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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 16

Section A : Machine Design + Power Plant Engineering **[All Topics]**

Section B : Renewable Sources of Energy + Industrial and Maintenance Engineering Robotics & Mechatronics **[All Topics]**

Section C : Theory of Machines - 2 **[Part Syllabus]**

Answer Key

1.	(d)	**16.**	(c)	**31.**	(b)	**46.**	(b)	**61.**	(a)
2.	(c)	**17.**	(c)	**32.**	(c)	**47.**	(a)	**62.**	(d)
3.	(d)	**18.**	(c)	**33.**	(c)	**48.**	(c)	**63.**	(a)
4.	(c)	**19.**	(a)	**34.**	(c)	**49.**	(b)	**64.**	(a)
5.	(b)	**20.**	(d)	**35.**	(b)	**50.**	(b)	**65.**	(b)
6.	(c)	**21.**	(c)	**36.**	(a)	**51.**	(c)	**66.**	(c)
7.	(a)	**22.**	(c)	**37.**	(d)	**52.**	(d)	**67.**	(a)
8.	(a)	**23.**	(c)	**38.**	(b)	**53.**	(d)	**68.**	(a)
9.	(b)	**24.**	(a)	**39.**	(d)	**54.**	(b)	**69.**	(c)
10.	(a)	**25.**	(c)	**40.**	(c)	**55.**	(b)	**70.**	(a)
11.	(d)	**26.**	(d)	**41.**	(b)	**56.**	(b)	**71.**	(b)
12.	(a)	**27.**	(b)	**42.**	(c)	**57.**	(a)	**72.**	(c)
13.	(a)	**28.**	(d)	**43.**	(c)	**58.**	(c)	**73.**	(d)
14.	(d)	**29.**	(c)	**44.**	(c)	**59.**	(a)	**74.**	(a)
15.	(d)	**30.**	(d)	**45.**	(d)	**60.**	(a)	**75.**	(c)

Section A : Machine Design + Power Plant Engg.

1. (d)

$$\text{Permissible tensile stress, } \sigma_t = \frac{S_{yt}}{f_s} = \frac{400}{2} = 200$$

$$\text{Size of bolt, } \sigma_t = \frac{P}{\frac{\pi}{4}d_c^2}$$

$$200 = \frac{10 \times 1000}{\frac{\pi}{4} \times \left(d_c^2\right)}$$

$$d_c^2 = \frac{40 \times 10^3}{200 \times \pi}$$

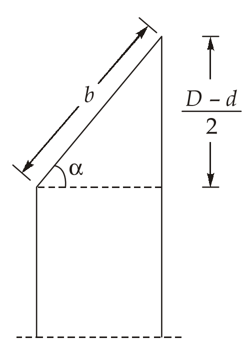
$$d_c = \sqrt{\frac{200}{\pi}}$$

$$d_c = 7.97 \text{ mm} \simeq 8 \text{ mm}$$

2. (c)

For starting a machine from rest clutch should have higher torque capacity. If the clutch is not designed for this increased torque, it will slip under the load and no power can be transmitted.

3. (d)



We know,

$$\sin\alpha = \frac{\left(\frac{D-d}{2}\right)}{b}$$

$$\sin 30° = \frac{\left(\frac{100-50}{2}\right)}{b}$$

$$b = 50 \text{ mm}$$

4. (c)

Self-energizing brakes require initial brake application as the shoe or pad rubs against the rotating drum of disc, a friction force is generated which assists in applying the brakes effectively.

5. (b)

The analysis of bending stresses in gear tooth was given by Mr. Wilfred Lewis, in which the gear tooth can be treated as a cantilever beam.

