \dfrac{\left(C_2^2 - C_1^2\right)/2}{\left(C_{2s}^2 - C_1^2\right)/2} = \dfrac{C_2^2 - C_1^2}{C_{2s}^2 - C_1^2}$$

- Velocity coefficient = $\dfrac{\text{Actual exit velocity at a given pressure}}{\text{Exit velocity when the flow is isentropic between the same given pressure}}$

$$= \dfrac{C_2}{C_{2s}}$$

- The velocity coefficient is the square root of the nozzle efficiency, when the inlet velocity is assumed to be negligible.

End of Solution

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69. Consider the following statements regarding steam turbines:
1. Blade efficiency is the ratio of the work done on the blade per second to the energy entering the blade per second.
2. Internal efficiency is the ratio of the heat converted into useful work to the total adiabatic heat drop.
3. Net efficiency is the ratio of brake thermal efficiency to diagram thermal efficiency.
Which of the above statements are correct?
(a) 1 and 3 only
(b) 2 and 3 only
(c) 1 and 2 only
(d) 1, 2 and 3

Ans. **(c)**

- Blade or diagram efficiency is the ratio of work done on the blade per second to energy entering the blade per second.

- $\eta_{internal} = \dfrac{\text{Heat converted into useful work}}{\text{Total adiabatic heat drop}}$

- Net efficiency or efficiency ratio $= \dfrac{\text{Brake thermal efficiency}}{\text{Thermal efficiency on the Rankine cycle}}$

- Actual thermal efficiency $= \dfrac{\text{Heat converted into useful work per kg of steam}}{\left[(\text{Total heat in steam at stop valve}) - (\text{Waste heat in exhaust})\right]}$

- Rankine efficiency $= \dfrac{\text{Adiabatic heat drop}}{\left[\left(\begin{array}{l}\text{Total heat in steam}\\ \text{at stop valve}\end{array}\right) - \left(\begin{array}{l}\text{Waste heat in}\\ \text{exhaust}\end{array}\right)\right]}$

- $\eta_{net} = \dfrac{\text{Heat converted into useful work}}{\text{Total adiabatic heat drop}}$

End of Solution

70. Consider the following statements :
1. Bleeding is the process of draining steam from the turbine at certain point during its expansion.
2. There is a usual practice in bleeding installation to allow the bled steam to mix with the preheated air, after that the mixture of steam and air proceeds to the boiler.
3. The objective of governing is to keep the turbine speed fairly constant irrespective of load.
Which of the above statements are correct?
(a) 1 and 3 only
(b) 2 and 3 only
(c) 1 and 2 only
(d) 1, 2 and 3

Ans. **(a)**

- Bleeding is the process of draining steam from the turbine, at certain points during its expansion and using this steam for heating the feed water supplied to the boiler.
- There is usual practice in bleeding installations to allow the bled steam to mix with the feed water. The mixture of steam and water then proceeds to the boiler.

End of Solution

71. The indicated work of a single-stage reciprocating air compressor is 250 kJ/min. What is the indicated power?

(a) 250 kW

(b) 0.24 kW

(c) 15 kW

(d) 4.16 kW

Ans. **(d)**

$$\text{Indicated power} = \frac{250 \text{ kJ/min}}{60} = 4.1667 \text{ kW}$$

End of Solution

72. Consider the following statements:

1. Thermal efficiency is the ratio of the network output to the heat supplied.
2. Compressor isentropic efficiency is the ratio of the work output in isentropic compression to the ideal work required.
3. Turbine isentropic efficiency is the ratio of the actual work output to the isentropic work output.

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)**

- $$\text{Thermal efficiency} = \frac{\text{Net work output}}{\text{Heat supplied}}$$

- $$\text{Compressor isentropic efficiency} = \frac{\text{Work input required in isentropic compression}}{\text{Actual work required}}$$

- $$\text{Turbine isentropic efficiency} = \frac{\text{Actual work output}}{\text{Isentropic work output}}$$

End of Solution

73. Consider the following statements regarding modes of failure:

1. A ductile material is one which has a relatively large tensile strain before fracture takes place.
2. A brittle material has a relatively small tensile strain before fracture.
3. A static load is defined as a force, which is gradually applied to a mechanical component and which changes its magnitude or direction with respect to time.

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)**

There is no change in magnitude and direction for a load which is static in nature.

End of Solution

74. Consider the following statements regarding theories of elastic failure :
1. Experimental investigations suggest that maximum principal stress theory gives good predictions for brittle materials.
2. Maximum shear stress theory predicts that the yield strength in shear is equal to the yield strength in tension.
3. Maximum shear stress theory is also known as Coulomb, Tresca and Guest theory.
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. **(b)**
According to maximum shear stress theory,

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

where, S_{ys}: Yield strength in shear
and S_{yt}: Yield strength in tension

End of Solution

75. Consider the following statements regarding distortion energy theory:
1. It is known as Huber-von Mises- Hencky theory.
2. The yield strength in shear is 0.577 times the yield strength in tension.
3. Experiments have shown that the distortion energy theory is in better agreement for predicting the failure of a brittle component than any other theory of failure.
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)**
MPST gives better results for failure of brittle components.

End of Solution

76. Air circulates at the rate of 68 kg/s and is to be heated from 16°C to 34°C. What is the water mass flow for an air heater coil having hot water entering at 85°C and leaving at 74°C? (Take specific heat of air at constant pressure as 1.02 kJ/kgK and specific heat of water as 4.187 kJ/kgK)
(a) 19 kg/s
(b) 17 kg/s
(c) 27 kg/s
(d) 14 kg/s

Ans. **(c)**

$$\dot{m}_c = 68 \text{ kg/s}$$
$$T_{c,i} = 16°C$$
$$T_{c,o} = 34°C \quad C_{pc} = 1020$$
$$T_{h,i} = 85°C$$
$$T_{h,o} = 74°C \quad C_{ph} = 4187$$

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Heat balance equation,

$$\dot{m}_c C_{ph}\left(T_{c,o} - T_{c,i}\right) = \dot{m}_h C_{ph}\left(T_{h,i} - T_{h,o}\right)$$

$$68 \times 1020(34 - 16) = \dot{m}_h \times 4187(85 - 74)$$

$$\dot{m}_h = 27.1072 \text{ kg/s}$$

End of Solution

77. A six-cylinder four-stroke diesel engine develops 125 kW at 3000 rpm. Its brake-specific consumption is 200 gm/kWh. What is the quantity of fuel to be injected per cycle per cylinder? (The specific gravity of the fuel is 0.85)
(a) 0.0726 cc/cycle
(b) 0.0379 cc/cycle
(c) 0.0981 cc/cycle
(d) 0.0545 cc/cycle

Ans. **(d)**

Given : k = 6; $N_i = \dfrac{N}{2}$; BP = 125 kW; N = 3000 rpm; bsfc = 0.2 kg/kWh; $S = 0.85$

$$\text{bsfc} = \frac{\dot{m}_f(\text{kg/hr})}{BP(\text{kW})}$$

$\Rightarrow$ $\dot{m}_f = 0.2 \times 125 = 25$ kg/hr $= 0.4167$ kg/min

For 2 revolution $\rightarrow$ 1 cycle
3000 rev/min $\rightarrow$ 1500 cycles/min

$$\dot{m}_f = \frac{0.4167(\text{kg/min})}{1500 \text{ cycles/min}} = 0.0002778 \text{ kg/cycle}$$

