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ESE 2026 : 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.	(b)	31.	(a)	46.	(d)	61.	(d)
2.	(b)	17.	(c)	32.	(c)	47.	(d)	62.	(c)
3.	(d)	18.	(b)	33.	(b)	48.	(d)	63.	(d)
4.	(d)	19.	(b)	34.	(c)	49.	(c)	64.	(c)
5.	(d)	20.	(a)	35.	(a)	50.	(c)	65.	(c)
6.	(a)	21.	(c)	36.	(a)	51.	(a)	66.	(c)
7.	(d)	22.	(a)	37.	(b)	52.	(d)	67.	(a)
8.	(a)	23.	(d)	38.	(d)	53.	(c)	68.	(a)
9.	(c)	24.	(c)	39.	(c)	54.	(a)	69.	(b)
10.	(b)	25.	(b)	40.	(a)	55.	(d)	70.	(c)
11.	(d)	26.	(a)	41.	(b)	56.	(c)	71.	(a)
12.	(d)	27.	(c)	42.	(c)	57.	(c)	72.	(d)
13.	(b)	28.	(c)	43.	(d)	58.	(b)	73.	(c)
14.	(c)	29.	(b)	44.	(b)	59.	(a)	74.	(b)
15.	(d)	30.	(c)	45.	(c)	60.	(b)	75.	(b)

Section A : Machine Design + Power Plant Engg.

1. (d)

Methods of Increasing the Thermal Efficiency:

Based on above two principles, the methods of increasing the thermal efficiency are as follows:

(i) By increasing the superheating temperature of steam

(ii) By increasing the maximum pressure of steam.

(iii) By reducing the exhaust pressure of steam.

(iv) By regenerative feed heating.

(v) By reheating of steam.

(vi) By water extraction.

(vii) By using binary-vapor.

2. (b)

Irreversibilities in Steam Power Plant based on Rankine-Cycle

Internal irreversibilities	External irreversibilities
• Fluid friction	• Temperature difference between working fluid and hot gases
• Mixing	
• Throttling	• Temperature difference between working fluid and cooling-water
• Valve pressure loss	

3. (d)

Requirements of an Ideal Working - Fluid

1. Ample availability at low cost.
2. Critical temperature should be higher than metallurgical limits.
3. Steep saturated vapor-line to minimize moisture problem during expansion in turbine.
4. Working fluid should wet boiler surfaces enveloping it for better heat transfers.
5. Low liquid specific heat and high vapor specific heat so that least heat is added at lower temperature and most of the heat is added at higher temperature.
6. It should be chemically stable at maximum temperature of boiler.
7. Freezing point should be much below atmospheric pressure.
8. Considerable decrease in volume upon condensation.

4. (d)

Heat rate : Amount of heat supplied (in kJ) per unit energy produced (in kWhr)

$$\text{H.R.} = \frac{Q_s(\text{in kJ})}{W_{net}(\text{in kWhr})} = \frac{Q_s(\text{kJ})}{W_{net}(\text{kJ})\dfrac{\text{Hr}}{\text{sec}}}$$

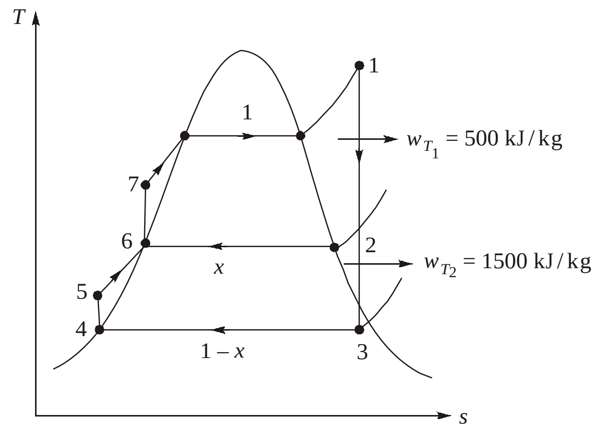
$$= \frac{Q_s(\text{kJ})}{W_{net}(\text{kJ}) \times \dfrac{1}{3600}}(\text{kJ/kWhr})$$

$$\text{H.R.} = \frac{3600}{\eta_{th}}(\text{kJ/kWhr}) = \frac{3600}{0.36}$$

$$= 100 \times 100 = 1000 \text{ (kJ/kWhr)}$$

5. (d)