6. (c)

Consider the work cycle of one minute duration,

$$n_1 = \frac{1240}{4} = 310 \text{ rev}$$

$$n_2 = \frac{360}{2} = 180 \text{ rev}$$

$$n_3 = \frac{1440}{4} = 360 \text{ rev}$$

The average speed of rotation is given by,

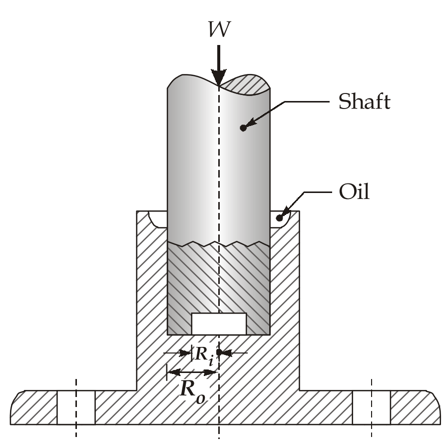
$$n_{avg} = n_1 + n_2 + n_3$$

$$n_{avg} = 310 + 180 + 360 = 850 \text{ rev}$$

As we have considered cycle of 1 minutes

$$n_{avg} = 850 \text{ rpm}$$

7. (a)



Radius of shaft and recess, $R_i = 0.6\ R_o$

$$W = \pi\left(R_o^2 - R_i^2\right)P_b$$

$$500 \times 1000 = \pi\left(R_o^2 - (0.6R_o)^2\right)4$$

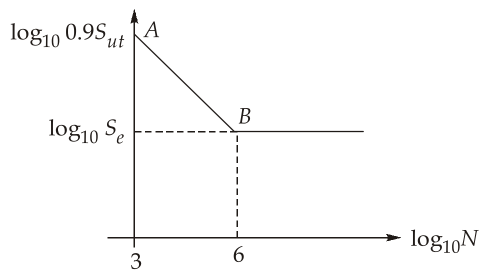
$$\frac{500 \times 1000}{4 \times \pi} = 0.64R_o^2$$

$$R_o^2 = \frac{500 \times 1000}{4 \times \pi \times 0.64}$$

$$R_o = 249.34 \text{ mm} \simeq 250 \text{ mm}$$

8. (a)

The S-N curve is a follows:



9. (b)

Axle is a shaft that supports rotating elements like wheel, hoisting drum, or rope sheave and which is fitted to the housing by means of bearing.

10. (a)

11. (d)

Total number of contacting surface $= n_1 + n_2 - 1$

Here, $n_1 = 8; \quad n_2 = 7$

Total pair $= 8 + 7 - 1 = 14$

12. (a)

Railway trains commonly uses shoe brake.

13. (a)

$$A = t \times \pi D = 0.707 \times \sqrt{2} \times \pi \times 10$$

$$\text{Direct shear stress, } \tau = \frac{P}{A} = \frac{10 \times 1000}{0.707 \times \sqrt{2} \times \pi \times 10} = 318.3 \text{ MPa}$$

14. (d)

Theoretical stress concentration factor,

$$k_t = \left[1 + 2\frac{b}{a}\right] = 1 + \left[2 \times \frac{1}{2}\right]$$

$$k_t = 2$$

Fatigue stress concentration factor,

$$k_f = 1 + q(k_t - 1)$$

$$= 1 + 0.9(1)$$

$$= 1.9$$

15. (d)

The plane of maximum shear stress is inclined at 45° in parallel fillet weld and at 67.5° in transverse fillet weld and strength of transverse fillet weld is 1.17 times of the strength of parallel fillet weld.

16. (c)

There are 4 rivets subjected to single shear,

$$4\left(\frac{\pi}{4}\right)d^2 \times \tau = P$$

$$\frac{22}{7} \times d^2 \times 70 = 10 \times 10^3$$

$$d^2 = \frac{1000}{22}$$

$$d = 6.74 \simeq 7 \text{ mm} \quad \text{...(i)}$$

For crushing consideration,

$$4 \times d \times t \times \sigma_c = P$$

$$4 \times d \times 3 \times 100 = 10 \times 10^3$$

$$d = \frac{100}{12} = 8.33 \simeq 9 \text{ mm} \quad \text{...(ii)}$$

here crushing becomes the criteria of design,

$$\therefore \quad d = 9 \text{ mm}$$

17. (c)

18. (c)