Specific gravity, $S = \dfrac{\rho_{fuel}}{\rho_{water}}$

$\Rightarrow$ $\rho_{fuel} = 0.85 \times 1000 = 850$ kg/m³

$\Rightarrow$ $\rho_{fuel} = \dfrac{m_f}{V_f}$

$$V_f = \frac{m_f}{\rho_{fuel}} = \frac{0.0002778}{850} = 3.2682 \times 10^{-7} \text{ m}^3/\text{cycle}$$

$$V_f = 0.32682 \text{ cm}^3/\text{cycle}$$

$$V_f = \frac{0.32682}{6} = 0.0545 \text{ cm}^3/\text{cycle/cylinder}$$

End of Solution

78. In a crank and slotted lever quick return motion mechanism, the distance between the fixed centres is 240 mm and the length of the driving crank is 120 mm. What is the time ratio of cutting stroke to return stroke?
(a) 1
(b) 0.5
(c) 2
(d) 3

Ans. (c)

$O_1O_2 = 240$ mm, $r = 120$ mm

$$\cos\theta = \frac{r}{O_1O_2} = \frac{120}{240}$$

$\Rightarrow$ $\theta = \cos^{-1}\left(\frac{120}{240}\right) = \cos^{-1}\left(\frac{1}{2}\right) = 60°$

Quick return ratio, $QRR = \frac{(180° - \theta)}{\theta} - \frac{(180° - 60°)}{60°} = \frac{120°}{60°} = 2$

Hence, the time ratio of cutting stroke to return stroke is 2.

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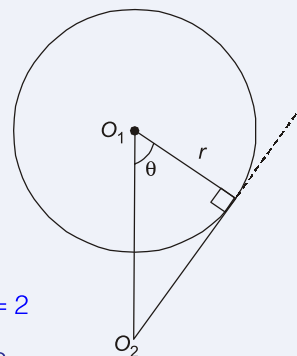
79. ABCD is a four-bar chain in which link AD is the driver, link BC is the driven, and DC is fixed. The driver rotates uniformly at a speed of 120 r.p.m. and the constant driving torque is 50 N-m. At a particular phase of the mechanism, the angular velocity of the driven link is 2 rad/s. What is the ideal mechanical advantage?
(a) 5.26
(b) 6.28
(c) 8.98
(d) 10

Ans. (b)
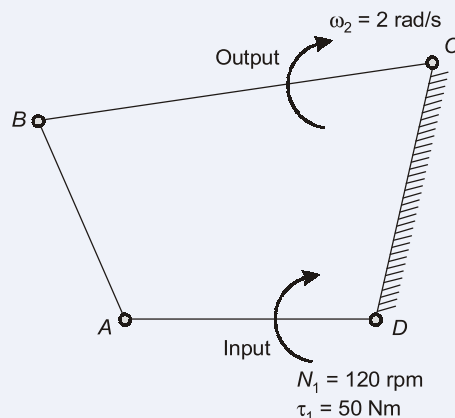
AD link $\rightarrow$ Driver
BC link $\rightarrow$ Driven
CD link $\rightarrow$ Fixed

$N_1 = N_{input} = 120$ rpm

$\Rightarrow$ $\omega_1 = \frac{2\pi N}{60} = 2\pi \times \left(\frac{120}{60}\right) = 4\pi$ rad/s

By power conservation (assuming $\eta_{mechanism} = 1$):

$\tau_{input} \cdot \omega_{input} = \tau_{output} \cdot \omega_{output}$

$\Rightarrow$ $50 \times 4\pi = \tau_{output} \times 2$

$\Rightarrow$ $\tau_{output} = 100\ \pi$ Nm

Mechanical advantage:

$$MA = \frac{\tau_{output}}{\tau_{input}} = \frac{100\pi}{50} = 2\pi = 6.283$$

80. The distance between two parallel shafts is 18 mm and they are connected by an Oldham's coupling. The driving shaft revolves at 160 r.p.m. What is the maximum speed of sliding of the tongue of the intermediate piece along its groove?

(a) 0.415 m/s   (b) 0.586 m/s

(c) 0.302 m/s   (d) 0.845 m/s

Ans. **(c)**

$$d = 18 \text{ mm} = 0.018 \text{ m}$$
$$D_{driver} = 160 \text{ rpm}$$

Maximum sliding velocity of sliding of the tongue of the intermediate piece,

$$v = d \times \omega_{driver}$$
$$= 0.018 \times 2\pi \times \frac{160}{60}$$
$$= 0.30159 \text{ m/s} \simeq 0.302 \text{ m/s}$$

End of Solution

81. In a thrust bearing, the external and the internal diameters of the contacting surfaces are 320 mm and 200 mm respectively. The total axial load is 80 kN. The shaft rotates at 400 r.p.m. Taking the coefficient of friction as 0.06, what is the power lost in overcoming the friction?

(a) 26.602 kW   (b) 21 kW

(c) 44.23 kW   (d) 46 kW

Ans. **(a)**

Given: $D_o = 320$ mm, $D_i = 200$ mm, $W = 80$ kW, $N = 400$ rpm, $\mu = 0.06$,
$R_o = D_o/2 = 160$ mm, $R_i = D_i/2 = 100$ mm

The frictional toque is given as:

$$T_f = \frac{2}{3}\mu W\left(\frac{R_o^3 - R_i^3}{R_o^2 - R_i^2}\right) = \frac{2}{3} \times 0.06 \times 80 \times \left[\frac{(0.160)^3 - (0.100)^3}{(0.160)^2 - (0.100)^2}\right]$$
$$= 0.63507 \text{ kN-m}$$

The power loss is given as

$$\text{Power} = T_f \times \omega = T_f \times \frac{2\pi N}{60} = 0.63507 \times \frac{2 \times \pi \times 400}{60}$$
$$= 26.60175 \text{ kW} \simeq 26.602 \text{ kW}$$

End of Solution

82. The number of teeth of a spur gear is 30 and it rotates at 200 r.p.m. What is the pitch line velocity if it has a module of 2 mm?

(a) 376.9 mm/s   (b) 628.3 mm/s

(c) 850.7 mm/s   (d) 246.1 mm/s

Ans. **(b)**

$$T = 30, \ N_G = 200 \text{ rpm}, \ m = 2 \text{ mm}$$

$$R = \frac{mT}{2} = \frac{2 \times 30}{2} = 30 \text{ mm} = 0.030 \text{ m}$$

$$v_{\text{pitchline}} = R \times \omega_G$$

$$= 0.030 \times \frac{2\pi \times 200}{60} = 0.6283 \text{ m/s}$$

$$= 628.3 \text{ mm/s}$$

83. Two spur gears have a velocity ratio of 1/3. If the driven gear has 72 teeth, then what is the number of teeth of the driver gear?

(a) 72   (b) 36

(c) 24   (d) 12

Ans. **(c)**

$$\text{VR} = \frac{1}{3}, \ T_{Driven} = 72$$

$$\text{Velocity ratio, VR} = \frac{T_{Driver}}{T_{Driven}}$$

$$\frac{1}{3} = \frac{T_{Driver}}{72}$$

$$\Rightarrow \qquad T_{\text{Driven}} = \frac{72}{3} = 24$$

84. The following data relate to two meshing gears :

Velocity ratio = 1/3

Module = 4 mm

Centre distance = 200 mm

How many number of teeth are there on the gear wheels?