$h_1 = 3000$ kJ/kg; $h_4 \simeq h_5 = 200$ kJ/kg



Energy balance of feed water-heater

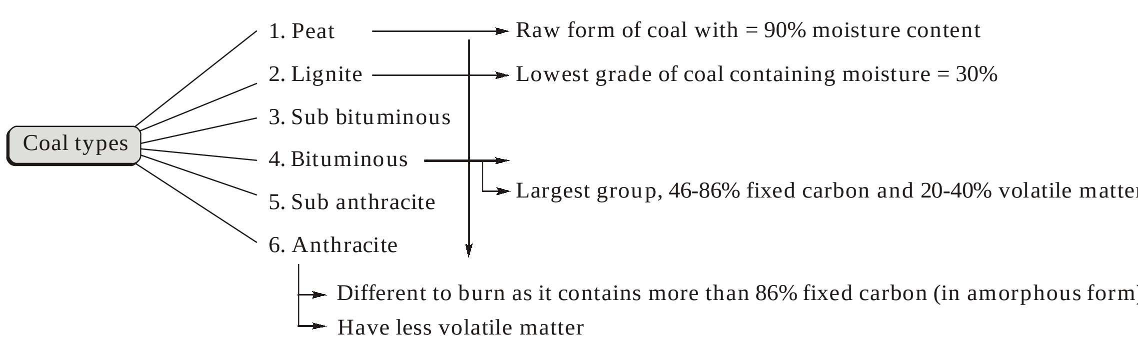
$$(h_1 - w_{T_1})x + h_5(1 - x) = h_6 \times 1$$

$$(3000 - 500)x + 200(1 - x) = h_6$$

$$2300x + 200 = 1350$$

$$x = 0.5$$

6. (a)



7. (d)

The amount of draught necessary for a certain boiler depends on the following :

(i) rate at which combustion takes place.

(ii) characteristics of fuel and its depth on the grate.

(iii) design of combustion chamber and the method of burning the fuel.

(iv) resistances in fine gases circuits offered by baffles, tubes, superheaters, reheater, evaporator, economiser, preheater, etc.

8. (a)

Classification of Boilers.

Based on tube-contents

1. Fire Tube : Cochran, Cornish, Lancashire, locomotive boilers.
2. Water Tube : Babcock and Wilcox boiler, Stirling boiler, power boilers for utility.

9. (c)

Boiler Mountings : These are mounted over boiler body for safety to complete control over process of steam generation.

(i) Safety Fittings : Safety valves, water level indicator, fusible-plug.

(ii) Control Fittings : Steam stop valve, feed check valve, Pressure gauge.

Boiler Accessories : These are mounted either inside or outside the boiler to increase the efficiency and proper working of plant.

e.g. Air Preheater, Economiser, superheater, feed pump, Steam trap, steam separator, pressure reducing valve.

Economiser Vs Air-Preheater

Economiser : To heat feed-water using hot flue gas leaving superheater or reheater

Air-Preheater's : To heat Air before entering the furnace using hot flue gases before exhausting them.

Steam Pressure Control / Boiler - Master

To maintain steam pressure by adjusting fuel and combustion air flows.

Desuperheating/Attempering

It is reduction of Steam temperature and used to control the temperature of steam.

