DETAILED SOLUTIONS

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 18

Full Syllabus Test 2 : Paper-II

Answer Key

1. (d)	26. (a)	51. (d)	76. (a)	101. (a)	126. (c)
2. (c)	27. (d)	52. (a)	77. (c)	102. (d)	127. (c)
3. (c)	28. (d)	53. (b)	78. (b)	103. (c)	128. (c)
4. (a)	29. (b)	54. (a)	79. (d)	104. (d)	129. (a)
5. (c)	30. (c)	55. (c)	80. (c)	105. (d)	130. (d)
6. (c)	31. (d)	56. (d)	81. (a)	106. (d)	131. (b)
7. (a)	32. (d)	57. (a)	82. (c)	107. (c)	132. (a)
8. (c)	33. (b)	58. (c)	83. (b)	108. (c)	133. (a)
9. (c)	34. (c)	59. (c)	84. (b)	109. (d)	134. (c)
10. (b)	35. (d)	60. (c)	85. (b)	110. (c)	135. (d)
11. (d)	36. (c)	61. (b)	86. (c)	111. (c)	136. (c)
12. (a)	37. (c)	62. (d)	87. (d)	112. (b)	137. (c)
13. (d)	38. (a)	63. (d)	88. (b)	113. (b)	138. (b)
14. (b)	39. (b)	64. (b)	89. (c)	114. (c)	139. (b)
15. (a)	40. (d)	65. (b)	90. (c)	115. (a)	140. (a)
16. (c)	41. (a)	66. (c)	91. (b)	116. (d)	141. (c)
17. (b)	42. (d)	67. (b)	92. (c)	117. (c)	142. (a)
18. (c)	43. (a)	68. (d)	93. (b)	118. (c)	143. (a)
19. (d)	44. (a)	69. (d)	94. (c)	119. (c)	144. (d)
20. (d)	45. (d)	70. (a)	95. (b)	120. (b)	145. (b)
21. (d)	46. (a)	71. (d)	96. (d)	121. (c)	146. (b)
22. (c)	47. (d)	72. (d)	97. (a)	122. (d)	147. (a)
23. (a)	48. (d)	73. (c)	98. (a)	123. (d)	148. (b)
24. (d)	49. (a)	74. (c)	99. (b)	124. (b)	149. (b)
25. (b)	50. (d)	75. (a)	100. (a)	125. (a)	150. (d)

1. (d)

The convection heat transfer coefficient h is not a property of the fluid. It is an experimentally determined parameter whose value depends on all the variables influencing convection such as the surface geometry, the nature of the fluid motion, the properties of the fluid, and the bulk fluid velocity.

2. (c)

Given : i = 2000 A / cm^2 = 2 × 10^7 A / m^2 ; $\dot{q}$ = 6 × 10^7 W / m^3

$$\because \quad \dot{q} = \frac{I^2 R}{AL} \times \frac{A}{A} \qquad \left\{\because \; R = \frac{\rho L}{A}\right\}$$

$$= \frac{I^2}{A^2} \times \frac{RA}{L}$$

$$\Rightarrow \quad \dot{q} = i^2 \times \rho$$

$$\Rightarrow \quad \rho = \frac{6 \times 10^7}{(2 \times 10^7)^2} = 1.5 \times 10^{-7}\ \Omega\text{-m}$$

ir ρ = 1.5 × 10^{-5} Ω-cm

3. (c)

Given : $\dot{q}$ = 6 × 10^6 W / m^3; R_0 = 0.06 m; k = 12 Wm-K; T_s = 90°C

$$T_o = T_s + \frac{\dot{q} R_0^2}{6k} = 90 + \frac{6 \times 10^6 \times (0.06)^2}{6 \times 12}$$

$$T_o = 390°\text{C} = 663\ \text{K}$$

4. (a)

Given : T_s = 127°C = 400 K; T_∞ = 17°C; T_{surr} = 27°C = 300 K; h = 15 W / m^2-K; A = 4 m^2

$$q_{Loss} = hA(T_s - T_\infty) + \sigma A\left(T_s^4 - T_{surr}^4\right)$$

$$= 15 \times 4 \times (127 - 17) + 5.67 \times 10^{-8} \times 4 \times (400^4 - 300^4)$$

$$= 6600 + 3969 = 10569\ \text{W}$$

or q_{loss} = 10.57 kW

5. (c)

Resistance heater wire :

Cylindrical system with heat generation,

$$k = \text{constant}; \frac{\partial T}{\partial t} = 0 \ \text{(steady state)}$$

Heat conductivity equation,

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r \frac{\partial T}{\partial r}\right) + \frac{\dot{q}}{k} = 0$$

6. (c)

We know that,

$$\frac{(T - T_\infty)}{(T_i - T_\infty)} = e^{-t/\tau} \qquad (\tau : \text{Time constant})$$

after $t = \tau$

$$T - T_\infty = \frac{(T_i - T_\infty)}{e} = 0.3678(T_i - T_\infty)$$

∴ Temperature difference decrease to 36.78% of initial.

$$q = hA(T - T_\infty)$$

∴ Rate of heat loss from lump decreases to 63.2% of initial.

7. (a)

Given : $(c_p)_h$ = 4.25 kJ/kgK; $\dot{m} = 1.5$ kg/s; $(T_h)_i = 80°\text{C}$; $(T_h)_o = 45°\text{C}$

$$\text{Heat transfer rate, } q = UA_s(\text{LMTD}) = \dot{m}_h (c_p)_h (T_{h,i} - T_{h,o})$$

$$\Rightarrow \quad 1050 \times 3 \times \text{LMTD} = 1.5 \times 4.25 \times 10^3 \times 35$$

$$\Rightarrow \quad \text{LMTD} = 70.83°\text{C}$$

8. (c)

$$\rho = 0.4, \ \tau = 0.15$$

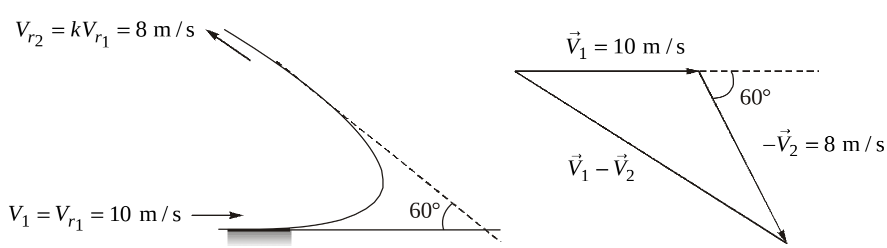
$$\alpha + \rho + \tau = 1$$

$$\alpha + 0.4 + 0.15 = 1$$

$$\alpha = 0.45$$

$$\alpha = \varepsilon = 0.45 \text{ from Kirchoff's law}$$

9. (c)



$$\vec{F}_{on\ jet} = \Delta\vec{p}_{of\ jet} = \dot{m}(\vec{V}_2 - \vec{V}_1)$$

$$\vec{F}_{on\ blade} = \Delta\vec{F}_{on\ jet} = \dot{m}(\vec{V}_1 - \vec{V}_2)$$

$$|\vec{F}_{on\ blade}| = \dot{m}\left|(\vec{V}_1 - \vec{V}_2)\right|$$

$$\dot{m}\left|\left(\vec{V}_1 - \vec{V}_2\right)\right| = 10 \times \sqrt{\left|\vec{V}_1\right|^2 + \left|\vec{V}_2\right|^2 + 2\left|\vec{V}_1\right|\left|\vec{V}_2\right|\cos\theta}$$

$$= 10 \times \sqrt{10^2 + 8^2 + 2(10)(8)\cos 60°}$$

$$= 10 \times \sqrt{244}$$

$$= 10(15.62) = 156.2 \text{ N}$$

10. (b)

$$\eta_o = \eta_m \cdot \eta_H$$
$$= 0.9 \times 0.85$$
$$= 0.765 = 76.5\%$$

11. (d)

$$\eta_{max} = \frac{1 + k\cos\alpha}{2} = \frac{1 + (0.8)\frac{\sqrt{3}}{2}}{2}$$

$$= 0.5 + 0.2\left(\sqrt{3}\right) = 0.8464 = 84.64\%$$

12. (a)

Equation which describes energy transfer in rotating is "Euler's energy equation".

$$E = T\omega$$

$$= \left(V_{w_1}u_1 - V_{w_2}u_2\right) = \frac{1}{2}\left[\left(V_1^2 - V_2^2\right) + \left(u_1^2 - u_2^2\right) - \left(V_{r_1}^2 - V_{r_2}^2\right)\right]$$

13. (d)

Uses of air vessel in a reciprocating pump:

(a) Suction side:

(i) Reduces the possibility of cavitation.

(ii) The pump can be run at a higher speed.

(iii) The length of the suction pipe below the air vessel can be increased.

(b) Delivery side:

(i) A large amount of power consumed in supplying the accelerating head can be saved.

(ii) Maintains almost a constant rate of discharge.