Life in million revolution, $L_{10} = L_{90} = \left(\frac{C}{P_e}\right)^n$

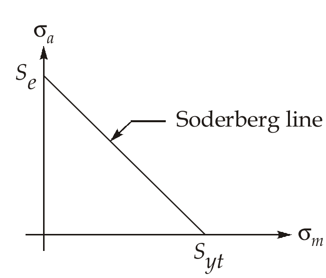
$$L_{10} = L_{90} = \left(\frac{5000}{500}\right)^3 = 1000 \text{ million revolution}$$

$$L_{10} \times 10^6 = (L_{10})_{\text{hours}} \times 60 \times N_{\text{rpm}}$$

$$1000 \times 10^6 = (L_{10})_{\text{hours}} \times 60 \times 50$$

$$= (L_{10})_{\text{hours}} = 0.33 \times 10^6 \text{ hours}$$

19. (a)



Soderberg criteria formula,

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

$$\text{Mean stress, } \sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{100+50}{2} = 75$$

$$\sigma_m = 75$$

$$\text{Alternating stress amplitude, } \sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{100-50}{2} = 25$$

Using Soderberg equation,

$$\frac{75}{300} + \frac{25}{200} = \frac{1}{N}$$

$$N = \frac{8}{3} = 2.67$$

20. (d)

The advantages of PBFBC are as follows :

1. There is an increase in its specific power output and hence, a potential reduction in capital cost. At a typical fluidizing velocity of 2 m/s the bed area of AFBC at 1 bar is 2 m^2/MW, while it is 0.2 m^2/MW at 10 bar.
2. By combining a gas turbine with a steam turbine, the overall efficiency of power generation system can be increased from 33% for conventional power plants to more than 40% in PBFBC plants.
3. The emission of nitrogen oxides can be substantially reduced.
4. The PBFBC has a higher combustion efficiency than an AFBC.
5. The gas residence time in an AFBC is about 0.5 s, whereas it is about 5s in a PBFBC (due to low fluidizing velocity of about 1 m/s for a higher gas density). Therefore, the sulphur capture is more.

21. (c)

We know that,

$$\text{Collection efficiency, } \eta_0 = 1 - e^{(-AV/Q)} = 1 - e^{\left(\frac{-625\times 0.16}{25}\right)} = 1 - e^{-4}$$

$$= 1 - \frac{1}{e^4} = 1 - \frac{1}{\left(e^2\right)^2}$$

$$= 1 - \frac{1}{(7.34)^2} = 0.9814 = 98.14\%$$

22. (c)

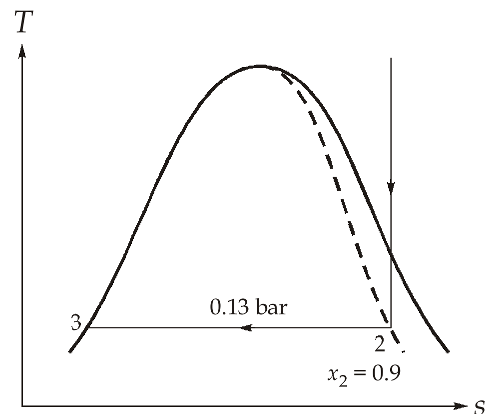
- **Grindability index :** It is inversely proportional to the power required to grind the coal to a specified particle size for burning.
- **Caking coal :** Some types of coal during and after release of volatile matter become soft and pasty and form agglomerates. There are called caking coal.

23. (c)

This air affects the condenser performance badly because of the following reasons:

1. It reduces the heat transfer considerably.
2. It reduces the condenser vacuum and increases the turbine exhaust pressure thus reducing the turbine output.

24. (a)



At 0.13 bar,

$$h_2 = h_f + x_2 h_{fg}$$
$$= 213.4 + 0.9 \times 2380.5$$
$$h_2 = 2355.85 \text{ kJ/kg}$$
$$h_f \text{ at } 45°\text{C} = 188.4 \text{ kJ/kg}$$

By energy balance,

$$\dot{m}_w c_{p_w}\left(t_{w_2} - t_{\omega_1}\right) = \dot{m}_s\left(h_2 - h_3\right)$$
$$\frac{\dot{m}_w}{\dot{m}_s} = \frac{2355.85 - 188.4}{4.18 \times (40 - 30)}$$
$$\frac{\dot{m}_w}{\dot{m}_s} = 51.85 \text{ kg water/kg steam}$$