(a) 90   (b) 60

(c) 45   (d) 75

Ans. **(d)**

$$VR = \frac{1}{3}, m = 4 \text{ mm}, \ O_1O_2 = 200 \text{ mm}$$

$$\text{Centre distance, } O_1O_2 = R_P + R_G$$

$$200 = R_P + R_G \qquad \qquad \qquad ...(i)$$

$$\text{Velocity ratio, VR} = \frac{T_P}{T_G} = \frac{(2R_P/m)}{(2R_G/m)} = \frac{R_P}{R_G}$$

$$\Rightarrow \qquad \frac{1}{3} = \frac{R_P}{R_G} \qquad \qquad \qquad ...(ii)$$

Using equation (i) and (ii)

$$R_P = 50 \text{ mm and } R_G = 150 \text{ mm}$$

$$\Rightarrow \qquad T_G = \frac{D_G}{m} = \frac{2R_G}{m} = \frac{2 \times 150}{4} = 75$$

85. An epicyclic gear train consists of an arm and two gears A and B having 30 teeth and 40 teeth respectively. The arm rotates about the centre of gear A at a speed of 80 r.p.m. counterclockwise. What is the speed of gear B if gear A is fixed?

(a) 140 r.p.m.   (b) 180 r.p.m.

(c) 120 r.p.m.   (d) 200 r.p.m.

Ans. **(a)**

$$T_A = 30$$
$$T_B = 40$$
$$N_{arm} = 80 \text{ rpm (Anticlock)} = -80 \text{ rpm}$$
$$N_A = 0$$
$$N_B = ?$$

Motion	Arm	A 30	B 40
1. Let Arm fixed gear A speed $+x$ CW	O	$+x$	$-x \times \dfrac{30}{40}$
2. Arm rotates at $+y$ CW	y	$y + x$	$\left(y - \dfrac{3x}{4}\right)$

$$N_{arm} = y = -80$$
$$N_A = y + x = 0$$
$$-80 + x = 0$$
$$\Rightarrow \qquad x = 80$$

$$N_B = y - \frac{3x}{4} = -80 - \frac{3(80)}{4}$$
$$= -80 - 60 = -140$$
$$= 140 \text{ rpm}$$

86. A flywheel with a mass of 3 kN has a radius of gyration of 1.6 m. What is the energy stored in the flywheel when its speed increases from 315 r.p.m. to 340 r.p.m.?

(a) 757.5 kJ   (b) 896.2 kJ

(c) 412.1 kJ   (d) 684.9 kJ

Ans. **(*)**

$$mg = 3 \text{ kN} = 3000 \text{ N}$$
$$m = 305.81039 \text{ kg}$$
$$k = 1.6 \text{ m}$$
$$I = mk^2 = 782.87461 \text{ kg-m}^2$$

$$\Delta E = \frac{1}{2}I\omega^2_{max} - \frac{1}{2}I\omega^2_{min}$$

$$= \frac{1}{2} \times 782.87461\left[\left(\frac{2\pi \times 340}{60}\right)^2 - \left(\frac{2\pi \times 315}{60}\right)^2\right]$$

$$= \frac{1}{2} \times 782.87461 \times \frac{4\pi^2}{(60)^2} \left[340^2 - 315^2 \right]$$

$$= 70291.16828 \text{ J}$$

$$= 70.291 \text{ kJ}$$

End of Solution

87. A flywheel fitted to a steam engine has a mass of 800 kg. Its radius of gyration is 360 mm. The starting torque of the engine is 580 N-m and may be assumed constant. What is the kinetic energy of the flywheel after 12 seconds?
(a) 233.27 kJ
(b) 263.27 kJ
(c) 333.27 kJ
(d) 363.27 kJ

Ans. (a)

$$m = 800 \text{ kg}, \ k = 360 \text{ mm} = 0.360 \text{ m}$$

$$I = mk^2 = 103.68 \text{ kgm}^2$$

$$T_{mean} = 580 \text{ Nm}$$

$$T_{mean} = I \cdot \alpha$$

$$580 = 103.68 \times \alpha$$

$$\alpha = 5.594135 \text{ rad/s}^2$$

$$\omega = \cancel{\omega_0}^{\ 0} + \alpha t$$

$$\omega = 5.594135 \times 12 = 67.1296 \text{ rad/s}$$

$$E = \frac{1}{2} I \omega^2 = 233611.11 \text{ J} = 233.611 \text{ kJ}$$

End of Solution

88. An aeroplane makes a complete half circle of 50 metres radius, towards left, when flying at 200 km/h. The rotary engine and propeller of the plane have a mass of 400 kg and radius of gyration of 0.3 m. The engine rotates at 2400 r.p.m. clockwise when viewed from the rear. What is the gyroscopic couple on the aircraft?
(a) 10 kN-m
(b) 15 kN-m
(c) 18 kN-m
(d) 12 kN-m

Ans. (a)

$$R = 50 \text{ m}$$

$$V = 200 \text{ km/h} = 200 \times \frac{5}{18} \text{ m/s}$$

$$(\omega_p)_{turning} = \frac{V}{R} = \frac{200 \times 5}{18 \times 50} = \frac{20}{18} = \frac{10}{9} \text{ rad/s}$$

$$m = 400 \text{ kg}$$

$$k = 0.3 \text{ m}$$

$$I = mk^2 = 36 \text{ kgm}^2$$

$$N = 2400 \text{ rpm}$$

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$$\omega = \frac{2\pi \times 2400}{60} = 2\pi \times 40 = 80\,\pi \text{ rad/s}$$

$$C = I\omega\,\omega_p = 36 \times 80\pi \times \frac{10}{9} = 40 \times 80\pi$$

$$= 10053.09 \text{ N-m} = 10.053 \text{ kN-m}$$

End of Solution

89. What is the vertical height of a Watt governor when it rotates at 60 r.p.m.?
(a) 0.157 m   (b) 0.192 m
(c) 0.205 m   (d) 0.248 m

Ans. **(d)**

Vertical height for a watt governor is given as;

$$h = \frac{895}{N^2} = \frac{895}{(60)^2} = 0.248611\,\text{m} \simeq 0.248 \text{ m}$$

End of Solution

90. The degree of freedom (DOF) for globular or spherical pair is
(a) 1   (b) 2
(c) –1   (d) 3

Ans. **(d)**

The degree of freedom of globular or spherical pair is 3.

End of Solution

91. Optical pyrometer works based on the principle of
(a) conduction only   (b) convection only
(c) radiation   (d) conduction and convection

Ans. **(c)**

End of Solution

92. Consider the following common defects in steel due to heat treatment :
1. Warping
2. Oxidation
3. Quenching cracks
Which of the above defects are correct?
(a) 1 and 2 only   (b) 2 and 3 only
(c) 1 and 3 only   (d) 1, 2 and 3

Ans. **(d)**

Warping/distortion, oxidation, quench cracks are the defects in steel in heat treatment.

End of Solution

93. Consider the following conditions to be fulfilled before a powder metallurgy product can be made :
1. It must be possible to form a continuously bonded matrix.
2. The metal in the powder form must be able to respond to solid phase welding.
3. The powders in which the basic materials are available must be sufficiently close packing under pressure.

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

94. Consider following the statements regarding mechanical properties of metals:
1. The phenomenon leading to fracture under repeated stresses having a maximum value less than the ultimate strength of material is called creep.

2. A time-temperature parameter used to predict stress rupture due to creep is called Larson-Miller parameter.

3. Time-dependent deformation of a material when subjected to a constant load or stress is called fatigue

Which of the above statements are correct?
(a) 1 and 2 only
(b) 2 only
(c) 3 only
(d) 1, 2 and 3

Ans. **(b)**
Larson-miller parameter (P) is used for predicting creep life of metals. It is expressed as

$$P = T\{C + \log(t)\}$$

where, C = Constant, T = Temperature in K, t = Time in hours

End of Solution

95. Consider the following statements regarding mechanical properties of metals:
1. The process of atoms moving over each other during the permanent deformation of a metal is called slip.
2. An empirical equation that relates the strength of a metal to its grain size is known as Hall-Petch relationship.
3. The ability of some metals to deform plastically by 1000-2000 percent at high temperatures and low loading rates is called superplasticity.