10. (b)

$$\dot{Q}_{friction} = \frac{\dot{m}}{2}\left(V_{r_1}^2 - V_{r_2}^2\right); \text{(Relative velocity reduces due to blade friction)}$$

$$\dot{W}_T = \dot{m}\left[\left(\frac{V_1^2 - V_2^2}{2}\right) - \left(\frac{V_{r_1}^2 - V_{r_2}^2}{2}\right)\right]$$

11. (d)

For the same blade (peripheral) velocity, the velocity at inlet to moving blades for maximum efficiency is

$$C_1 = \frac{u}{\cos\alpha_1} \quad \text{For 50\% reaction stage}$$

$$C_1 = \frac{2u}{\cos\alpha_1} \quad \text{For simple impulse stage}$$

$$C_1 = \frac{4u}{\cos\alpha_1} \quad \text{For a 2-row curtis stage}$$

12. (d)

In surface condensers (indirect type), there is no mixing of cooling water and steam. It is a shell and tube type heat exchanger. The heat released upon condensation is transferred to circulating cooling water through the walls of the tubes.

13. (b)

$$\text{Range, } R = T_{\text{Hot in}} - T_{\text{cold out}}$$

$$R = 50°\text{C} - 35°\text{C} = 15°\text{C}$$

14. (c)

$$\text{Cooling efficiency} = \frac{\text{Actual cooling}}{\text{Maximum possible cooling}}$$

$$\eta_{cooling} = \frac{T_{c_1} - T_{c_2}}{T_{c_1} - T_w}$$

$$\eta_{cooling} = \frac{50-35}{50-25} \times 100\% = 60\%$$

15. (d)

$$\text{Back work ratio } (r_B) = \frac{W_C}{W_T}$$

$$\text{Work ratio } (r) = \frac{W_{net}}{W_T}$$

$$r + r_B = 1$$

$$r = \frac{W_{net}}{W_T} = \frac{0.6W_T}{W_T} = 0.6$$

Alternatively,

$\because$ $r_B = 0.4$

$\Rightarrow$ $r = 1 - 0.4 = 0.6$

16. (b)

$$\text{sfc} = \frac{\dot{m}_f}{P(\text{kW}\cdot\text{Hr})/s} = \frac{3600\dot{m}_f(\text{kg/s})}{P(kW)}(\text{kg/kW.Hr})$$

$$= \frac{3600\dfrac{\dot{m}_a(\text{kg/s})}{(\text{A/F})_{\text{ratio}}}}{\text{P(kW)}}$$

$$\text{C.V.} = 45 \text{ MJ/kg}$$

$$\text{Available, C.V.} = \eta_{\text{comb}}\cdot\text{C.V.} = 0.95 \times 45 \text{ MJ/kg} = 40.5 \text{ MJ/kg}$$

$$E_{\text{comb}} = \dot{m}_f\left(\eta_{comb}\cdot C.V.\right) = 81 \text{ MW}$$

$$\text{Power produced} = 40 \times 10^3 \text{ BHP}$$
$$= 29.44 \times 10^6 \text{ W}$$
$$= 29.44 \times 10^3 \text{ kW} \qquad (\because \; 1 \text{ HP} \simeq 746 \text{ W}; 1 \text{ BHP} ; 736 \text{ W})$$

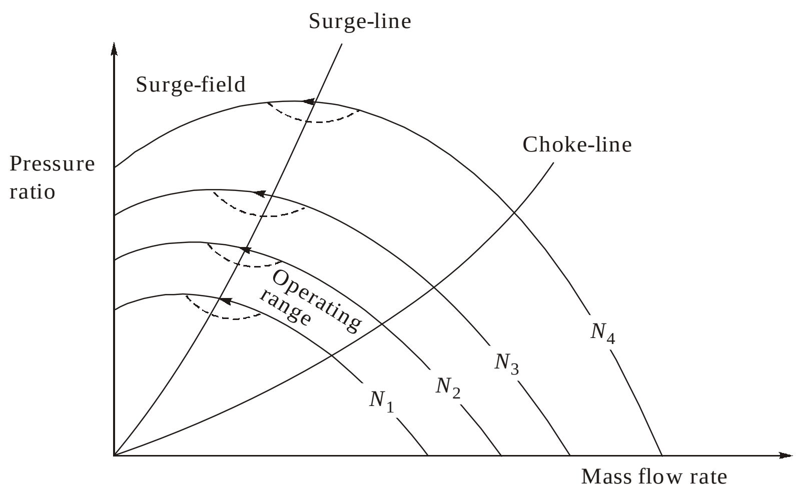
$$\text{sfc} = \frac{3600\left(\frac{100}{50}\right)\text{kg/s}}{29.44 \times 10^3 \, kW} = 0.25 \text{ kg/kWhr}$$