25. (c)

$$(W_{net})_{max} = c_p\left(\sqrt{T_{max}} - \sqrt{T_{min}}\right)^2$$
$$= 1.005 \times \left(\sqrt{1050} - \sqrt{300}\right)^2 = 228.64 \text{ kJ/kg}$$
$$\eta_{cycle} = 1 - \sqrt{\frac{T_{min}}{T_{max}}} = 1 - \sqrt{\frac{300}{1050}}$$
$$= 0.4654 \text{ or } 46.54\%$$

26. (d)

The functions of the drum in a water-tube boiler can follows: be summarized as

1. To store water and steam sufficiently to meet varying load requirement.
2. To aid in circulation.
3. To separate vapour or steam from water-steam mixture, discharged by the risers.
4. To provide enough surface area for liquid-vapour disengagement.
5. To maintain a certain desired ppm in the drum water by phosphate injection and blowdown.

27. (b)

The main advantages of mechanical draught cooling towers are:

1. Low capital and construction costs.
2. Assured supply of the required quantity of air at all loads and climatic conditions.
3. Small physical structure.
4. Suitable for low approach and broad range.

28. (d)

$$W_{net} = 150 \text{ kJ/kg}, \eta_T = 0.8, \eta_c = 0.85$$

$$\text{Back work ratio} = \frac{W_C}{W_T} = 0.4$$

$$\therefore \quad W_C = 0.4\, W_T \quad \text{...(i)}$$

$$W_{net} = W_T - W_C = W_T - 0.4W_T$$

$$150 = 0.6W_T$$

$$W_T = 250 \text{ kJ/kg}$$

From equation (i)

$$W_C = 0.4 \times 250 = 100 \text{ kJ/kg}$$

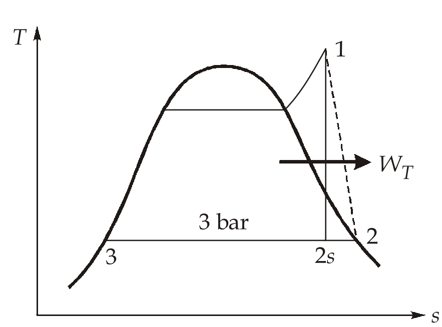
$$(W_T)_{actual} = \eta_T \times W_T = 0.8 \times 250 = 200 \text{ kJ/kg}$$

$$(W_C)_{actual} = \frac{W_C}{\eta_C} = \frac{100}{0.8} = 125 \text{ kJ/kg}$$

$$(W_{net})_{actual} = (W_T)_{actual} - (W_C)_{actual}$$

$$\therefore \quad (W_{net})_{actual} = 200 - 125 = 75 \text{ kJ/kg}$$

29. (c)



Let $\dot{m}$ = mass flow rate of steam

$$\dot{m}(h_1 - h_2) = 1000 \text{ kW}$$

$$h_1 - h_2 = \frac{1000 \times 3600}{10000} = 360 \text{ kJ/kg}$$

$$h_1 - h_{2s} = \frac{h_1 - h_2}{\eta_T} = \frac{360}{0.7} = 514.3 \text{ kJ/kg}$$

30. (d)

$$\text{Specific power output} = 700 \text{ kW/kg}$$

$$C_p(T_3 - T_4) = 700$$

$$1 \times (T_3 - 700) = 700$$

$$T_3 = 1400 \text{ K}$$

$$\text{Pressure ratio, } \frac{p_3}{p_4} = \left(\frac{T_3}{T_4}\right)^{\frac{\gamma}{\gamma-1}} = \left(\frac{1400}{700}\right)^{\frac{1.4}{0.4}}$$

$$= \left(\frac{1400}{700}\right)^{3.5} = (2)^{3.5}$$

$$= (2)^3 \times (2)^{1/2} = 8 \times 1.41$$

$$= 11.28 \simeq 11$$

31. (b)

32. (c)

$$\text{Blade efficiency, } \eta_b = \frac{2u\left(V_{w_1} + V_{w_2}\right)}{V_1^2} = \frac{2 \times 200 \times (700 + 250)}{(800)^2}$$

$$= 0.5937 \text{ or } 59.37\%$$

33. (c)

It is suitable for large power plants, where a high condenser vacuum is required.