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)**
The term 'slip' is used to describe atomic movement over each other, in permanent deformation.

According to Hall-Petch equation $\sigma_y = \sigma_i + kd^{-1/2}$

$\because$
- σ_y = Yield strength of a polycrystalline material
- d = Average grain size
- k = Hall-Petch constant
- σ_i = Yeild stress of the material at an infinite grain rise.

The ability of a material to exhibit extensive permanent deformation (1000 – 2000%) of high temperature and low strain rates is called superplastic deformation.

End of Solution

96. The Rolls-Royce CV12 turbocharged four-stroke direct injection diesel engine has a displacement of 26.1 litres. The engine has a maximum output of 900 kW at 2300 r.p.m. What is the brake mean effective pressure?

(a) 18 bar (b) 15 bar
(c) 10.15 bar (d) 21 bar

Ans. **(a)**

$$V_s = 26.1 \text{ litres}; \ BP = 900 \text{ kW}; \ N = 2300 \text{ rpm}$$

$$BP = \frac{P_{mep} \cdot L.A.N.K}{60n}$$

$$\Rightarrow \qquad 900 \times 10^3 = \frac{P_{mep} \times 26.1 \times 10^{-3} \times 2300 \times 1}{60 \times 2}$$

$$\Rightarrow \qquad P_{mep} = 17.99 \times 10^5 \text{ Pa}$$
$$= 17.99 \text{ bar} \simeq 18 \text{ bar}$$

End of Solution

97. A high-performance four-stroke SI engine has a compression ratio 10: 1. The ideal air standard Otto cycle efficiency is 0.602. The indicated efficiency is 55 percent of the corresponding ideal air standard Otto cycle efficiency. The engine mechanical efficiency is 85 percent, and the volumetric efficiency is 90 percent. The calorific value of the fuel is 44 MJ/kg. What is the engine arbitrary overall efficiency?

(a) 26.1% (b) 28.1%
(c) 29.5% (d) 30.5%

Ans. **(b)**

Given: $r = 10; \ \eta_{\text{air std.}} = 0.602; \ \eta_{\text{ith}} = 0.55 \times \eta_{\text{air std.}} \ \eta_m = 0.85;$

$$\eta_{\text{vol}} = 0.90; \ CV_{\text{fuel}} = 44 \text{ MJ/kg}$$

$$\eta_{\text{overall}} = \eta_{\text{ith}} \times \eta_m$$
$$= 0.55 \times \eta_{\text{air std.}} \times \eta_m$$
$$= 0.55 \times 0.602 \times 0.85$$
$$= 0.2814 \text{ or } 28.14\%$$

End of Solution

98. The performance test of an air- conditioning unit rated as 140.7 kW (40 TR) seems to be indicating poor cooling. The test on heat rejection to atmosphere in its condenser shows the following:

Cooling water flow rate : 4 L/s

Water temperatures: In 30 °C; Out 40 °C

Power input to motor: 48 kW (95% efficiency)

What is the actual refrigeration capacity of the unit? (The specific heat capacity of water is 4.1868 kJ/kg-K)

(a) 101.5 kW   (b) 167.4 kW
(c) 121.9 kW   (d) 189.3 kW

Ans. **(c)**

Given : P_{motor} = 48 kW (95% efficiency); T_{w0} = 40°C; T_{wi} = 30°C; $\dot{V}_W = 4L/s$;

C_{PW} = 4.1868 kJ/kgK

$$Q_H = \dot{m}C_p\Delta T$$

$$= \rho VC_{PW}\Delta T - \rho VC_{PW}(T_{WO} - T_{Wi})$$

$$= 1000 \times 4 \times 10^{-3} \times 4.1868 \times (40 - 30)$$

$$= 167.472 \text{ kW}$$

$$\dot{W}_{in} = 48 \times 0.95 = 45.6 \text{ kW}$$

$\therefore$ $$Q_L = Q_H - W_{in} = 167.472 - 45.6$$

$$= 121.872 \text{ kW} \simeq 121.9 \text{ kW}$$
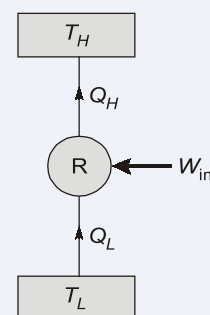
End of Solution

99. If the partial pressure of water vapour for the mixture of dry air and water vapour is 12.79 mm Hg and its total pressure is 736 mm Hg, then what is the specific humidity?

(a) 0.068 kg w.v./kg d.a.   (b) 0.011 kg w.v./kg d.a.
(c) 0.023 kg w.v./kg d.a.   (d) 0.044 kg w.v./kg d.a.

Ans. **(b)**

Given : P_V = 12.79 mm Hg; P_t = 736 mm Hg

$\therefore$ Specific humidity, $\omega = 0.622 \times \dfrac{P_v}{P_t - P_v}$

$$= 0.622 \times \frac{12.79}{736 - 12.79} = 0.011 \text{ kg w.v./kg d.a.}$$

End of Solution

100. If 1 m³ of a gas is compressed adiabatically (the ratio of specific heats = 1.4) from 1 bar to 5 bar in a reciprocating compressor, what is the work of compression?

(a) 192543 N-m   (b) 245361 N-m
(c) 158643 N-m   (d) 204050 N-m

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Ans. **(d)**

Given: $P_1 = 1$ bar, $P_2 = 5$ bar, $V_1 = 1$ m^3

For adiabatic compression,

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$
$$1 \times (1)^{1.4} = 5 \times V_2^{1.4}$$
$$\Rightarrow \qquad V_2 = 0.3167 \text{ m}^3$$

Now, work of compression is

$$W = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1} = \frac{1 \times 100 \times 1 - 5 \times 100 \times 0.3167}{0.4}$$
$$= -145.875 \text{ kJ} = -145875 \text{ N/m}$$

This is not given in any options.

Now, considering compressor work (i.e. open system)

$$W_C = \frac{\gamma}{\gamma - 1}(P_1 V_1 - P_2 V_2) = \gamma \times W = 1.4 \times (-145875) = -204224 \text{ Nm}$$

Thus, among the options, the most appropriate is (d).

End of Solution

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101. An R134a thermostatic expansion valve, not equipped with an external equalizer, has a superheat setting of 7 °C, while supplying the refrigerant to the evaporator at 0°C. The power fluid is same as refrigerant. What is the difference in pressure in opposite sides of the diaphragm required to open the valve? (Consider evaporator pressure at 0°C and 7°C as 2.928 bar and 3.748 bar respectively)

(a) 2.928 bar
(b) 3.748 bar
(c) 0.82 bar
(d) 6.676 bar

Ans. **(c)**

At 7°C $P_{evap,2} = 3.748$ bar
At 0°C $P_{evap,1} = 2.928$ bar

$\therefore$ The difference in pressure in opposite sides of the diaphragm required to open the valve

$$= 3.748 - 2.928 = 0.82 \text{ bar}$$

End of Solution

---

102. A machine working on a Carnot cycle operates between 305 K and 260 K. What is the COP when it is operated as a refrigerating machine?