17. (c)

The coal burning rate is expressed as,

$$\dot{m}_f = \frac{200}{0.9 \times 24} = 9.26 \text{ kg/s}$$

18. (b)



Surging: There is an unstable limit of operation of centrifugal and axial flow compressors, known as surging. Surging is caused due to unsteady, periodic and reversal of flow through the compressor when the compressor has to operate at less mass flow rate than a predetermined value (a value corresponding to maximum pressure, at a particular speed).

19. (b)

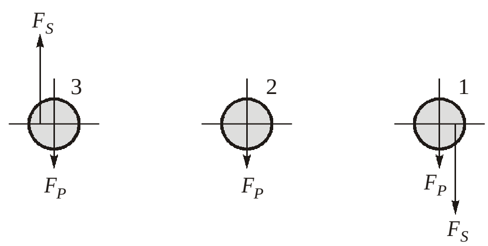
$$\sigma_{max} = +100 \text{ MPa}$$
$$\sigma_{min} = -100 \text{ MPa}$$
$$\sigma_m = 0$$
$$\sigma_a = 100 \text{ MPa}$$

According to Soderberg's criteria,

$$\frac{\sigma_m}{\sigma_y} + \frac{\sigma_a}{\sigma_e} = \frac{1}{N}$$

$$N = \frac{1}{\frac{0}{300} + \frac{100}{200}} = 2$$

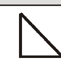
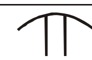
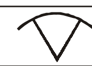
20. (a)



(F_{net}) at bolt 1 is maximum

∴ Bolt-1 is critical

21. (c)

Type of Weld	Symbol
Fillet	
Square Butt	
Single V-Butt	
Double V-Butt	
Spot	
Seam	
Projection	

22. (a)

$$\tau_{max} = \frac{P}{\frac{t}{\sqrt{2}} \cdot 2l} = \frac{10 \text{ kN}}{\frac{14.14}{1.414} \cdot (2)(50)}$$

$$= \frac{10000}{10 \times 100} \text{N/mm}^2 = 10 \text{ MPa}$$

23. (d)

L_{10} = 8000 million revolutions

$$L_{10} = \left(\frac{C}{P}\right)^n ; \left[n = 3 \text{ for ball bearing; } n = \frac{10}{3} \text{ for roller bearing}\right]$$

$$C = (L_{10})^{1/n} \cdot P = (8000)^{1/3} \cdot 70$$

$$= 20 \times 70 = 1400 \text{ kN}$$

24. (c)

$$\text{Equivalent dynamic load, } P = XF_r + YF_a$$
$$= 0.5(2000) + 1.1(500) = 1000 + 550$$
$$= 1550 \text{ N}$$

25. (b)

As $L_{50} \simeq 5L_{90}$

$\therefore$ $$\frac{L_{90}}{L_{50}} = \frac{1}{5} = 0.2$$

26. (a)

$$\frac{T_{old}}{T_{new}} = \frac{\left(\dfrac{R_o + R_i}{2}\right)}{\dfrac{2}{3}\left[\dfrac{R_o^3 - R_i^3}{R_o^2 - R_i^2}\right]}$$

$$= \frac{3}{4}\left[\frac{0.2^2 - 0.1^2}{0.2^3 - 0.1^3}\right](0.2 + 0.1) = 0.964$$