34. (c)

NAME	FUNCTION
Safety valves :	Do not allow boiler pressure to rise beyond its safe pressure
Water level indicator :	Shows working level of water in the boiler
Pressure gauge :	Indicates working pressure of boiler
Steam stop valve :	Regulates the amount of outgoing steam
Feed check valve :	Checks the amount of feed water going to the boiler and does not allow its return
Man hole :	Allows a person to go inside the boiler drum for repairs. etc.
Feed pipe :	Lead the feed water to the inside of the boiler

35. (b)

We know that, Pump work, $W_P = V_f(P_1 - P_2)$

$= 0.001037(3000 - 75)$

$= 3.03$ kJ/kg

36. (a)

Advantages and Disadvantages of Surface Condensers

Advantages:

1. The surface condenser lowers the back pressure (7 to 8 kPa) of steam at the turbine exit, and thus allows the expansion of steam through a higher pressure ratio.
2. It has high vacuum efficiency, and is thus suitable for large power plants.
3. It gives a pure condensate which can be recirculated as feed water to the boiler.
4. Since the condensate is reused, it saves the cost of fresh water to be circulated and the cost of its chemical treatment.
5. It requires low power input for air-extraction pump.
6. Since the cooling water is in indirect contact of steam, low quality cooling water can be used in the condenser.
7. The cooling of condensate can be controlled by regulating the flow of cooling water.

Disadvantages:

1. Indirect cooling takes place in the condenser, and thus large cooling water is required.
2. Construction is complicated, requires higher installation cost.

37. (d)

Cornish Boiler : It is very similar to a Lancashire boiler. It is also a horizontal, fire tube, internally fired, natural circulation, stationary boiler. However, it differs from a Lancashire boiler in two respects.

1. It is small in size.
2. It has only one flue tube.

The Cornish boiler consists of a horizontal cylindrical shell of 1.25 m to 1.75 m diameter and 4 m to 7 m long. It has flat ends. The flue tubes containing the furnace are located in the centre of the boiler shell.

Section B : RSE + Industrial & Maintenance Engg. + Robotics & Mechatronics

38. (b)

Gas required for cooking for the family = $5 \times 0.227 = 1.135$ m^3/day

Gas required for lighting = $0.126 \times 2 \times 3 = 0.756$ m^3/day

Total daily gas requirement of the family = $(1.135 + 0.756)$ m^3/day

$= 1.891$ m^3/day

Let n be the number of cows.

$$\text{Then, gas production per day} = 0.428 \times n \text{ m}^3/\text{day} = 1.891 \text{ m}^3/\text{day}$$

$$\therefore \quad n = \frac{1.891}{0.428} = 4.41 \simeq 5$$

$$n = 5 \text{ cows}$$

39. (d)

Advantages:
- Rocks are abundant, low cost, easy to handle, non-toxic and non-combustible.
- High storage temperatures are possible.
- Heat exchanger can be avoided.
- No freezing problem.
- No corrosion problem

Disadvantages:
- Storage volumes are large.
- High pressure drop.
- Simultaneous charging and discharging are not possible.

40. (c)

The global potential in winds for large-scale grid-connected power generation has been estimated as 9,000 TWh/year or 1 TW_e ($1T = 10^{12}$). It is also estimated that favourable winds for small-scale applications such as wind pumps, battery chargers, heaters, etc., are available on about 50% of the Earth's surface which means that small-scale wind turbines can be practical in many parts of the world.

41. (b)

$$\text{Motor power output} = 648 \text{ Watt}$$

$$\text{Electrical power required by the motor} = \frac{648}{0.80} = 810 \text{ Watt}$$

$$\text{Area in one module} = 9 \times 4 \times a^2 \times 10^{-6} \text{ m}^2$$

$$\text{Output of solar array} = 1000 \times 36a^2 \times 10^{-6} \times 8 \times 0.125$$

$$= 0.036a^2$$

The output of solar array is the input to the motor

$$\therefore \quad 0.036a^2 = 810$$

$$a^2 = 22500$$

$$a = 150$$

Hence, cell size is 150 mm × 150 mm.

42. (c)

Because of high temperature of operation, a catalyst is not necessary.