14. (b)

Energy Equation with Acceleration Head

If the unsteady term of the Euler's equation, i.e., the temporal derivative of the velocity is taken care of in the derivation of Bernoulli's equation, then we can arrive at a modified form of the Bernoulli's equation for an unsteady but incompressible flow as

$$\frac{1}{g}\int\frac{\partial V}{\partial t}dS + \int\frac{V^2}{2g} + \frac{p}{\rho g} + z = C$$

where C is a constant along a streamline. The first term in equation represents the accelerative head. Therefore, Bernoulli's equation between two points 1 and 2 along a streamline can be written, for an unsteady flow, along with the consideration of friction loss as

$$\frac{p_1}{\rho g}+\frac{V_1^2}{2g}+z_1 = \frac{p_2}{\rho g}+\frac{V_2^2}{2g}+z_2+h_f+h_i$$

where h_f is the head loss due to friction, and

$$h_i = \frac{1}{g}\int_1^2 \frac{\partial V}{dt}dS \text{ is the acceleration head}$$

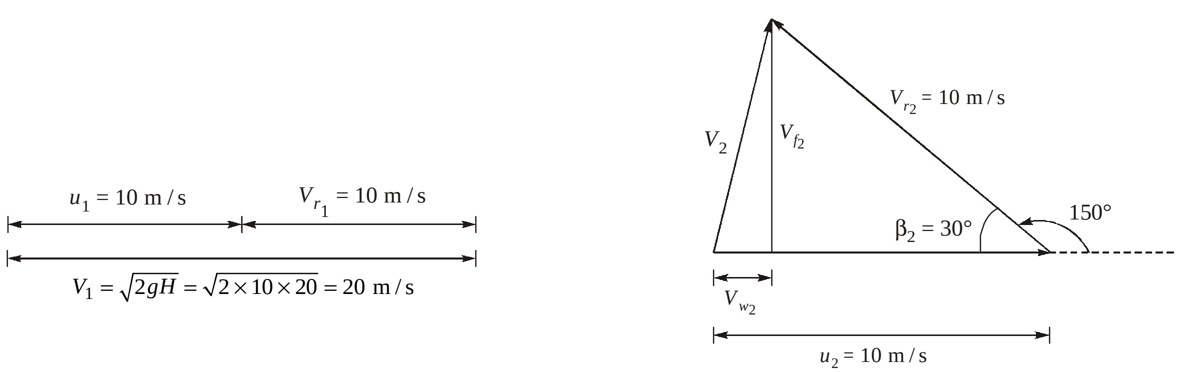
15. (a)

For single acting reciprocating pump = 84.8% of work is saved

For double acting reriprocating pump = 39.2% of work is saved

16. (c)

17. (b)



$$e = V_{w_1}u_1 - V_{w_2}u_2$$

$$\text{Power} = \dot{E} = \dot{m}e = \rho Q\left(V_{w_1}-V_{w_2}\right)u; \qquad \left(\because\ u_1 = u_2 = u = 10 \text{ m/s}\right)$$

$$= 1000(1)[20-(10-10\cos 30°)](10)$$

$$= 1000 \times 1 \times (20 - 10(1 - \cos 30°)) \times 10$$

$$= 10^5 \times \left(2-1+\frac{\sqrt{3}}{2}\right) = 186.6025 \text{ kW}$$

18. (c)

19. (d)

In the Parson's reaction turbine, it is assumed that the blade section and the mean diameter of fixed as well as the moving blades are the same and the blade height is progressively so increased such that the velocity of steam at exit from each row of blades is uniform throughout the stage thus, the velocity triangle at the inlet and outlet of moving blades will be similar.

The angle $\alpha_1 = \beta_2$, $\alpha_2 = \beta_1$ and velocity $C_{r_2} = C_1$, and $C_2 = C_{r_1}$

20. (d)

A quantity that is transferred to or from a system during an interaction is not a property since the amount of such a quanity depends on more than just the state of the system. Heat and work are energy transfer mechanism between a system and its surroundings, and

(i) Both are recognized at boundaries of a system as they cross the boundaries. That is both heat and work are boundary phenomena.

(ii) System posses energy, but not heat or work.

(iii) Both are associated with a process, not a state. Unlike properties, heat and work has no meaning at a state.

(iv) Both are path functions.

21. (d)

Given : m = 0.5 kg; T_1 = 30°C; P_1 = 3.5 bar; $\dot{w}$ = 26W, Δt = 20 min

$$W_{\text{shaft}} = \dot{w}\Delta t$$

$$= 26 \times 20 \times 60 = 31.2 \text{ kJ}$$

Using energy balance on the system,

$$W_{\text{sh, in}} = \Delta U = m(u_2 - u_1) = mc_v \, \Delta T$$

or

$$31.2 = 0.5 \times 3.12 \times (T_2 - 30)$$

$$T_2 = 50°\text{C}$$

22. (c)

- The entropy generated during a process is called entropy generation. Noting that the difference between the entropy change of a closed system and the entropy transfer is equal to entropy generation.
- The entropy generation is always a positive quantity or zero. Its value depends on the process and thus it is not a property of the system.

Also, in the absence of any entropy transfer, the entropy change of a system is equal to the entropy generation.

23. (a)

Carnot principles:

- The efficiency of an irreversible heat engine is always less then the efficiency of a reversible one operating between the same two reservoirs.
- The efficiencies of all reversible heat engines operating between the same two reservoirs are the same.
- $$\eta_{\text{rev}} = 1 - \frac{T_L}{T_H}$$

$$\eta_{\text{rev}} = 100\% \text{ only if } T_L = 0 \text{ K}$$

24. (d)

Given : Closed system, T_1 = 127°C = 400 K; T_2 = 57°C = 330 K; R = 0.3 kJ/kgK

$$PV^2 = C \text{ or } P = CV^{-2}$$

$$\text{Work-done by the gas, } W = \int_1^2 PdV$$

or for polytropic process (n = 2)

$$W = \frac{P_1V_1 - P_2V_2}{n-1} = \frac{mR(T_1 - T_2)}{n-1}$$

$$\Rightarrow \quad w = \frac{0.3(127-57)}{2-1} = 21 \text{ kJ/kg}$$

$$\text{or workdone on the gas} = -21 \text{ kJ/kg}$$

25. (b)

Given : $C = (15 + T)$ J/kgK; $T_1 = 300$ K; $T_2 = 600$ K

$$\because \quad Tds = du = CdT$$

$$\Rightarrow \quad ds = \frac{CdT}{T} = \frac{(15+T)}{T}dT$$

$$\Rightarrow \quad \int ds = \int_{300}^{600}\left(\frac{15}{T}+1\right)dT$$

$$\Rightarrow \quad \Delta s = [15\ln T + T]_{300}^{600} = 15 \ln 2 + 300$$

$$\Rightarrow \quad \Delta s = 310.4 \text{ J/kgK}$$

26. (a)

As all faces are free to deform, there is no thermal stress.

27. (d)

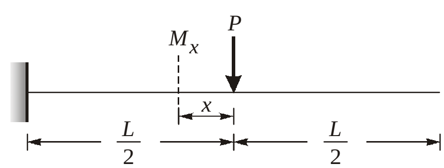
$$3K(1 - 2\nu) = 2G(1 + \nu)$$

$$3 - 6\nu = 2 + 2\nu$$

$$1 = 8\nu$$

$$\nu = \frac{1}{8}$$

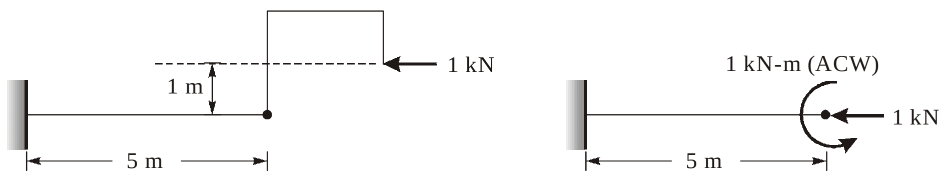
28. (d)



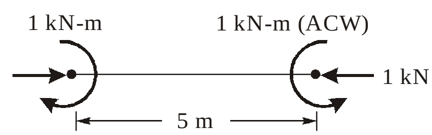
$$U_{\text{bending}} = \int_0^{L/2} \frac{M_x^2 dx}{2EI} = \frac{P^2}{2EI}\left[\frac{x^3}{3}\right]_0^{L/2}$$

$$U_{\text{bending}} = \frac{P^2L^3}{48EI}$$

29. (b)



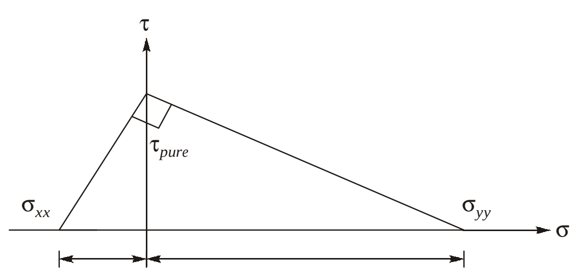
30. (c)



$$M = \text{Constant}$$

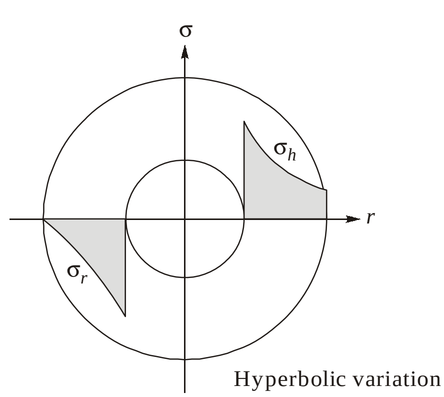
$$\Rightarrow \quad \frac{dM}{dx} = F = 0$$

31. (d)