27. (c)

$$\sigma_{per} = \rho V_{max}^2 = \frac{S_{yt}}{FOS}$$

$$V_{max} = \sqrt{\frac{S_{yt}}{N \cdot \rho}}$$

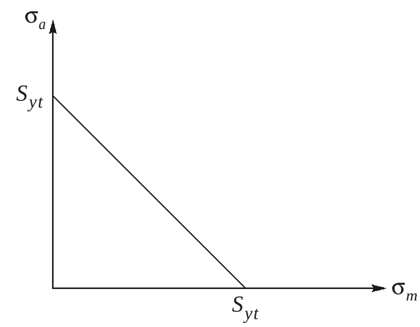
$$V_{max} = \sqrt{\frac{S_{yt}}{3\rho}}$$

28. (c)

The fatigue stress concentration factor,

$$K_f = \frac{\text{Endurance limit of the notch-free specimen}}{\text{Endurance limit of the notched specimen}}$$

29. (b)



The equation of Langer line is given as:

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

30. (c)

Given : μ = 0.4 poise = 0.04 Pa.s; N = 600 rpm; $n = \frac{N}{60} = 10$ rps; W = 4000 N; L = 100 mm; D = 50 mm; C_R = 50 µm; $C_D = 2C_R$ = 100 µm

$$\text{Pressure, } P = \frac{W}{LD} = \frac{4000}{(100\times10^{-3})(50\times10^{-3})} = 8\times10^5\,\text{Pa}$$

Bearing characteristic number is given as

$$\text{BCN} = \frac{\mu n}{P} = \frac{0.04\times10}{8\times10^5} = 5\times10^{-7}$$

31. (a)

Sommerfeld number is given as,

$$S = \frac{\mu n}{P}\left(\frac{D}{C_D}\right)^2 = \frac{0.04\times10}{8\times10^5}\times\left(\frac{50\times10^{-3}}{100\times10^{-6}}\right)^2 = 0.125$$

32. (c)

33. (b)

$$\text{Throat thickness, } h = \frac{\text{Leg size}}{\sqrt{2}} = \frac{t}{\sqrt{2}}$$

$$\frac{\sigma}{y} = \frac{M}{I}$$

$$\Rightarrow \quad (\sigma_b)_{\max} = y_{\max}\cdot\frac{M}{I}$$

$$= \frac{D}{2}\times\frac{M}{\left(\frac{\pi D^3 h}{8}\right)} = \frac{4M}{\pi D^2 h} = \frac{4\sqrt{2}M}{\pi D^2 t}$$

34. (c)

For Lewis equation:

- The effect of radial component of load, which induces compressive stress, is neglected.
- The tangential component of load is assumed to be uniformly distributed over the face width of the gear.

35. (a)

The endurance limit, in a true sense, is not exactly a property of material like ultimate tensile strength because it is affected by factors such as the size of the component, shape of component, the surface finish, temperature and the notch sensitivity of the material.

36. (a)

The performance of cyclone-separator is described by parameter called collection-efficiency which is defined as the ratio of amount of particles separated to the amount of gas-solid mixture.

Collection Efficiency increases with increasing

- Particle size
- Particle density
- Inlet-gas velocity
- Cyclone body length
- Number of gas revolutions
- Smoothness of cyclone wall surface.

37. (b)

Theoretical (or Adiabatic) Flame Temperature:

A fuel burning with no heat exchange with the surroundings and no work done will result in the theoretical or adiabatic flame temperature. It is greater for stoichiometric than either a lean or rich mixture because, as above, a lean mixture has a dilution effect, whereas a rich mixture results in incomplete combustion. It will also be greater if the fuel is burned in oxygen than in air because of the dilution effect of nitrogen.

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

38. (d)

- A subclass of the joined cylindrical manipulator is the SCARA type of robot; its shoulder and elbow rotational axes are vertical.
- These devices are relatively inexpensive and are used in applications that require rapid and smooth motions.
- Because of its construction, the SCARA is extremely stiff in the vertical direction but has some lateral compliance, thereby facilitating the insertion process.
- Some SCARAs even permit the lateral compliance to be increased during an operation by reducing appropriate electronic amplifier gains.

39. (c)

Non-tactile sensors: These are "contactless sensors" which senses the signal remotely, but only within the specified range of distance from the object.