43. (c)

$$\bar{H}_0 = 22863.3 \text{ kJ/m}^2\text{-day}, \quad \bar{H}_g = 14413.82 \text{ kJ/m}^2\text{-day}$$

We know that,

Monthly average daily clearance index,

$$\bar{k}_T = \frac{\bar{H}_g}{\bar{H}_0}$$

$$\bar{k}_T = \frac{14413.82}{22863.3} = 0.63$$

Also, $$\frac{\bar{H}_d}{\bar{H}_g} = 1.354 - 1.570\,\bar{k}_T$$

$$\frac{\bar{H}_d}{\bar{H}_g} = 1.354 - 1.570 \times 0.63$$

$$\bar{H}_d = 5260 \text{ kJ/m}^2\text{-day}$$

44. (c)

$$\text{Average consumption} = \frac{600}{30} = 20 \text{ units per day}$$

Maximum consumption is of 50 units per day.

$$\text{Buffer stock} = (50 - 20) \times \text{L.T.}$$

$$= 30 \times 10 = 300 \text{ units}$$

$$\text{Reorder level (ROL)} = \text{Average DDLT + Buffer stock}$$

$$= 20 \times 10 + 300$$

$$= 500 \text{ units}$$

45. (d)

$$\text{EOQ } (Q^*) = \sqrt{\frac{2 \times 600 \times 80}{0.40}} = 489.89 \simeq 490 \text{ units}$$

$$\text{Average inventory level} = \text{Buffer stock} + \frac{1}{2} \times Q^*$$

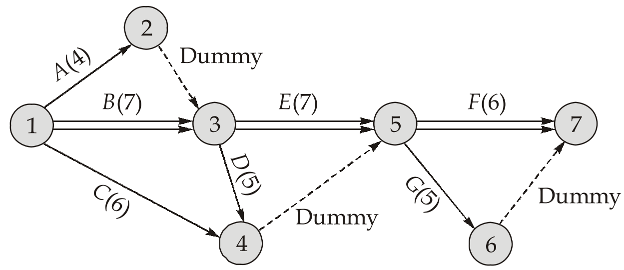
$$= 300 + \frac{1}{2} \times 490$$

$$= 545 \text{ units}$$

$$\text{Inventory carrying cost per month} = ₹545 \times 0.40$$

$$= ₹218$$

46. (b)



Critical path → 1 - 3 - 5 - 7

Duration of critical path = Minimum time of completion of the project

= 7 + 7 + 6 = 20 days

47. (a)

Common DAC limitations are an anomalous step size between adjacent binary numbers, non-monoatomic behavioir, or a zero output.

48. (c)

Piezoelectric materials that are usable in transducer design must have the following properties: stability, high output, insensitivity to temperature and humidity changes and the ability to be worked into a desired configuration or shape. As no material is optimal for all the above properties, transducer design requires certain compromises.

49. (b)

- **Capacitive Proximity Sensors :** These are similar to inductive proximity sensors except that they sense the presence of almost any material.
- **Photoelectric Proximity Sensors :** Photoelectric proximity sensors comprise an infrared light emitting diode (LED) source and a light sensitive switch known as a detector.
- **Digital Optical Encoder :** It is a device that converts motion into a sequence of digital pulses. By counting a single bit or by decoding a set of bits, the pulses can be converted to relative or absolute position measurements.

50. (b)

$$V_{s_1} = V_1 \sin\alpha = 50 \times \sin 120°$$

$$= 50 \times \frac{\sqrt{3}}{2} = 25\sqrt{3}\text{ V}$$

$$V_{s_2} = V_2 \cos\alpha = 50 \times \cos 120°$$

$$= 50 \times \left(-\frac{1}{2}\right) = -25\text{ V}$$

$$\frac{V_{s_1}}{V_{s_2}} = \frac{25\sqrt{3}}{-25} = -\sqrt{3}$$

51. (c)

1. **Time-based Maintenance :** To maintain the machine after certain predetermined period of time.
2. **Reliability-centred Maintenance :** To enhance the reliability of the equipment and build the confidence of the user.
3. **Breakdown Maintenance or Corrective Maintenance** : To repair the machine after failure occurs.
4. **Maintenance Prevention :** To prevent the maintenance by replacing with new parts when old parts fail.
5. **Productive Maintenance :** To improve the productivity by carrying out the maintenance on machine parts by providing alternative without shutting down the machine.