(a) 5.78
(b) 4.35
(c) 1.17
(d) 6.78

Ans. **(a)**

Given : $T_L = 260$K; $T_H = 305$K

$$\text{COP}_{Ref} = \frac{T_L}{T_H - T_L} = \frac{260}{305 - 260}$$
$$= 5.778$$
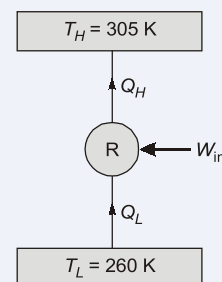
End of Solution

103. A cold storage plant is required to store fish. The fish is supplied at a temperature of 30 °C. The fish is stored in cold storage which is maintained at –8 °C. If the plant requires 75 kW to drive it, what is the capacity of the plant? (Assume actual COP of the plant as 0.3 of the Carnot COP)

(a) 40.8 TR   (b) 35.9 TR
(c) 44.8 TR   (d) 54.6 TR

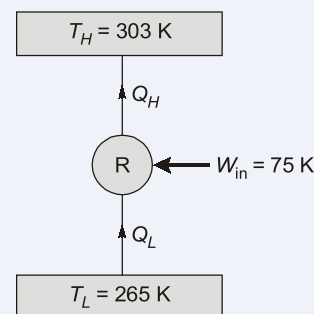**Ans. (c)**

Given :
$$T_H = 30°C = 30 + 273 = 303 \text{ K}$$
$$T_L = -8°C = -8 + 273 = 265 \text{ K}$$
$$COP_{act} = 0.3 \times COP_{carnot}$$
$$= 0.3 \times \frac{265}{303 - 265} = 2.092$$

$$\Rightarrow \quad COP_{act} = 2.092 = \frac{Q_L}{W_{in}}$$

$$\Rightarrow \quad Q_L = W_{in} \times 2.092$$
$$= 75 \times 2.092 = 156.91 \text{ kW}$$

$$\Rightarrow \quad Q_L = \frac{156.91}{3.5} = 44.83 \text{ TR} \simeq 44.8 \text{ TR}$$

[Diagram: $T_H = 303$ K at top, Q_H arrow up, R (reservoir circle) with $W_{in} = 75$ K arrow, Q_L arrow up, $T_L = 265$ K at bottom]

End of Solution

104. On a particular day, the atmospheric air records a partial pressure of water vapour 9.62 mm Hg and the saturation pressure of vapour is 31.8 mm Hg. The barometric pressure is observed to be 756 mm Hg. What are the relative humidity and the specific humidity respectively?

(a) 30.25%, 0.008   (b) 30.25%, 0.014
(c) 35.87%, 0.014   (d) 35.87%, 0.008

Ans. (a)

Given : $P_V = 9.62$ mm Hg; $P_{VS} = 31.8$ mm Hg; $P_t = 756$ mm Hg

∴ Relative humidity, $\phi = \dfrac{P_V}{P_{VS}} = \dfrac{9.62}{31.8} = 0.3025 = 30.25\%$

Specific humidity, $\omega = 0.622 \times \dfrac{P_V}{P_t - P_V} = 0.622 \times \dfrac{9.62}{756 - 9.62}$
$$= 0.008 \text{ kg w.v./kg d.a.}$$

End of Solution

105. A small water-cooled condenser uses mains water at 13 °C and heats this to 24 °C before it goes to waste. The evaporator duty is 4.2 kW and the motor output is 1.7 kW. What is the water mass flow?

(a) 0.09 kg/s   (b) 0.19 kg/s
(c) 0.21 kg/s   (d) 0.13 kg/s

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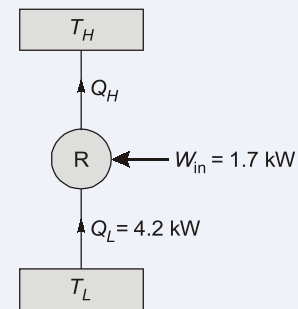**Ans.** **(d)**

$$Q_H = Q_L + W_{in}$$
$$= 4.2 + 1.7 = 5.9 \text{ kW}$$

$$\therefore \qquad Q_H = \dot{m}_w C_{pw}(T_0 - T_i)$$

$$5.9 = \dot{m}_w \times 4.187 \times (24 - 13)$$

$$\Rightarrow \qquad \dot{m}_w = \frac{5.9}{4.187 \times 11}$$
$$= 0.128 \text{ kg/s} \simeq 0.13 \text{ kg/s}$$

T_H — *Q_H* — R ← W_{in} = 1.7 kW — Q_L = 4.2 kW — *T_L*

106. Consider that the Rankine cycle efficiency is improved in the following ways:
1. By reducing heat addition in boiler
2. By increasing expansion work steam turbine
3. By reducing feed pump work

Which of the above are correct?
(a) 1 and 2 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans. **(b)**

$$\uparrow \eta_{th} = 1 - \left(\frac{Q_R}{Q_s \uparrow}\right)\downarrow$$

Thus, by increasing heat addition in boiler, results in improved efficiency.

107. What is the actual pressure of air in the tank if the pressure of compressed air measured by manometer is 30 cm of mercury and atmospheric pressure is 101 kPa?
(Take g = 9.78 m/s² and density of mercury at room temperature as 13550 kg/m³)
(a) 140.76 GPa
(b) 140.76 MPa
(c) 140.76 kPa
(d) 140.76 Pa

Ans. **(c)**

Given: h = 30 cm of Hg, P_{atm} = 101 kPa, ρ_{Hg} = 13550 kg/m³, g = 9.78 m/s².

$$P_{actual} = P_{atm} + P = P_{atm} + \rho g h$$
$$= (101 \times 10^3) + (13550 \times 9.78 \times 0.30)$$
$$= 140755.7 \text{ Pa} = 140.7557 \text{ kPa}$$
$$\simeq 140.76 \text{ kPa}$$

108. The equation for two-dimensional steady-state conduction without heat sources is

(a) $\dfrac{d^2T}{dr^2} + \dfrac{q}{k} = 0$

(b) $\dfrac{d^2T}{dx^2} + \dfrac{1}{r}\dfrac{dT}{dr} = 0$

(c) $\dfrac{d^2T}{dx^2} = 0$

(d) $\dfrac{\partial^2T}{\partial x^2} + \dfrac{\partial^2T}{\partial y^2} = 0$

Ans. (d)

The governing equation for two-dimensional steady-state conduction without internal heat generation is given by:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0$$

109. Which one of the following expressions is correct about the relation among Grashof number (Gr), Prandtl number (Pr) and Rayleigh number (Ra)?

(a) Ra = Gr Pr
(b) Gr = Ra Pr
(c) Ra = Gr − Pr
(d) Gr = Ra − Pr

Ans. (a)

Rayleigh number = Grashof number × Prandtl number

Ra = Gr Pr

110. An order-of-magnitude analysis of the free convection boundary layer equations will indicate a general criterion for determining whether free convection effects dominate. The criterion is that when

(a) $Gr/Re^2 < 10$, then free convection is of primary importance
(b) $Gr/Re^2 = 10$, then free convection is of primary importance
(c) $Gr/Re^2 > 10$, then free convection is of primary importance
(d) $Gr/Re^2 > 10$, then forced convection is of primary importance

Ans. (c)

- If $\dfrac{Gr}{Re^2} > 10$, then free convection is of primary importance.

- If $\dfrac{Gr}{Re^2} < 10$, then force convection is of primary importance.

111. If the monochromatic emissivity of a body is independent of wavelength, it is called

(a) transparent body
(b) reflective body
(c) black body
(d) gray body

Ans. (d)

For grey body, monochromatic emissivity is independent of wavelength.

$\in_\lambda$ = Constant

112. Which one of the following equations is called Kirchhoff's identity?

(a) $\varepsilon = \dfrac{E}{E_b}$

(b) $\varepsilon = \dfrac{E_b}{E}$

(c) $\varepsilon = \infty$

(d) $\varepsilon = 1$

Ans. **(*)**

According to Kirchoff's identity, $\varepsilon = \alpha$

where, ε = Total emissivity

α = absorptivity

Note: There is typing error 'α' is written as '∞'.