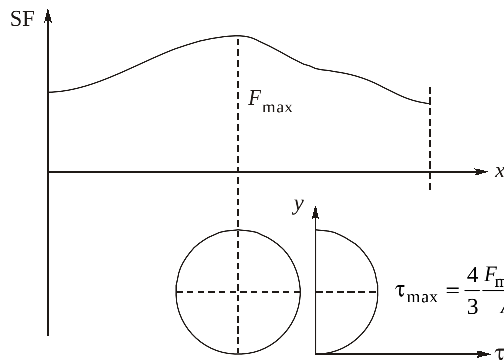


$$\tau_{\text{pure}} = \sqrt{-\sigma_{xx} \cdot \sigma_{yy}}$$

32. (d)



33. (b)



34. (c)

$$P = T\omega = T\cdot\frac{2\pi N}{60} \quad \text{...(i)}$$

$$\tau_{max} = \frac{16T}{\pi d^3} \quad \text{...(ii)}$$

From (i) and (ii),

$$\tau_{max} = \frac{16T}{\pi d^3}\left[\frac{60P}{2\pi N}\right] = \frac{480P}{\pi^2 d^3 N}$$

$$\tau_{max} = \frac{(480)(1000\times 10^3)}{\pi^2 \times (0.1)^3 \times 480}$$

$$= 101.32 \text{ MPa}$$

35. (d)

36. (c)

Given : RSH = 55 kW; t_o = 45°C; t_i = 25°C; BPF = 0.2

$$\text{OASH} = 0.0204 \times \text{cmm} \times (t_o - t_i)$$

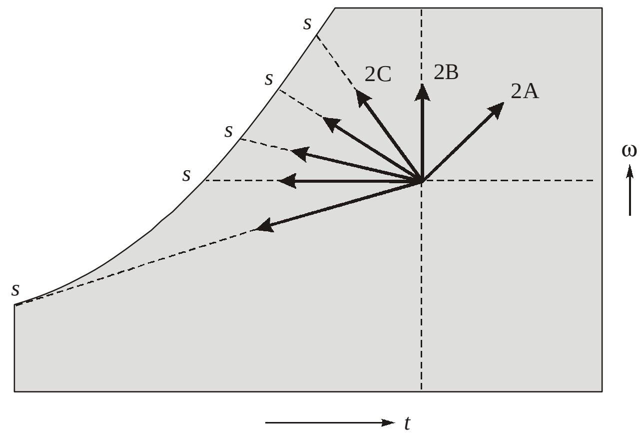
$$= 0.0204 \times 100 \times 20 = 40.8 \text{ kW}$$

$$\text{ERSH} = \text{RSH} + \text{OASH} \times \text{BPF}$$

$$= 55 + 40.8 \times 0.2 = 63.16 \text{ kW}$$

37. (c)

The range of Psychrometric processes with an air washer.



38. (a)

The screw compressor combines many advantages features of both centrifugal and reciprocating compressors, along with some of its own. As it is a positive displacement machine, high pressure refrigerants as in reciprocating compressors, such as R22 and ammonia are used in it. As it is a high speed rotary machine, a large volume, as in centrifugal compressors, can be handled by it.

39. (b)

$$SO_2 = 32 + 2 \times 16 = 64$$

∴ Designation of Sulphur dioxide $= R\ (700 + 64)$

$= R\ 764$

40. (d)

Steam jet refrigeration system: When a refrigeration system must utilize condensing temperature over 35°C, it is usually not economical to use a steam-jet in place of a mechanical refrigerating unit. Evaporative or barometric condensers on steam jet unit can usually maintain condensing temperature below 35°C. This enables the steam jet cycle to be used economically in comfort air conditioning application which would be un-economical if a surface condenser were employed.

41. (a)

Given : $c = 0.04$; $v_1 = 0.25\ m^3//kg$; $v_2 = 0.04\ m^3/kg$

$$\because \quad \eta_v = 1 + c - c\left(\frac{v_1}{v_2}\right)$$

$$= 1 + 0.04 - 0.04\left(\frac{0.25}{0.04}\right) = 0.79$$

or $$\eta_v = 79\%$$

42. (d)

Given : $\eta_{HE} = 0.3$; RC = 1 TR = 3.5 kW

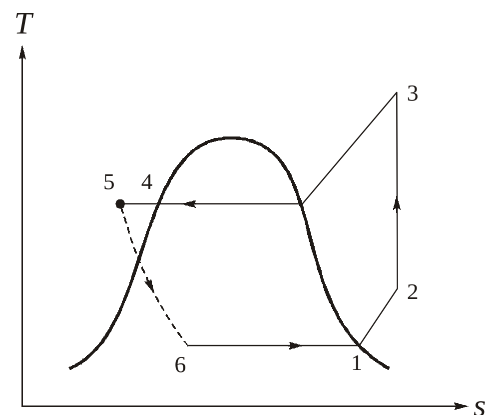
$$COP_R = \frac{1}{\eta} - 1 = \frac{7}{3}$$

$$W_{in} = \frac{RC}{COP} = \frac{3.5 \times 3}{7} = 1.5 \text{ kW}$$

$\therefore$ $$HRR = RC + W_{in} = 5 \text{ kW}$$

43. (a)

Given : $h_1 = 170$ kJ/kg; $h_2 = 175$ kJ/kg; $h_4 = 110$ kJ/kg



$$\text{Enthalpy (superheat)} = \text{Enthalpy (subcooling)}$$

$\because$ $$h_4 - h_5 = h_2 - h_1$$

$\Rightarrow$ $$h_5 = 105 \text{ kJ/kg}$$

$\therefore$ $$RE = h_1 - h_6 \qquad \{\because \; h_6 = h_5\}$$

$$= 170 - 105 = 65 \text{ kJ/kg}$$

44. (a)

Given : $T_E = -3°C = 270$ K; $T_0 = 27°C = 300$ K; COP = 1.5

$\because$ $$COP = \frac{T_E}{T_G}\left(\frac{T_G - T_0}{T_0 - T_E}\right)$$

$\Rightarrow$ $$1.5 = \frac{270}{300}\left(\frac{T_G - 300}{30}\right)$$

$\Rightarrow$ $$T_G = 300 + \frac{1.5 \times 10 \times 30}{9}$$

$\Rightarrow$ $$T_G = 350 \text{ K} = 77°C$$

45. (d)

A microcontroller is a microprocessor with added integrated elements such as memory and ADC and DAC converters; these can be connected directly to the plant being controlled.

46. (a)

While PLCs are similar to computers they have certain features which are specific to their use as controllers. These are:

1. They are rugged and designed to withstand vibrations, temperature, humidity and noise.
2. The interfacing for inputs and outputs is inside the controller.
3. They are easily programmed.

47. (d)

Sensors are used by the robot to collect information about the environment and about the state of its joints and links. For example, rotary potentiometers can be used to monitor the angles between joints in a robotic hand. Force sensors such as strain-gauged load cells can be used to determine loading on robotic arms. Force / touch-sensitive sensors can be used on the fingers and palm of the hand to give feedback on when contact has been made with an object being grasped by a robotic hand. A touch-and-slip sensor can be used on the thumb of a robot hand to indicate when a gripped object is slipping and a tighter grip should be applied. This can be achieved by interpreting the outputs from an array of touch sensors on the thumb or it may involve a specially designed slip sensor. One such slip sensor involves a needle which is pressed against the rough surface of an object. When the object slips, the needle oscillates as it is dragged along the surface and this oscillation is sensed by a piezoelectric crystal and the gripping force can then be adjusted until the oscillation stops.

48. (d)

The following are some of the applications of robotics:

1. Machine loading
2. Pick-and-place operations
3. Welding
4. Painting
5. Assembly
6. Inspection
7. Assisting disabled individuals
8. Operating in hazardous or inaccessible locations

49. (a)

When a pulse is supplied to a stepper motor we have essentially an input to an inductor–resistor circuit and the resulting torque is applied to the load, resulting in angular acceleration. As a consequence, the system will have a natural frequency; it will not go directly to the next step position but will generally, have damped oscillations about it before settling down to the steady-state value.

50. (d)

Typical faults in microprocessor systems are:

1. Chip failure
2. Passive component failure
3. Externally introduced interference

4. Software faults
5. Short circuits
6. Open circuits

51. (d)

52. (a)

With the microcontrollerMC68HC11, the basic strobed input/output operates as follows. The handshaking control signals use pins STRA and STRB. Port C is used for the strobed input and port B for the strobed output. When data is ready to be sent by the microcontroller a pulse is produced at STRA and sent to the peripheral device.

53. (b)

The main disadvantage of the resolver is the requirement of oscillator and digital converter. These requirements make it costly as well.