52. (d)

Eddy current testing is one of the methods of detecting discontinuities and flaws. The method is based on the principle that when the alternate current carrying conductor coil is brought near a metallic conductive specimen, eddy currents are induced in the specimen due to electromagnetism. These eddy currents produce their own magnetic field that opposes the field of the current carrying coil, thereby increasing the impedance (resistance). Coil impedance can be measured whose variation indicates the crack or flaw.

53. (d)

FMEA drives process improvements as the primary objectives, with an emphasis an mistake proofing solution.

54. (b)

55. (b)

$$F_{new} = \text{Trans}(d_x, d_y, d_z) \times F_{old}$$
$$= \text{Trans}(0, 12, 6) \times F_{old}$$
$$F_{new} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 12 \\ 0 & 0 & 1 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix} \times \begin{bmatrix} 0.369 & -0.259 & 0.423 & 12 \\ 0.527 & 0.819 & 0.439 & 0 \\ -0.766 & 0 & 0.643 & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$
$$F_{new} = \begin{bmatrix} 0.369 & -0.259 & 0.423 & 12 \\ 0.527 & 0.819 & 0.439 & 12 \\ -0.766 & 0 & 0.643 & 12 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

56. (b)

SCARA configuration provides high stiffness to the arm in vertical direction and high compliance in the horizontal plane.

Section C : Theory of Machines - 2

57. (a)

$$\omega = \frac{2\pi \times 360}{60} = 12\pi \text{ rad/s}$$

$$a_{max} = \frac{4\omega^2 h}{\theta^2} \text{ during descent}$$

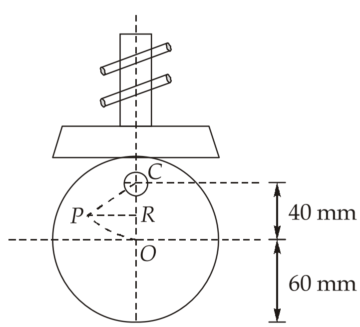
$$= \frac{4 \times (12\pi)^2 \times 40 \times 10^{-3}}{\left(\frac{\pi}{3}\right)^2} = 207.36 \text{ m/s}^2$$

58. (c)

$$\text{During ascent, } \omega = \frac{2\pi N}{60} = \frac{2\pi \times 300}{60} = 10\pi$$

$$V_{max} = \frac{2h\omega}{\phi_a} = \frac{2 \times (0.02) \times (10\pi)}{120 \times \frac{\pi}{180}} = 0.6 \text{ m/s}$$

59. (a)



Given : e = 40 mm; m = 3 kg; s = 5 N/mm = 5000 N/m; P = 60 N + mg = 60 + 3 × 9.81

Speed at which the follower begins to lift from the cam surface or the jump speed is

$$\omega = \sqrt{\frac{2se + P}{me}} = \sqrt{\frac{2 \times 5000 \times 0.04 + 60 + 3 \times 9.81}{3 \times 0.04}}$$

$$= \sqrt{4078.6} = 63.86 \text{ rad/s}$$

$$\frac{2\pi N}{60} = 63.86 \text{ rad/s}$$

$$N = 609.9 \text{ rpm} \simeq 610 \text{ rpm}$$

60. (a)

$$VR = \frac{N_2}{N_1}$$

$$= \frac{T_1}{T_2} = \frac{1}{4}$$

$$\frac{T_1}{64} = \frac{1}{4}$$

$$T_1 = 16$$

61. (a)

Given : $G = 3$

$$T_{min} = \frac{2A_G}{\sqrt{1 + \frac{1}{G}\left(\frac{1}{G} + 2\right)\sin^2\phi} - 1}$$

$$= \frac{2}{\sqrt{1 + \frac{1}{3}\left(\frac{1}{3} + 2\right)\sin^2 20} - 1}$$

$$= 44.9 \simeq 45$$

62. (d)

Given : $a_w = 0.84$; Pressure angle, $\phi = \cos^{-1}(0.94)$

For pinion with a rack, $$t_{min} \geq \frac{2a_r}{\sin^2\phi}$$

$$0 \geq \frac{2 \times 0.84}{0.1169} = 14.371$$

$$t_{min} = 15$$

63. (a)