End of Solution

113. The interface angles of rhombohedral crystal systems are

(a) $\alpha = \beta = \gamma \neq 90°$

(b) $\alpha = \beta = \gamma = 90°$

(c) $\alpha = \beta = 90° \neq \gamma$

(d) $\alpha = \beta = 90°; \gamma = 120°$

Ans. **(a)**

The interface angles of rhombohedral crystal system, are $\alpha = \beta = \gamma \neq 90°$.

End of Solution

114. Consider the following statements for the characteristics of ionic compounds :

1. Ionic compounds are generally crystalline in nature and rigid.
2. They are generally non-conductors of electricity.
3. They are insoluble in organic solvents, but highly soluble in water.

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)**

The three given statements are properties of ionic compounds.

End of Solution

115. Consider the following statements for the characteristics of covalent compounds:

1. They can exist in all states of matter.
2. They are generally electric insulators.
3. They are insoluble in water, but soluble in non-polar solvents such as benzene and alcohol, etc.

Which of the above statements are correct?

(a) 1 and 3 only

(b) 2 and 3 only

(c) 1 and 2 only

(d) 1, 2 and 3

Ans. **(d)**

Covalent compounds exist in all states of matter, they are poor conductors/Insulators. They are insoluble in water, but can become soluble in non-polar solvents like benzene and alcohol.

End of Solution

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116. Consider the following statements:
1. X-rays are not deflected by electric or magnetic fields.
2. They produce fluorescence in many substances.
3. They are highly penetrating and destructive on living tissues on excessive exposure.
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)**

X-rays are not defected by electric/magnetic field because they do not carry any charge. They are only electro-magnetic radiations.

End of Solution

117. Consider the following statements:
The application of X-rays in scientific research is
1. to investigate the structure of crystalline solids.
2. to study complex organic compounds by analyzing their structures.
3. to find the atomic numbers and energy levels to identify the elements.
Which of the above statements are correct?
(a) 1 and 3 only
(b) 2 and 3 only
(c) 1 and 2 only
(d) 1, 2 and 3

Ans. **(d)**

Henry moseley experiments, showed that the frequencies of the x-rays emitted from an element (under bombardment by cathode rays) were characteristics of that element and could be used to identify the charge on its atomic nucleus.

End of Solution

118. Consider the following statements:
The influence of molybdenum element in steels
1. imparts higher temperature strength.
2. enhances resistance to creep
3. minimizes temperature brittleness
Which of the above statements is/are correct?
(a) 1 only
(b) 2 and 3 only
(c) 1 and 2 only
(d) 1, 2 and 3

Ans. **(d)**

Molybdenum is a carbide forming element in steel. It increases high temperature strength, creep resistance and inhibits temperature embrittlement.

End of Solution

119. The alloying elements of tungsten-based tool steels are
(a) Cr, V, Co and W
(b) Cr and V only
(c) Cr, Ni and Mo
(d) Cr, W, V and Mo

Ans. **(d)**

18-4-1 tool steels contains 18% W, 4% Cr, 1% V and 9.5% Co. Cobalt increases heat resistance.
India does not have secured source of Cobalt. Hence, in its place Molybdenum is used".

End of Solution

120. Consider the following disadvantages of LAUE methods :
1. Various reflections may make the appearance of the photograph complicated.
2. Due to the wide range of wavelengths, there is overlapping of diffraction images.
3. There is a variation of incident X-ray beam due to the large range of wavelengths.
Which of the above disadvantages is/are correct?
(a) 1 and 3 only
(b) 1 and 2 only
(c) 3 only
(d) 1, 2 and 3

Ans. **(d)**
LAUE method is also called powder method for determination of crystal structure. It can not be used for quantitative analysis because wavelength of X-ray beam that is causing a specific spot is unknown, clearly. It also required a large crystal. It is best suited for single crystal samples. It relies on the order and periodic arrangement of atoms within a single crystal, to produce a clear diffraction pattern. LAUE diffraction relates to scattering of waves in the process of diffraction of crystal.

End of Solution

121. When a body is acted upon by pure shear stresses on two perpendicular planes, the planes inclined at 45° are subjected to
(a) a tensile stress of magnitude equal to that of the shear stress
(b) a compressive stress of magnitude equal to that of the shear stress
(c) a torsional stress of magnitude equal to that of the shear stress
(d) a bending stress of magnitude equal to that of the shear stress
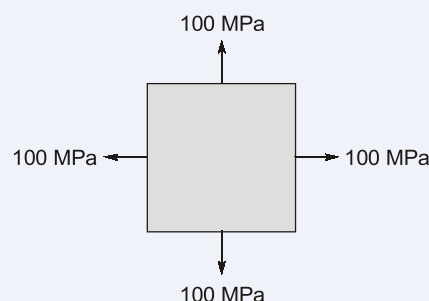
Ans. **(a, b)**
Here, it is not mentioned that the plane is inclined by 45° in clockwise or anticlockwise manner. Also, the sense of applied shear stresses is not mentioned. Hence, the stress on given plane can be both tensile or compressive.
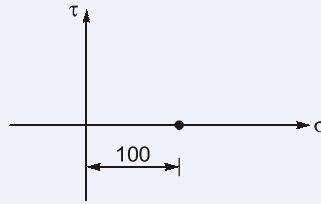
End of Solution

122. A piece of material is subjected to same two perpendicular tensile stresses of 100 MPa each. What is the direct stress?
(a) 90 MPa
(b) 100 MPa
(c) 96 MPa
(d) 86 MPa

Ans. **(b)**
In element is shown below

The corresponding Mohr circle will be a point as shown below:

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$$\tau$$

100

$$\sigma$$

Hence, direct stress on every plane will be 100 MPa.

123. The strain energy per unit volume required to cause the material to rupture is called
(a) modulus of toughness
(b) modulus of rigidity
(c) resilience
(d) proof resilience

Ans. **(a)**

124. Consider the following regarding buckling concept:
1. Buckling can occur when the induced stresses are compressive such as in a column.
2. Buckling analysis uses the Young's modulus of the material and the moment of inertia of the column cross-section, as well as its length.
3. The load that buckles the column is called the crushing load.
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)**

Load responsible for buckling is known as buckling load. Crushing load is generally observed for short columns.

125. Consider the following statements regarding theories of failures:
1. Maximum principal strain theory is known as St. Venant's theory.
2. Maximum shear strain energy theory is known as Mises and Hencky theory.
3. Maximum strain energy theory is known as Guest and Tresca theory
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)**
- Maximum strain energy theory is known as Haigh's or Beltrami's theory.
- Maximum shear stress theory is known as Guest and Tresca theory.

126. Consider the following statements regarding beams :
1. Beams with one end fixed and the other end simply supported are known as propped cantilevers.

    2.   Beams supported at more than two sections are known as fixed beams.

    3.   Beams with one end fixed and the other end free are known as cantilevers.

    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.   **(b)**

    Fixed beams are the beams with fixed supports at its two ends.

End of Solution

127.   Consider the following statements regarding effective length of a column:

    1.   The effective length is the distance between the points of inflection in the deformed shape of the column, which is referred to as the elastic curve.