54. (a)

Arrival Rate, λ = 10 customer/hour

Service Rate, μ = 5 min per customer = 12 customer/hour

Probability that a newly arrived customer have to wait = $\frac{\lambda}{\mu} = \frac{10}{12} = 0.833$

Probability that a newly arrived customer do not have to wait = $\left(1 - \frac{\lambda}{\mu}\right) = 0.167$

55. (c)

$$(\text{EOQ})_{\text{old}} = \sqrt{\frac{2DC_0}{C_h}}$$

$$(\text{EOQ})_{\text{new}} = \sqrt{\frac{2\times(3D)(2C_0/3)}{(C_h/2)}} = 2(\text{EOQ})_{\text{old}}$$

$$\Rightarrow \quad \frac{(\text{EOQ})_{\text{new}}}{(\text{EOQ})_{\text{old}}} = 2$$

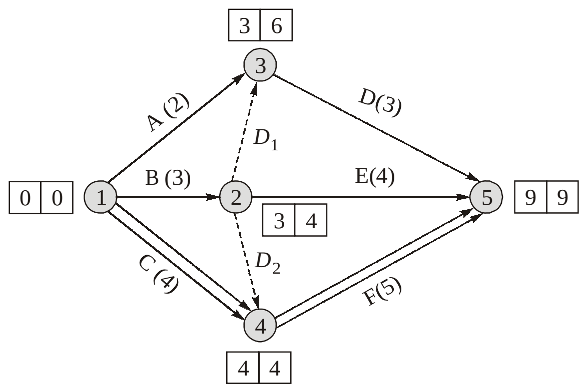
56. (d)

Following are the main advantages of linear programming methods:

1. It helps in attaining the optimum use of productive factors. Linear programming indicates how a manager can utilize his productive factors most effectively by a better selection and distribution of these elements. For example, more efficient use of manpower and machines can be obtained by the use of linear programming.
2. It improves the quality of decisions. The individual who makes use of linear programming methods becomes more objective than subjective. The individual having a clear picture of the relationships within the basic equations, inequalities or constraints can have a better idea about the problem and its solution.

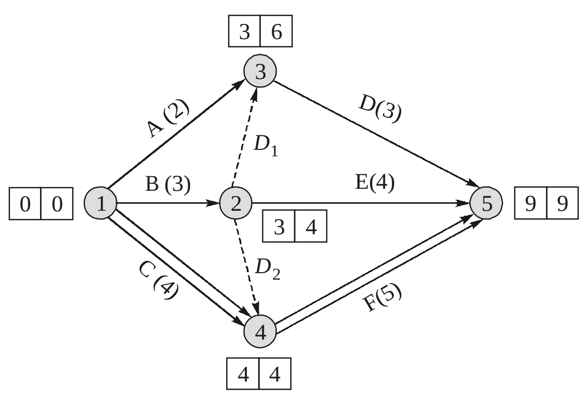
3. It also helps in providing better tools for adjustments to meet changing conditions. It can go a long way in improving the knowledge and skill of future executives.
4. Most business problems involve constraints like raw materials availability, market demand, etc. which must be taken into consideration. Just because we can produce so many units of products does not mean that they can be sold. Linear programming can handle such situations also since it allows modification of its mathematical solutions.
5. It highlights the bottlenecks in the production processes. When bottlenecks occur, some machines cannot meet demand while others remain idle, at least part of the time. Highlighting of bottlenecks is one of the most significant advantages of linear programming.

57. (a)



Network diagram : C → F is critical path.

58. (c)



Network diagram : C → F is critical path.

Total float of activity D is = $L_J - E_i - t_{ij}$ = 9 – 3 – 3 = 3 days

59. (c)

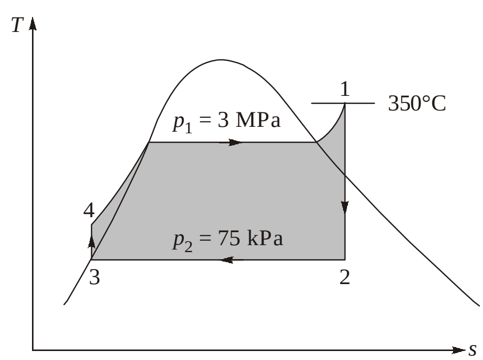
The benefits of MRP are as follows:

1. Reduction in work-in-process. MRP makes it possible to have right components in the right quantity at the right time. This minimizes unnecessary work in process inventory without any shortages.

2. Priority benefits. MRP system identifies needed materials and keep their priorities up-to-date. Materials are ordered at the correct due date and that due date is kept valid. Whenever changes occur, the MRP system computes the due dates of affected order and can effect scheduling changes with minimum delays.
3. Effective utilization of capacity. By generating anticipated material requirements over a sufficiently long time horizon, facility and labour time can be effectively planned and used.
4. Improved customer service.
5. Reduction in lead time.
6. Reduction in past due orders.
7. Reduction in finished goods inventory, raw material, components and parts, and safety stock.
8. Increased productivity.
9. Increased inventory turn over

60. (c)

Refer figure,



$$h_1 = 3116 \text{ kJ/kg}, h_2 = 2400 \text{ kJ/kg}, h_3 = 385 \text{ kJ/kg}$$

$$\text{Pump work, } w_p = v_f(P_1 - P_2) = 0.00104(3000 - 75)$$

$$w_p = 3.04 \text{ kJ/kg}$$

Enthalpy at state 4:

$$h_4 = h_3 + w_p = 385 + 3.04 = 388.04 \text{ kJ/kg}$$

$$\text{Rankine cycle efficiency, } \eta_{\text{rankine}} = 1 - \frac{h_2 - h_3}{h_1 - h_4}$$

$$\therefore \quad \eta_{\text{rankine}} = 1 - \frac{2400 - 385}{3116 - 388.04} = 0.2613 \text{ or } 26.13\%$$

61. (b)

$$\text{Back work ratio, } r_{bw} = \frac{\text{Pump work}}{\text{Turbine work}} = \frac{3.04}{3116 - 2400}$$

$$r_{bw} = 0.0042$$

62. (d)

63. (d)

Anthracite is the next generation of bituminous coal and has the highest rank. It is a hard coal composed of about 90% carbon with little volatile content and practically no moisture, it has highest heating value, approximately 3600 kJ/kg.

64. (b)

Theoretical air required for complete combustion

$$= \frac{100}{23}\left[\frac{8}{3}C + 8\left(H - \frac{O}{8}\right) + S\right]$$

Considering 1 kg of coal,

$$\text{Mass of carbon} = 0.8 \text{ kg, and}$$

$$\text{Mass of hydrogen} = 0.12 \text{ kg}$$

$$\therefore \quad \left(\frac{A}{F}\right)_{th} = \frac{100}{23}\left[\frac{8}{3} \times 0.8 + 8 \times 0.12 + 0\right]$$

$$= 13.45 \text{ kg/kg of fuel}$$

65. (b)

66. (c)

The La Mont boiler is a high-pressure, water tube type boiler. It works on a forced-circulation principle. The water circulation is maintained by a centrifugal pump.

67. (b)

A steam trap is a device that drains away the condensed steam and air automatically from the steam pipe, steam jackets or steam separator without discharging the steam.

68. (d)

Temperature of chimney gases for maximum discharge is given by

$$T_g = 2T_a\left[\frac{m_a + 1}{m_a}\right]$$

$$= 2 \times 303\left[\frac{20+1}{20}\right] = 636.3 \text{ K}$$

69. (d)

Advantages of artificial draught over natural draught:

(i) Forced draught puts better control on combustion.

(ii) Low-grade fuel can be efficiently burnt.

(iii) Overall efficiency of a thermal power plant is higher due to better heat recovery from the exhaust flue gases in economisers and preheaters.

(iv) The height of the chimney can be reduced than that required in natural draught.

(v) Higher the rate of fuel-burning capacity on the grate, higher the heat-supply rate at higher effective temperature.

(vi) Smoke formation is less.
(vii) Tendency for air leakage in the furnace is less.

70. (a)

$$\text{Blade efficiency, } \eta_b = \frac{\text{Work done on the blade}}{\text{Energy supplied to the blade}}$$

71. (d)

In by-pass governing, when a steam turbine is overloaded, additional fresh steam is admitted through a by-pass valve to later stages of the turbine.

72. (d)

Jet condenser has low vacuum efficiency, thus it is less suitable for large plants.

73. (c)

$$T_{c_1} = 21°\text{C};\ T_{c_2} = 35°\text{C};\ T_{sat} = 42°\text{C}$$

$$\text{Condenser efficiency, } \eta_{\text{cond}} = \frac{\text{Temperature rise of cooling water}}{\text{Maximum possible temperature rise of water}}$$

$$\eta_{\text{cond}} = \frac{35-21}{42-21} = 0.667 \text{ or } 66.7\%$$

74. (c)

$$\dot{m}_a = 30 \text{ kg/min} = 0.5 \text{ kg/sec};\ T_1 = 30°\text{C} = 303 \text{ K};\ T_2 = 480 \text{ K};\ n = 1.25$$

$$\therefore \quad \text{Indicated power, I.P.} = \frac{n}{n-1} \times \dot{m}_a R (T_2 - T_1)$$

$$\text{I.P.} = \frac{1.25}{0.25} \times 0.5 \times 0.287 \times (480 - 303)$$

$$= 126.99 \simeq 127 \text{ kW}$$

75. (a)

$$\text{The motor brake power,} \quad \text{B.P.} = \frac{I.P.}{\eta_{mech}} = \frac{127}{0.8} = 158.75 \text{ kW}$$

76. (a)

For stable equilibrium of a partially submerged body
- Metacentre lies above the centre of gravity.
- Metacentric height must be positive.

77. (c)

The velocity coefficient C_V, contraction coefficient C_C and the discharge coefficient C_d are related as

$$C_d = C_C \times C_V$$

$$\text{Velocity coefficient, } C_V = 0.95 \text{ to } 0.98$$

$$\text{Coefficient of discharge, } C_d = 0.6 \text{ to } 0.8$$

$$\text{Coefficient of contraction, } C_C = 0.61 \text{ to } 0.69$$

Since C_d is product of C_V and C_C, so it is always minimum out of the three coefficient values.