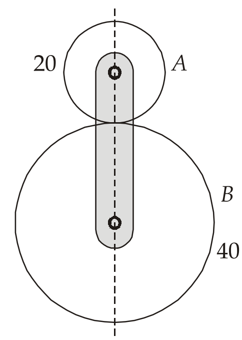
64. (a)

$$\frac{N_F}{N_A} = \frac{T_A}{T_B} \times \frac{T_C}{T_D} \times \frac{T_E}{T_F}$$

$$= \frac{25}{52} \times \frac{20}{80} \times \frac{30}{70}$$

$$N_F = 20.6 \text{ rpm}$$

65. (b)



Action	Arm	A	B
Arm fixed, A + 1 rev	0	$+x$	$-\frac{x \times 20}{40}$
Add y	y	$y+x$	$y-\frac{x}{2}$

Gear A is fixed, thus $y + x = 0$

Arm rotates at 60 rpm, $y = 60$ (ACW)

$x = -60$ (CW)

$$\text{Speed of gear } b = y - \frac{x}{2} = 60 - \left(\frac{-60}{2}\right)$$

$$= 60 + 30 = 90 \text{ rpm}$$

66. (c)

Given : $N_S = 800$ rpm; $N_A = 0$; $\eta = 0.9$

$\Sigma TN = 0$

$$T_S N_S + T_a N_a + T_A N_A = 0 \quad \text{...(i)}$$

$$T_S = \frac{\text{Power input}}{\frac{2\pi N}{60}} = \frac{5000}{\frac{2\pi \times 800}{60}} = 59.7 \text{ Nm}$$

$$T_a = \text{Theoretical torque at output} = \frac{\text{Actual torque at output}}{\eta}$$

From equation (i),

$$59.7 \times 800 + \frac{T_a'}{0.9} \times 89 + T_A \times 0 = 0$$

$$T_a' = -482.9 \text{ Nm}$$

$$T_S + T_a' + T_A = 0$$

$$59.7 - 482.9 + T_A = 0$$

$$T_A = 423.266 \text{ Nm}$$

67. (a)

Mass to be balanced at the crankpin $= cm_{reci} + m_{rot}$

$= 0.6 \times 40 + 20 = 44$ kg

$$m_c r_c = mr$$

$$m_c \times 300 = 44 \times 150$$

$$m_c = 22 \text{ kg}$$

68. (a)

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 300}{60} = 10\pi$$

$$c = I\omega\omega_p$$

$$Mgl = I\omega\omega_p$$

$$10 \times 10 \times 0.2 = 10 \times (0.1)^2 \times 10\pi \times \omega_p$$

$$\omega_p = 6.36 \text{ rad/s}$$

69. (c)

Given : $m = 400$ kg; $K = 0.3$ m

$$\omega = \frac{2\pi \times 3000}{60} = 100\pi$$

$$v = 64 \text{ m/s}$$

$$I = mk^2 = 400 \times (0.3)^2 = 36 \text{ kg.m}^2$$

$$\omega_p = \frac{V}{r} = \frac{64}{60}$$

$$c = I\omega\omega_p$$

$$= 36 \times 100\pi \times \frac{64}{60}$$

$$= 12.057 \text{ kNm}$$

70. (a)

- Adding a counterweight at a suitable radius is direct method to balance part of the shaking force.
- Increasing the engine frame weight will only add inertia.
- Using a countermass to balance centrifugal forces will reduce unbalanced rotating forces.

71. (b)

72. (c)

Lubrication type does not influence the geometrical path of contact, though it affects friction and wear.

73. (d)

Spur rack is special case of a spur gear where it is made of infinite diameter so that the pitch surface is a plane.

74. (a)

A more convex cam surface increases the contact duration, this slow down the rate of rise of the follows, spreading the load over a longer time and reducing shock and lateral force on the bearings. Hence, less pressure is generated because the acceleration and jerk are lower.

75. (c)

The velocity ratio depends on pitch circle diameters, not base circle diameters. Base circles are only used for generating the involute profile, not for determining the velocity ratio, hence the statement II is false.

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