    2.   At the inflection point, the moment does not change sign and the member is not expected to resist any moment.

    3.   At the transition point, the curvature is changed and it is called the contraflexure point.

    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.   **(b)**

End of Solution

128.   Consider the following statements regarding power transmitted through a circular shaft :

    1.   The stress and deformation induced in the shaft can be calculated by relating power to torque.

    2.   The power produced by a motor is rated in terms of shaft horsepower at a specified rotational speed.

    3.   Power is defined as the work done per unit time.

    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)**

End of Solution

129.   When a body is acted upon by pure shear stresses on two perpendicular planes, the planes subjected to inclined at 135° are

    (a) a tensile stress of same magnitude with no shear stress on these planes.

    (b) a compressive stress of same magnitude with no shear stress on these planes.

    (c) a torsional stress of same magnitude with no shear stress on these planes.

    (d) a bending stress of same magnitude with no shear stress on these planes.

Ans. **(a, b)**

Here, it is not mentioned that the plane is inclined by 135° in clockwise or anticlockwise manner. Also, the sense of applied shear stresses is not mentioned. Hence, the stress on given plane can be both tensile or compressive.

End of Solution

130. Which one of the following is the ability of a material to regain its original shape on removal of the applied load?
(a) Proof resilience
(b) Resilience
(c) Modulus of resilience
(d) Gradual resilience

Ans. **(c)**

End of Solution

131. Which one of the following properties is not an extensive property of a system?
(a) Energy
(b) Enthalpy
(c) Volume
(d) Temperature

Ans. **(d)**

End of Solution

132. Two cylindrical vessels of 2 m^3 each are inter-connected through a pipe with a valve in-between. Initially, the valve is closed and one vessel has 20 kg air while 4 kg of air is there in second vessel. Assuming the system to be at 27 °C temperature initially and perfectly insulated, what is the final pressure in vessels after the valve is opened to attain equilibrium?
(a) 516.6 kPa
(b) 51.66 kPa
(c) 561.6 kPa
(d) 56.16 kPa

Ans. **(a)**

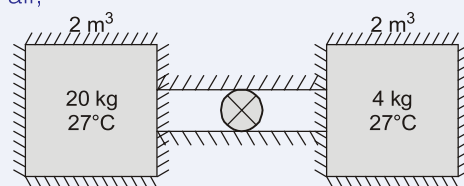After attainment of equilibrium, total mass of air,

$$m = 24 \text{ kg}$$

Final total volume, $V = 2 + 2 = 4 \text{ m}^3$

Assuming air to be an ideal gas,

$$PV = mRT$$

$$P = \frac{24 \times 287 \times 300}{4} = 516600 \text{ N/m}^2$$

$$P = 516.6 \text{ kPa}$$

End of Solution

133. Thermoelectric thermometer works on the principle of
(a) Wheatstone bridge
(b) entropy
(c) Seebeck effect
(d) ohmmeter

Ans. (c)

In 1821, German physicist Thomas Seebeck discovered that when two wires made from dissimilar metals are joined at two ends to form a loop, and if the two junctions are maintained at different temperatures, a voltage develops in the circuit. This phenomenon is therefore named after him.

End of Solution

134. Isentropic expansion efficiency is expressed as
(a) Ideal work in expansion – Actual work in expansion
(b) Actual work in expansion + Ideal work in expansion
(c) $\dfrac{\text{Ideal work in expansion}}{\text{Actual work in expansion}}$
(d) $\dfrac{\text{Actual work in expansion}}{\text{Ideal work in expansion}}$

Ans. (d)

Isentropic expansion efficiency is the ratio of actual work in expansion to ideal work in expansion.

End of Solution

135. In the reheat cycle, the principal advantage of reheat is to increase the quality of steam at
(a) turbine exhaust   (b) turbine inlet
(c) feed pump inlet   (d) feed pump exhaust

Ans. (a)
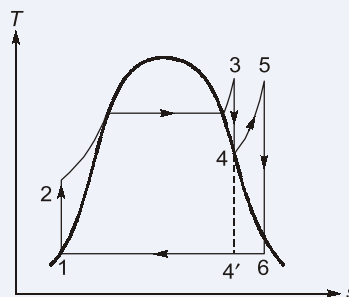
The principal advantages of reheating in Rankine cycle is to increase the quality of steam at turbine exhaust.

End of Solution

136. Consider the following statements:
1. Viscosity of liquid increases with increase in temperature.
2. Viscosity of gas decreases with increase in temperature.
3. In liquids, cohesive forces predominate the molecular momentum transfer.
4. In gases, cohesive forces are small and the molecular momentum transfer predominates.

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Which of the above statements are correct?

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

(c) 3 and 4 only   (d) 1, 2, 3 and 4

Ans. **(c)**

- Viscosity of liquid decreases with increase in temperature.
- Viscosity of gas increases with increase in temperature.

End of Solution

137. A fluid in which shear stress is more than the yield value and shear stress is proportional to the rate of shear strain is known as

(a) non-ideal plastic fluid   (b) Newtonian fluid

(c) non-Newtonian fluid   (d) ideal plastic fluid

Ans. **(d)**

The relation between shear stress and rate of deformation for non-Newtonian fluid is given as

$$\tau = A\left(\frac{du}{dy}\right)^n + B$$

where, n = Flow behaviour index,

                      A = Consistency index and

                      B = Residual strength

If $B \neq 0$ and $n = 1$.

It is ideal plastic fluid.
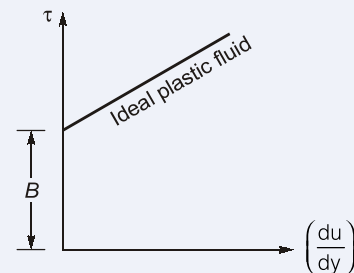
End of Solution

138. Two horizontal plates are placed 1.25 cm apart, the space between them being filled with an oil of viscosity 15 poises. What is the shear stress in the oil if the upper plate is moved with a velocity of 2.5 m/s?

(a) 280 N/m^2 (b) 260 N/m^2

(c) 300 N/m^2 (d) 250 N/m^2

Ans. **(c)**

Given: $h = 1.25$ cm $= 0.0125$ m, $\mu = 15$ poise $= 1.5$ Pa-s, $v = 2.5$ m/s

Using Newton's laws of viscosity,

$$\tau = \mu\frac{\Delta V}{\Delta h} = \mu\left(\frac{v-0}{h-0}\right) = \mu\frac{v}{h}$$

$$= 1.5 \times \frac{2.5}{0.0125} = 300 \text{ N/m}^2$$

End of Solution

139. What is the capillary rise in a glass tube of 2.0 mm diameter when immersed vertically in mercury? (Take surface tension of mercury as 0.52 N/m. The specific gravity of mercury is 13.6 and the angle of contact is 130°)

(a) –0.25 cm
(b) –0.65 cm
(c) –0.8 cm
(d) –0.5 cm

Ans. **(d)**

Given: $d = 2$ m = 0.002 m, $\sigma = 0.52$ N/m, $\rho = 13.6 \times 10^3$ kg/m³, $\theta = 130°$

Capillary rise is given as,

$$h = \frac{4\sigma\cos\theta}{\rho g d} = \frac{4 \times 0.52 \times \cos(130°)}{\left(13.6 \times 10^3\right) \times (9.81) \times (0.002)}$$

$$= -5.010 \times 10^{-3} \text{ m} = -5.010 \text{ mm}$$

$$= -0.5010 \text{ cm} \simeq -0.5 \text{ cm}$$

End of Solution

140. Consider the following statements :

1. One end of piezometer is connected to the point where pressure is to be measured and the other end is open to the atmosphere.
2. Inverted U-tube differential manometer is used to measure high pressure.
3. U-tube differential manometer contains heavy liquids.

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. **(b)**

• Inverted U-tube differential manometer is used to measure low pressure.