78. (b)

Given : μ = 5 poise = 0.5 Pa-s; h = 45 mm = 0.045 m; b = 800 mm = 0.8 m; $\frac{-\partial P}{\partial x} = 4 \times 10^3 \text{ N/m}^3$

$$\text{Maximum velocity, } u_{max} = \frac{1}{2\mu}\left(\frac{-\partial P}{\partial x}\right)\frac{h^2}{4}$$

$$= \frac{1}{2 \times 0.5} \times \left(4 \times 10^3\right) \times \frac{(0.045)^2}{4} = 2.025 \text{ m/s}$$

79. (d)

Given : μ = 0.5 Pa-s; h = 0.045 m; b = 0.8 m; $\frac{-\partial p}{\partial x} = 4 \times 10^3 \text{ N/m}^3$

$$\text{Average velocity, } \bar{u} = \frac{h^2}{12\mu}\left(\frac{-\partial P}{\partial x}\right) = u_{max} \times \frac{2}{3}$$

$$= 2.025 \times \frac{2}{3} = 1.35 \text{ m/s}$$

$$\text{Flow rate, } Q = \bar{u}hb$$

$$= 1.35 \times 0.045 \times 0.8$$

$$= 0.0486 \text{ m}^3/\text{s}$$

$$= 4.86 \times 10^{-2} \text{ m}^3/\text{s}$$

80. (c)

Given : U_∞ = 2 m/s; L = 2 m; b = 1 m; ρ = 1.2 kg/m^3; ν = 16 centistokes = 1.6×10^{-5} m^2/s

$$\text{Reynolds number, } Re_L = \frac{U_\infty L}{\nu} = \frac{2 \times 2}{1.6 \times 10^{-5}} = 2.5 \times 10^5$$

Clearly $Re_L < 3.2 \times 10^5$. So, the flow is laminar over the entire length of the plate.

The drag coefficient for the laminar flow is given as,

$$C_D = \frac{1.328}{\sqrt{\text{Re}_L}} = \frac{1.328}{\sqrt{2.5 \times 10^5}} = \frac{1.328}{500}$$

$$= 2.656 \times 10^{-3}$$

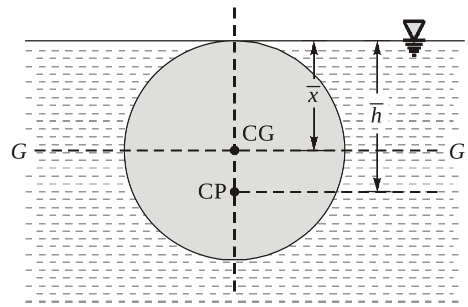
81. (a)

82. (c)

Given : D = 20 cm; σ = 0.05 N/m

$$\text{Work done} = \text{Surface tension} \times \text{Total surface area}$$
$$= \sigma \times \pi D^2$$
$$= 0.05 \times \pi \times (0.20)^2$$
$$= 6.2832 \times 10^{-3} \text{ Nm}$$
$$\simeq 6.28 \times 10^{-3} \text{ Nm}$$

83. (b)



Distance of centre of pressure from the free surface,

$$\bar{h} = \bar{x} + \frac{I_{GG}}{A\bar{x}}$$

$$= \frac{d}{2} + \frac{\left(\frac{\pi d^4}{64}\right)}{\left(\frac{\pi d^2}{4}\right)\left(\frac{d}{2}\right)} = \frac{d}{2} + \frac{d}{8} = \frac{5d}{8}$$

84. (b)

$$a = 5 \text{ m/s}^2;\ \theta = 30°$$

Horizontal component of acceleration,

$$a_h = a\cos(30°)$$

Vertical component of acceleration,

$$a_v = a\sin(30°)$$

$$\text{Slope of free liquid surface, } \tan\phi = \frac{a_h}{g + a_v} = \frac{a\cos(30°)}{g + a\sin(30°)}$$

$$= \frac{\left(5 \times \frac{\sqrt{3}}{2}\right)}{9.81 + \left(5 \times \frac{1}{2}\right)} = \frac{4.3301}{9.81 + 2.5} = 0.35175 \simeq 0.352$$

85. (b)

- A steam function is only defined for two dimensional, incompressible flow field. It can be either irrotational or rotational flow field.

- A valid stream function may or may not satisfy Laplace equation. But if it satisfies Laplace equation then it indicates that the flow field must be irrotational.

86. (c)

$$\frac{\partial \psi}{\partial y} = \frac{\partial \phi}{\partial x}$$

$$\frac{\partial \psi}{\partial y} = \frac{\partial}{\partial x}\left(\frac{xy^3}{3} - \frac{x^3 y}{3} + x^2 - y^2\right)$$

$$\frac{\partial \psi}{\partial y} = \frac{y^3}{3} - x^2 y + 2x$$

$$\psi = \int\left(\frac{y^3}{3} - x^2 y + 2x\right) \cdot dy$$

$$\psi = \frac{y^4}{12} - \frac{x^2 y^2}{2} + 2xy + f(x) \quad \text{...(i)}$$

and

$$\frac{\partial \psi}{\partial x} = -\frac{\partial \phi}{\partial y}$$

$$\frac{\partial \psi}{\partial x} = -\frac{\partial}{\partial y}\left(\frac{xy^3}{3} - \frac{x^3 y}{3} + x^2 - y^2\right)$$

$$\frac{\partial \psi}{\partial x} = -\left(xy^2 - \frac{x^3}{3} - 2y\right)$$

$$\psi = \int\left(-xy^2 + \frac{x^3}{3} + 2y\right) \cdot dx$$

$$\psi = \frac{-x^2 y^2}{2} + \frac{x^4}{12} + 2xy + f(y) \quad \text{...(ii)}$$

From equation (i) and (ii)

$$\psi = \frac{x^4}{12} + \frac{y^4}{12} - \frac{x^2 y^2}{2} + 2xy + \text{constant}$$

87. (d)

From the definition of the potential function;

$$u = \frac{-\partial \phi}{\partial x} = -\left(\frac{y^3}{3} - x^2 y + 2x\right) = \frac{-y^3}{3} + x^2 y - 2x$$

At point (1, 1),

$$u = \left(-\frac{1}{3} + 1 - 2\right) = \frac{-4}{3} \text{ units}$$

and

$$v = -\frac{\partial \phi}{\partial y} = -\left(xy^2 - \frac{x^3}{3} - 2y\right) = -xy^2 + \frac{x^3}{3} + 2y$$

At point (1, 1), $v = -1 + \frac{1}{3} + 2 = \frac{4}{3}$ units

$$\text{Magnitude of velocity} = \sqrt{u^2 + v^2} = \sqrt{\left(\frac{-4}{3}\right)^2 + \left(\frac{4}{3}\right)^2}$$

$$= \frac{4}{3} \times \sqrt{2} = \frac{4\sqrt{2}}{3} \text{ units}$$

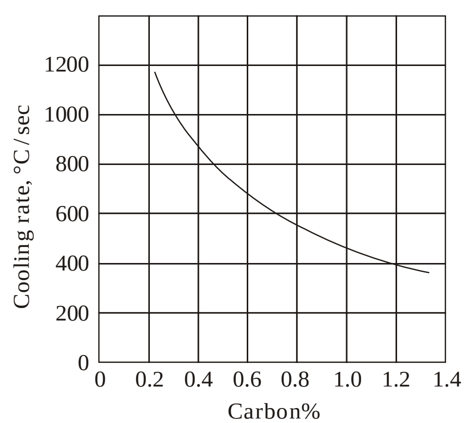
88. (b)

Carbon fibre is expensive compared to glass fibre.

89. (c)

90. (c)

The critical cooling rate required for getting the complete martensitic structure in steels depends on the carbon percentage as shown in figure below. Higher the carbon, lower is the cooling rate required.



Influence of carbon content on critical cooling rate for missing the transformation curve

91. (b)

- The stress fields around solute atoms interact with the stress field for a moving dislocation, thereby increasing the stress required for plastic deformation.
- The more the size difference between the solute and the solvent, the more intense is the stress field around the solute and its interaction with the moving dislocation is correspondingly stronger.
- With a large concentration of the solute, the moving dislocation interacts with the solute stress fields at many points along its length.

92. (c)

- The addition polymerisation consists of breaking the double carbon bond (C ═ C) in bifunctional polymers, so that the chain can be formed. For example, ethylene when polymerised will be called polyethylene.

- In condensation polymerisation, two different organic molecules react to form a plastic molecule. The reaction generally results in the separation of a small molecule such as H_2O as a by-product.

93. (b)

Given, edge length, a = 450 pm

Interplanar spacing between planes ($h\ k\ l$) is given by,

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

$$= \frac{450}{\sqrt{1^2 + 2^2 + 2^2}}$$

$$= \frac{450}{3} = 150 \text{ pm}$$

94. (c)

During solidification or recrystallization, new crystals form in different parts of the material. They are randomly oriented with respect to one another. They grow by the addition of atoms from the adjacent regions and eventually impinge on each other. When two crystals impinge in this manner, the atoms caught in between the two are being pulled by each of the two crystals to join its own configuration. They can join neither crystal due to the opposing forces, and therefore, take up a compromise. The boundary region is called a crystal or grain boundary.