End of Solution

141. A circular opening, 3 m diameter, in a vertical side of a tank is closed by a disc of 3 m diameter which can rotate about a horizontal diameter. What is the force on the disc if the head of water above the horizontal diameter is 5 m?

(a) 277.4 kN
(b) 324.4 kN
(c) 311.2 kN
(d) 346.7 kN

Ans. **(d)**

Given: $\bar{x} = 5$ m, $d = 3$ m, $\rho = 1000$ kg/m³
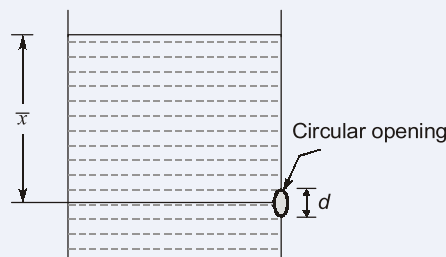
Force acting on the disc,

$$F_P = \rho A g \overline{x} = \rho \left(\frac{\pi}{4} d^2 \right) g \overline{x} = 1000 \times \frac{\pi}{4} \times (3)^2 \times 9.81 \times 5$$

$$= 346714.0192 \text{ N} = 346.714 \text{ kN}$$
$$\simeq 346.7 \text{ kN}$$

End of Solution

142. Consider the following statements regarding dynamics of fluid flow :
1. Pitot tube is a device used to measure rate of flow of fluid through a pipe.
2. Orifice meter is a device used for measuring velocity of flow at any point in a pipe.
3. Venturi meter consists of converging part, throat and diverging part.
Which of the above statements is/are correct?
(a) 1 and 3 only (b) 2 only
(c) 3 only (d) 1 and 2 only

Ans. **(c)**
- Pitot tube is a device used to measure velocity of flow at any point in a pipe.
- Orifice meter is a device used to measure rate of flow of fluid through a pipe.

End of Solution

143. What is the pressure gradient per metre width for the laminar flow of oil with a maximum velocity of 2 m/s between two horizontal parallel fixed plates which are 100 mm apart?
(Take dynamic viscosity = 2.5 N-s/m²)
(a) −4000 N/m² per m (b) −3700 N/m² per m
(c) −3500 N/m² per m (d) −3200 N/m² per m

Ans. **(a)**
Given: u_{max} = 2 m/s, h = 100 mm, μ = 2.5 N-s/m²
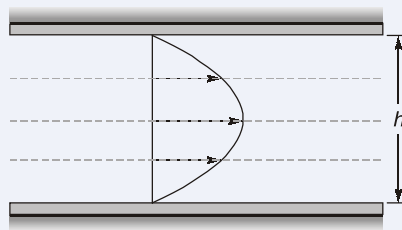
For fluid flow between two fixed parallel plate,

$$u_{max} = \frac{1}{8\mu} \left(-\frac{dP}{dx} \right) h^2$$

$$\Rightarrow \qquad 2 = \frac{1}{8 \times 2.5} \times \left(-\frac{dP}{dx} \right) \times (0.1)^2$$

$$\Rightarrow \qquad \frac{dP}{dx} = \frac{-2 \times 8 \times 2.5}{(0.1)^2} = -4000 \text{ N/m}^2 \text{ per m}$$

End of Solution

144. Consider following statements regarding dynamics of fluid flow :

1. Kinetic energy correction factor is defined as the ratio of kinetic energy of the flow per second based on actual velocity to kinetic energy of the flow per second based on average velocity.

2. Kinetic energy correction factor is defined as the ratio of kinetic energy of the flow per second based on average velocity to kinetic energy of the flow per second based on maximum velocity.

3. Momentum correction factor is defined as the ratio of momentum of the flow per second based on actual velocity to momentum of the flow per second based on average velocity.

4. Momentum correction factor is defined as the ratio of momentum of the flow per second based on average velocity to momentum of the flow per second based on maximum velocity.

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. **(b)**

Kinetic energy correction factor is given as,

$$\alpha = \frac{(\text{Kinetic energy of the flow per second})_{actual}}{(\text{Kinetic energy of the flow per second})_{average}}$$

Moment correction factor is given as,

$$\beta = \frac{(\text{Momentum of the flow per second})_{actual}}{(\text{Momentum of the flow per second})_{average}}$$

End of Solution

145. An oil is flowing through a pipe of diameter 300 mm with velocity of 5 m/s. What is the head loss to maintain the flow for a length of 1000 m? (Take coefficient of friction = 0.005)

(a) 60.2 m   (b) 72.4 m

(c) 76.7 m   (d) 84.9 m

Ans. **(d)**

Given: d = 300 mm, v = 5 m/s, L = 1000 m, f' = 0.005

Friction head loss is given as,

$$h_f = \frac{4f'Lv^2}{2gd} = \frac{4 \times 0.005 \times 1000 \times 5^2}{2 \times 9.81 \times 0.300}$$

$$= 84.947 \text{ m} \simeq 84.9 \text{ m}$$

End of Solution

146. Consider the following statements :
1. The apparent viscosity of a pseudoplastic fluid decreases with decrease in the shear rate.
2. The apparent viscosity of a dilatant fluid increases with increase in the shear rate.
3. Bingham plastic fluid requires a finite yield stress before beginning to flow.
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. **(c)**
- The apparent viscosity of a pseudoplastic fluid decreases with increase in the shear rate.

End of Solution

147. The dimensional formula of bulk modulus of elasticity in MLT notation system is
(a) MLT^{-1}
(b) $M^{-1} L T^2$
(c) $M^{-1}LT^{-1}$
(d) $M L^{-1} T^{-2}$

Ans. **(d)**

$$\text{Dimension of bulk modulus} = \frac{\text{Dimension of hydrostatic stress}}{\text{Dimension of volumetric strain}}$$

$$= \frac{\left[ML^{-1}L^{-2}\right]}{\left[M^0L^0T^0\right]} = \left[ML^{-1}T^{-2}\right]$$

End of Solution

148. Consider the following statements regarding general conventions in stress analysis :
1. Tensile stress is positive and compressive stress is negative.
2. A pair of shear stresses on parallel planes forming a clockwise couple is positive and a pair with a counterclockwise couple is negative.
3. Clockwise angle is taken as negative and counterclockwise couple is positive.
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)**

End of Solution

149. Consider the following statements regarding principle of superposition:
1. The principle of superposition states that if a body is acted upon by a number of loads on various segments of the body, then the net effect on the body is the sum of the effects caused by each of the loads acting independently on the respective segment of the body.
2. The superposition principle applies to all parameters like stress, strain and deflection.
3. The superposition principle is applicable to materials with non-linear stress-strain characteristic, which do not follow Hooke's law.

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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)**

Statement 3 is not correct as superposition principle applies only to linear cases.

End of Solution

150. Rails are laid such that they have no stress at 24 °C. What is the stress in the rails at 80 °C, when there is no allowance for expansion? (Assume coefficient of linear expansion = 11×10^{-6} °C^{-1} and Young's modulus of rails metal = 205 GPa)
(a) 126.28 MPa   (b) 251.84 MPa
(c) 296.72 MPa   (d) 325.35 MPa

Ans. **(a)**

Given: $T_1 = 24°C$, $T_2 = 80°C$, $\alpha = 11 \times 10^{-6}/°C$, $E = 205$ GPa $= 205 \times 10^3$ MPa.

Thermal stress, $\sigma = \alpha \Delta T E = \alpha(T_2 - T_1) \times E$

$$= 11 \times 10^{-6} \times (80 - 24) \times 205 \times 10^3$$

$$= 126.28 \text{ MPa}$$

End of Solution

■■■■