- The crystal orientation changes sharply at the grain boundary. The orientation difference is usually greater than 10 - 15°. For this reason, the grain boundaries are also known as high angle boundaries.
- The average number of nearest neighbours for an atom in the boundary of a closed packed crystal is 11, as compared to 12 in the interior of the crystal. On an average, one bond out of the 12 bonds of an atom is broken at the boundary.

95. (b)

Vickers hardness number, $$\text{VHN} = \frac{1.854P}{d_1^2}$$

where, P : Applied load (in kg)

d_1 : Size of indentation (in mm)

$$\therefore \quad \text{VHN} = \frac{1.854 \times 100}{(0.5)^2} = 741.6 \simeq 740$$

96. (d)

- For the single phase region (liquid or solid), from modified phase rule,

$$F = C - P + 1 = 2 - 1 + 1 = 2$$

So, both temperature and composition of the phase can be independently varied.

- In the two-phase region,

$$F = 2 - 2 + 1 = 1$$

As $F = 1$, only of three variables i.e. temperature, composition of the liquid phase and composition of the solid phase; is independent. If we arbitrarily choose the temperature, the compositions of the two phases are automatically fixed and are given by the end of the tie-line draw at that temperature.

97. (a)

The SCARA configuration has vertical major axis rotations such that gravitational load, Coriolis, and centrifugal forces do not stress the structure as much as they would if the axes were horizontal.

98. (a)

- Statement 1 is correct for forward kinematics.
- Statement 2 is correct for inverse kinematics.

99. (b)

Collision type	Coefficient of restitution (e)
(i) Perfectly elastic	$e = 1$
(ii) Perfectly inelastic	$e = 0$
(iii) Partially elastic	$0 < e < 1$

100. (a)

The area occupied below the velocity time graph gives the displacement.

So,

$$\text{Average velocity between } t = 0\text{s to } 50\text{s} = \frac{\text{Displacement between } t = 0\text{s to } 50\text{s}}{\text{Time duration}}$$

$$= \frac{\text{Area below velocity time plot between } t = 0\text{s to } 50\text{s}}{\text{Time duration}}$$

$$= \frac{\left[\frac{1}{2}\times 10\times 50+(30-10)\times 50+\frac{1}{2}\times(50+80)\times(40-30)+\frac{1}{2}\times(50+80)(50-40)\right]}{(50-0)}$$

$$= \frac{250+1000+650+650}{50} = 51 \text{ m/s}$$

101. (a)

Given : $v = 3x^2 - 2x + 2$

$$\Rightarrow \quad \frac{dv}{dx} = 6x - 2$$

The acceleration is given as,

$$a = v\cdot\frac{dv}{dx} = \left(3x^2 - 2x + 2\right)(6x - 2)$$

at $x = 1$ m, $a = (3 \times 1^2 - 2 \times 1 + 2)(6 \times 1 - 2)$
$= 12 \text{ m/s}^2$

102. (d)

Given : $k_t = 1.5; q = 0.5$

$$k_f = 1 + q(k_t - 1)$$
$$= 1 + 0.5(0.5) = 1.25$$
$$k_d = \frac{1}{k_f} = 0.8$$

$\Rightarrow$ $$Se = k_d S_e' = 0.8 S_e'$$

$\therefore$ % reduction = 20%.

103. (c)

- When the moment due to bracking effort and moment due to friction act in same direction, such a brake is called self-energizing brake.
- When no external force is required for the braking action. Such a brake is called self-locking brake. This is not desirable condition in normal applications. In this condition the actuating force is negative and results in uncontrolled bracking.

104. (d)

Given : $v = 7$ m/s

We know that for ordinary and commnercially cut gears made with form cutters and with ($v = 10$ m/s).

$$c_v = \frac{3}{3+v} = \frac{3}{3+7}$$

$\Rightarrow$ $$c_v = 0.3$$

105. (d)

Advantages of riveted joints over welded joints:

- Riveted joints are more reliable in applications which are subjected to vibrations and impact forces.
- Riveted joints can be used for metals with poor weldability like Al-alloys.
- The quality of riveted joints are easily checked while inspection for welded joints are costly and time consuming.
- Welded joints are in general, restricted to steel parts.

Disadvantages

- Riveting process creates more noise.
- Riveted assemplies have more weight than welded assembles.

106. (d)

Types of Rivet head and applications:

- Snap head $\rightarrow$ Boilers, pressure vessels etc.

- Countersunk head $\rightarrow$ Ship hulls
- Flat head $\rightarrow$ Light sheet metal work (AC duct, buckets)
- Half countersunk head $\rightarrow$ Steel plates upto 4 mm thickness

107. (c)

Given : M = 5 kNm; T = 12 kNm

Using, MSST $$T_{eq} = \sqrt{M^2+T^2} = \sqrt{5^2+12^2}$$

$$\Rightarrow \quad T_{eq} = 13 \text{ kNm}$$

Hence, shaft can resist a maximum torque of 13 kNm.

108. (c)

Given : P = 8 kN; $L_{10} = 10^6$ revolutions = 1 million revolution

We know that, $$L_{10} = \left(\frac{C}{P}\right)^3$$

$$\Rightarrow \quad 1 = \left(\frac{C}{8}\right)^3$$

$$\Rightarrow \quad C = 8 \text{ kN}$$

109. (d)

Given : $\varepsilon = 0.4$; $c_1 = 0.1$ mm; h_o = Minimum film thickness

$$\frac{h_o}{c_1} = \text{Minimum film thickness variable}$$

$$\because \quad c_1 = c_1\varepsilon + h_o$$

$$\Rightarrow \quad \frac{h_o}{c_1} = 1-\varepsilon = 1-0.4 = 0.6$$

110. (c)

Given : m_1 = 2 mm; S_{b_1} = 150 MPa; m_2 = 3 mm; S_{b_2} = ?

We know that, $$S_b = mb\sigma_b\gamma$$

$$\Rightarrow \quad S_b \propto m$$

$$\Rightarrow \quad \frac{S_{b_2}}{150} = \frac{3}{2}$$

$$\Rightarrow \quad S_{b_2} = 225 \text{ MPa}$$

111. (c)

Compared to fixed bed gasifiers, in fluidized bed gasifier, the gasification temperature is relatively low; an even temperature is selected in the range of 750°C to 900°C.

112. (b)

One of the limitation of solid media storage is that, simultaneous charging and discharging are not possible.

113. (b)

- Clearness index the ratio of average radiation on a horizontal surface to the average extra-terrestrial radiation.
- The clearness index is location specific.

114. (c)

$$\eta_{cell} = \frac{V_{max} \times I_{max}}{P_{in}}$$

$$\Rightarrow \quad V_{max} = \frac{P_{in} \times \eta_{cell}}{I_{max}} = \frac{0.9 \times 10^{-3} \times 0.22}{0.4 \times 11 \times 10^{-3}}$$

$$V_{max} = 0.045 \text{ V/cm}^2$$

$$V_{max} = 0.045 \text{ V/cm}^2 \times 1.2 \text{ cm}^2$$

$$= 0.054 \text{ V}$$

115. (a)

$$\text{Fill factor, (FF)} = \frac{P_{max}}{V_{oc} \times I_{sc}} = \frac{V_{max} \times I_{max}}{V_{oc} \times I_{sc}}$$

$$= \frac{0.4 \times I_{sc} \times 0.045}{I_{sc} \times 0.7} = 0.0257$$

116. (d)

Effective conversion of solar thermal energy to mechanical energy is associated with many limitations. Some of them are as follows:

1. The efficiency of a collector system decreases as the collection temperature increases while the efficiency of a heat engine increases as the working fluid temperature increases.
2. The conversion efficiency is low (about 9 to 18 per cent).
3. A part of thermal energy is lost during the transportation of the working fluid from the collector to the heat engine.
4. Solar collectors are generally more expensive than engines.
5. A very large area is required to install the solar-collector system.
6. Due to the intermittent nature of solar energy, storage of thermal energy is also required, which has its own problems like degradation of storage material with time.

117. (c)

Perturbation factor, $a = 0.6$

The power coefficient is given by,

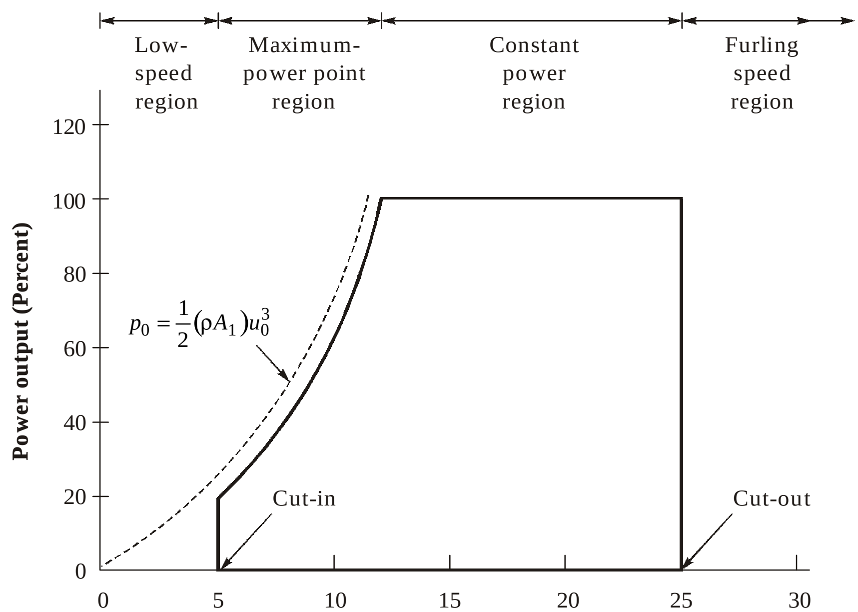
$$C_p = 4a \times (1 - a)^2$$

$$= 4 \times 0.6 \times (1 - 0.6)^2 = 0.384$$

118. (c)

Low-speed Region (Zero to Cut-in Speed) : In this region, the turbine is kept in braked position till minimum wind speed (about 5 m/s), known as cut-in speed becomes available. Below this speed, the operation of the turbine is not efficient.

Furling Speed Region (Cut-out Speed and Above) : Beyond a certain maximum value of wind speed (around 25 m/s), the rotor is shut down and power generation is stopped to protect the blades, generation and other components of the system.



Power versus wind speed characteristics

119. (c)

Cow requirement:

$$\text{Cow dung per cow} = 12 \text{ kg/day}$$

$$\text{Collected cow dung per day} = 12 \times \frac{70}{100} = 8.4 \text{ kg/day}$$

$$\text{Weight of dry cow dung (18\%)} = 0.18 \times 8.4$$

$$= 1.512 \text{ kg/day}$$

$$\text{Gas production (300 litre/kg)} = 0.3 \times 1.512$$

$$= 0.4536 \text{ m}^3\text{/day}$$

Let n be the number of cows required

∴ Gas produced by 'n' number of cows = $n \times 0.4536$

∴ $$n \times 0.4536 = 2.32$$

⇒ $$n = \frac{2.32}{0.4536} = 5.115 \simeq 6 \text{ cows}$$

120. (b)

In the ebb generation cycle operation, the sluice way is opened to fill the basin during high tide.

121. (c)

Advantages of a fuel cell are: (i) it is quiet in operation as it is a static device, (ii) it is less pollutant, (iii) its conversion efficiency is more due to direct single-stage energy conversion, (iv) fuel cell plant can be installed near the point of use, thus transmission and distribution losses are avoided, (v) no cooling water is needed as required in the condenser of a conventional steam plant. The heat generated can be easily removed and discharged to the atmosphere or used locally, (vi) because of modular nature, any voltage/current level can be realised and the capacity can be added later on as the demand grows, (vii) fuel-cell plants are compact and require less space.

122. (d)

$$\text{Sensitiveness of a governor} = \frac{\text{Range of speed}}{\text{Mean speed}}$$

123. (d)

The objectives for providing backlash in gear tooth are:

- It prevents mating teeth from jamming together.
- It compensates for maching errors.
- It compensates for thermal expansion of teeth.

124. (b)

In cycloidal profile, there is no abrupt changes in the velocity and the acceleration at any stage of the motion. Thus, it is the most ideal programme for high-speed follower motion.

125. (a)

In a simple gear trains the gears other than driving and driven gears are called idler gears. The functions of idler gear are as follows:

- Idler gears fill the space between the driving and driven gears.
- Idler gears changes the direction of rotation of the last driven shaft relative to the first driving shaft.

The rules regarding direction of rotation are as follows:

- If odd number of idler gears is used, the first and last shafts rotates in the same direction.
- If even (or zero) number of idler gears is used, the first and last shaft rotate in the opposite direction.

126. (c)

Given : $I = 8\ \text{kgm}^2$; $N_{\text{mean}} = 210$ rpm; $(\Delta E)_{\max} = 1200\ \text{J} = 1.2\ \text{kJ}$

$$\text{Rotational speed, } \omega_{\text{mean}} = \frac{2\pi}{60} \times N_{mean} = \frac{2\pi}{60} \times 210$$

$$= 21.99\ \text{rad/s} \simeq 22\ \text{rad/s}$$

$$\text{Fluctuation of energy, } (\Delta E)_{\max} = I\omega_{mean}^2 C_s$$

$$1200 = 8 \times (22)^2 \times C_s$$

$$\Rightarrow \quad C_s = \frac{1200}{8 \times (22)^2} = 0.3099 \simeq 0.31$$

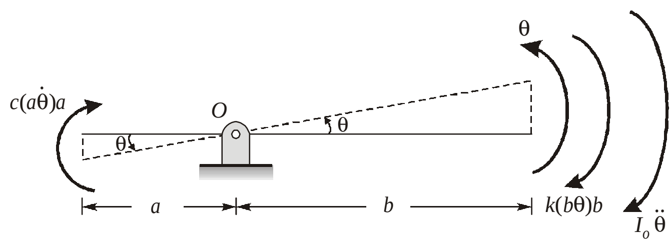
127. (c)

When an epicyclic gear consists of a number of sun and planet gears in series such that the pin of the arm of the first drives an element of another, it is known as compound epicyclic gear train.

128. (c)

Given : m = 12 kg; a = 200 mm; b = 600 mm; c = 500 Ns/m; k = 1 kN/m

On giving a small rotation θ to the bar,



$$I_o = I_G + m\left(\frac{a+b}{2} - a\right)^2$$

$$= \frac{1}{12}m(a+b)^2 + m\left(\frac{a+b}{2} - a\right)^2$$

$$= \frac{1}{12} \times 12 \times (0.8)^2 + 12 \times (0.2)^2 = 1.12 \text{ kg.m}^2$$

Torque about point O, $I_o\ddot{\theta} + ca^2\dot{\theta} + kb^2\theta = 0$

$$\Rightarrow \quad \ddot{\theta} + \frac{ca^2\dot{\theta}}{I_o} + \frac{kb^2\theta}{I_o} = 0$$

On comparing the above equation with standard equation, $\ddot{\theta} + (2\xi\omega_n)\dot{\theta} + \omega_n^2\theta = 0$, we get

$$\omega_n = \sqrt{\frac{kb^2}{I_o}} = \sqrt{\frac{1000 \times (0.6)^2}{1.12}}$$

$$= 17.9284 \text{ rad/s} \simeq 17.9 \text{ rad/s}$$

129. (a)

The vibration equation obtained is

$$I_o\ddot{\theta} + ca^2\dot{\theta} + kb^2\theta = 0$$

Here, damping coefficient $= ca^2$

$= 500 \times (0.2)^2$

$= 20$ Nms/rad

130. (d)

$$\text{Path of contact} = \text{Path of approach} + \text{Path of recess}$$

$$\text{Path of contact} = \frac{\text{Addendum of rack}}{\sin\phi} + \text{Path of recess}$$

$$30 = \frac{\text{Addendum of rack}}{\sin(17°)} + 16$$

$$\Rightarrow \quad \text{Addendum of rack} = (30 - 16) \times \sin(17°)$$

$$= 14 \times 0.292$$

$$= 4.088$$

131. (b)

Given : B = 75 kg; b = 500 mm = 0.5 m; W = 36 kN

The maximum speed of the locomotive without lifting the wheel from the rails will be when the dead load becomes equal to the hammer blow.

$$\text{Hammer blow} = \text{Dead load}$$

$$Bb\omega^2 = W$$

$$75 \times 0.5 \times \omega^2 = 36 \times 10^3$$

$$\omega^2 = \frac{36 \times 10^3}{75 \times 0.5} = 960$$

$$\Rightarrow \quad \omega = \sqrt{960} = 30.9838 \text{ rad/s} \simeq 30.98 \text{ rad/s}$$

132. (a)

133. (a)

(i) **Blow :** It is a fairly large, well-rounded cavity produced by the gases which displace the molten metal at the cope surface of a casting. Blows usually occur on a convex casting surface and can be avoided by having a proper venting and an adequate permeability. A controlled content of moisture and volatile constituents in the sand-mix also helps in avoiding the blow holes.

(ii) **Scar :** A shallow blow, usually found on a flat casting surface, is referred to as a scar.

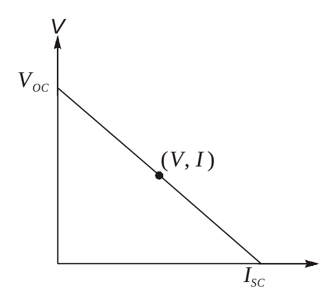
(iii) **Blister :** This is a scar covered by the thin layers of a metal.

(iv) **Dross :** Lighter impurities appearing on the top surface of a casting are called dross. It can be taken care of at the pouring stage by using items such as a strainer and a skim bob.

134. (c)

$$V_{OC} = 60 \text{ V}$$

$$I_{SC} = 400 \text{ A}$$



Variation of $V - I$ is linear

$$\Rightarrow \quad \frac{V}{V_{OC}} + \frac{I}{I_{SC}} = 1$$

$$\Rightarrow \qquad V = \left(1 - \frac{I}{I_{SC}}\right) \times V_{OC} = \left(1 - \frac{I}{400}\right) 60$$

$$\text{Power} = V \times I = \left(1 - \frac{I}{400}\right) \times 60 \times I$$

$$\text{For maximization, } \frac{dP}{dI} = 60\left[1 - \frac{2I}{400}\right] = 0$$

$$\Rightarrow \qquad I = \frac{400}{2} = 200 \text{ A}$$

$$\text{So, } \qquad V = \left(1 - \frac{200}{400}\right) \times 60 = 30 \text{ V}$$

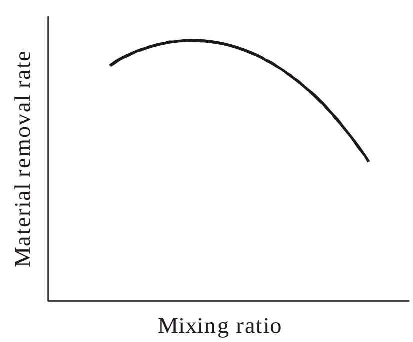
135. (d)

(i) It shields the weld pool from an atmospheric contamination by creating a suitable gaseous atmosphere and a slag. The slag also refines the molten metal.

(ii) It acts as a carrier for alloying elements, deoxidants, and other elements necessary to produce the desired arc and metal transfer characteristics. The thickness of the coating governs the size of the weld pool. With a high thickness, the weld pool is found to be narrower and deeper.

The four most common coatings used in practice are (i) cellulosic coating, (ii) rutile coating, (iii) ironoxide coating, and (iv) basic or low hydrogen coat.

136. (c)



Variation with mixing ratio

Mainly two types of abrasives are used, viz., (i) aluminium oxide and (ii) silicon carbide. However, generally aluminium oxide abrasives are preferred in most applications. The shape of these grains is not very important, but, for a satisfactory wear action on the work surface, these should have sharp edges. Al_2O_3 and SiC powders with a nominal grain diameter of 10–50 μm are available. The best cutting is achieved when the nominal diameter is between 15 μm and 20 μm. A reuse of the abrasive powder is not recommended as the (i) cutting capacity decreases after the first application, and (ii) contamination clogs the small orifices in the nozzle. The mass flow rate of the abrasive particles depends on the pressure and the flow rate of the gas. When the mass fraction of the abrasives in the jet (mixing ratio) increases, the mir initially increases, but with a further increase in the mixing ratio, it reaches a maximum and then drops. When the mass flow rate of the abrasive increases, the mir also increases.

137. (c)

(i) **Structure** Since the grinding wheel is similar to a milling cutter with a very large number of teeth randomly oriented, it must have voids to allow space for the chips. If the voids are too small for the chips, the chips stay in the wheel, blocking the voids. This is known as loading of the wheel. Loading causes inefficient cutting. If the voids are too large, again the cutting action is inefficient since there will be too few cutting edges. In an open structure, the grains are not too densely packed, and in a wheel with a closed structure, the grains are tightly packed. For grinding ductile work materials, larger chips are produced, and to reduce the tendency of loading, an open structure is preferred. In the case of hard and brittle work materials, a closed structure is selected. The structure depends on the required grade and also the nature of cut. For a rough cut, an open structure is more suitable.

(ii) **Grade** The grade is determined by the strength of the bonding material. So, a hard wheel means strong bonding and the abrasive grains can withstand large forces without getting dislodged from the wheel. In the case of a soft wheel, the situation is just the opposite. When the work material is hard, the grains wear out easily and the sharpness of the cutting edges is quickly lost. This is known as glazing of the wheel. A glazed wheel cuts less and rubs more, making the process inefficient. To avoid this problem, a soft wheel should be used so that the grains which lose the sharpness get easily dislodged as the machining force on the individual grains increases. Thus, the layers of new grains are exposed, maintaining the sharpness of the wheel. When the work material is soft, a hard wheel should be used since the problem of glazing will be absent and a longer wheel life will be achieved. So, for a work material, there exists an optimal grade—too hard a wheel causes glazing, whereas too soft a wheel wears out very fast. Figure shows the nature of growth of power requirement as the grinding operation continues for too hard, optimum, and too soft wheels.

138. (b)

In broaching, only one motion, i.e., the primary cutting motion, is provided by the machine, whereas the feed is obtained by placing the teeth progressively deeper.

139. (b)

The forming processes can be grouped under two broad categories, namely, (i) cold forming, and (ii) hot forming. If the working temperature is higher than the recrystallization temperature of the material, then the process is called hot forming. Otherwise the process is termed as cold forming. The flow stress behaviour of a material is entirely different above and below its recrystallization temperature. During hot working, a large amount of plastic deformation can be imparted without significant strain hardening. This is important because a large amount of strain hardening renders the material brittle. The frictional characteristics of the two forming processes are also entirely different. For example, the coefficient of friction in cold forming is generally of the order of 0.1, whereas that in hot forming can be as high as 0.6. Further, hot forming lowers down the material strength so that a machine with a reasonable capacity can be used even for a product having large dimensions.

140. (a)

In multi-disk clutch, more heat is generated due to increased number of contacting surface. Heat dissipation is a serious problem in the multi-plate clutch. Therefore, multi-plate clutches are wet clutches, while single plate clutches are dry. The coefficient of friction decreases due to cooling oil, thereby reducing the torque tranmitting capacity of the multiplate clutch. The coefficient of friction is high in dry single plate clutch.

141. (c)

Adverse pressure gradient along the flow tends to decelerate the flow resulting in rapid growth of boundary layer, because the fluid mass in the layer close to the wall has to work against friction alongwith the increasing or adverse pressure gradient. This causes the layers to show a tendency to separate from the surface even earlier.

142. (a)

Since ferrite has a body centred cubic structure, the inter-atomic spaces are small and significantly oblate and cannot readily accommodate even a small carbon atom. Therefore, the solubility of carbon in ferrite is very low, of the order of 0.006% at room temperature.

143. (a)

	Characterized by	Caused by	Reduced by
Burn-in	DFR	Manufacturing defects : Welding flaws, cracks, defective parts, poor quality control, contamination, poor wormanship	Burn-in testing, Screening, Quality control, acceptance testing
Useful life	CFR	Environment, Random loads, Human error "Acts of God" chance events	Redundancy Excess strength
Wear out	IFR	Fatigue, Corrosion, Aging, Friction Cyclic loading	Derating, Preventive maintenance, Parts replacement, Technology

144. (d)

Programme Evaluation and Review Technique (PERT) :

It uses event oriented network in which successive events are joined by arrows. It is preferred for projects that are non-repetitive and in which time for various activities cannot be precisely pre-determined. There is no significant past experience to guide; they are once-through projects. Launching a new product in the market by a company, research and development of a new war weapon, launching of satellite, sending space craft to Mars are PERT projects. Three time estimates - the optimistic time estimate, pessimistic time estimate and the most likely time estimate are associated with each and every activity to take into account the uncertainty in their times.

Critical Path Method (CPM) :

It uses activity oriented network which consists of a number of well recognised jobs, tasks or activities. Each activity is represented by arrow and the activities are joined together by events. CPM is generally used for simple, repetitive types of projects for which the activity times and costs are certainly and precisely known. Projects like construction of a building, road, bridge, physical verification of store, yearly closing of accounts by a company can be handled by CPM. Thus it is deterministic rather than probabilistic model.

145. (b)

Defuzzification is the conversion of the fuzzy output value into an equivalent crisp value for actual use. As fuzzy rules are evaluated and corresponding values are calculated for different output fuzzy sets, there are a number of different possibilities for defuzzification. Two common and useful techniques are the centre of gravity method and Mamdani’s inference method.

Defuzzification to a crisp output is done using the centroid method, by computing the centre of mass of the region of the output variable defined by the fuzzy output.

146. (b)

VARS : There should be a large difference in the normal boiling point of the two substances, at least 200°C, so that the absorbent exerts negligible vapour pressure at the generator temperature. Thus, almost absorbent-free refrigerant is boiled-off from the generator and the absorbent alone returns to the absorber. If absorbent vapour goes with the refrigerant vapour to refrigerant circuit, the refrigeration produced will not be isothermal. In case a solid absorbent used, it does not exert any vapour pressure.

147. (a)

A mixture of two or more phases of a pure substance is still a pure substance as long as the chemical composition of all phases is the same. A mixture of ice and liquid water, for example, is a pure substance because both phases have the same chemical composition.

148. (b)

The ramjet and pulse jet engines come under the category of pilotless operation.

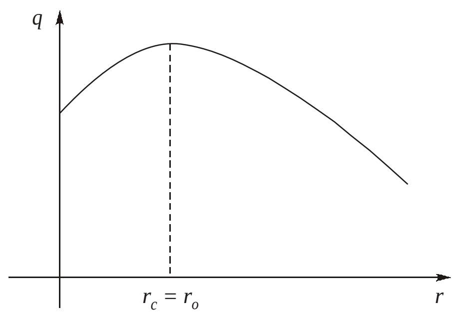
149. (b)

- An important consideration in the design of finned surfaces is the selection of the proper fin length. Normally, the longer the fin, the larger the heat transfer area and thus the higher the rate of heat transfer from the fin.
- The fin efficiency decreases with increasing fin length because of the decrease in fin temperature with length. Fin lengths that cause fin efficiency to drop below 60 percent usually cannot be justified economically and should be avoided.

150. (d)

Given: $k_i = 0.5$ W / m-K; $d_o = 50$ mm; $r_o = 25$ mm; $h = 20$ W / m^{2}K

$$\text{Critical radius of insulation, } r_c = \frac{k_i}{h} = \frac{0.5}{20} = 0.025 \text{ m} = 25 \text{ mm}$$



Since, $r_o = r_c$, so further increase of insulation decrease the heat loss always.

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