Typical non-contact robotic sensors include:

(a) Proximity Sensors

(b) Electro-optical sensors

(c) Range-imaging sensors

40. (a)

Given, Under normal condition

⇒ Slider is at centre

Hence, the resistance of the potentiometer = $\frac{8000}{2} = 4000\,\Omega$

The Resistance of the potentiometer wire per unit length = $\frac{8000}{80} = 100\,\Omega\,/\,\text{mm}$

$$\text{For resistance} = 2550\ \Omega$$

$$\text{Charge from normal position} = 4000 - 2550 = 1450\ \Omega$$

$$\therefore \quad \text{Linear displacement} = \frac{1450}{100} = 14.5\ \text{mm}$$

41. (b)

Given, Output voltage = 1.6 mV ; Displacement = 0.5 mm

$$\text{Sensitivity} = \frac{\text{Output voltage}}{\text{Displacement}} = \frac{1.6}{0.5} = 3.2\ \text{mV/mm}$$

42. (c)

A Stepper motor is a special type of D.C. motor , is an incremental motion machine.

- It can rotate in both directions.
- It can move in precise angular increments.
- It can sustain a holding torque at zero speed.
- It can be controlled with digital circuits.
- A variable-reluctance stepper motors has no permanent magnet on the rotor and the rotor employed is a ferro-magnetic multi-toothed one.
- A hybrid stepper motor is infact a permanent magnet stepper motors with construction features of toothed and stacked rotor adopted from the variable-reluctance motor.

43. (d)

- Buses are the paths along which digital signals move from one section to another.
- A bus is just a number of conductors along which electrical signals can be carried.
- It might be a tracks on a printed circuit board or wires in a ribbon cable.

44. (b)

Microprocessor	Data width (Bits)
4004	4
8008	8
8085	8
8086	16
80286	16
80386	32
Pentium	32
Pentium III	32
Pentium 4	64

45. (c)

Given, $t = 1.5$ mm ; $A = 5$ mm × 5 mm = 25 mm^2

$$\because \quad E = g\,t\,p$$

$$126 = 0.056 \times (1.5 \times 10^{-3})\ p$$

$$\Rightarrow \quad p = 1.5 \times 10^{6}\ \text{N/m}^2$$

$$\text{Force, } F = p \times A$$

$$= 1.5 \times 10^{6} \times 25 \times 10^{-6} = 37.5\ \text{N}$$

46. (d)

Given :

$$P = 4\hat{i} - 3\hat{j} + 6\hat{k}$$

$$\theta_x = -90^\circ \quad (\because \text{ clockwise})$$

$$\vec{T} = -2\hat{i} + \hat{j} - 4\hat{k}$$

After rotating about x-axis

$$P' = R_x(\theta)P = \begin{bmatrix} 1 & 0 & 0 \\ 0 & c_\theta & -s_\theta \\ 0 & s_\theta & c_\theta \end{bmatrix}\begin{bmatrix} P \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix}\begin{bmatrix} 4 \\ -3 \\ 6 \end{bmatrix} = \begin{bmatrix} 4 \\ 6 \\ 3 \end{bmatrix}$$

Translation:

$$P'' = P' + T = \left(4\hat{i} + 6\hat{j} + 3\hat{k}\right) + \left(-2\hat{i} + \hat{j} - 4\hat{k}\right)$$

$$P'' = 2\hat{i} + 7\hat{j} - \hat{k}$$

47. (d)

NDT methods		Where to use
Liquid Penetrant Test	:	All metals, glass, ceramics, castings, field inspection, cutting tools
Magnetic Particle Test	:	Only for ferromagnetic materials
Ultrasonic Test	:	All metals and hard non-metals
Eddy current Test	:	Tubing and bar stock, parts of uniform geometry, sheets and wire
Radiography; X-rays	:	Assemblies of electronic parts, castings, welded vessels, corrosion surveys
Radiography; γ-rays	:	Forging castings, tubings, welded pipes

48. (d)

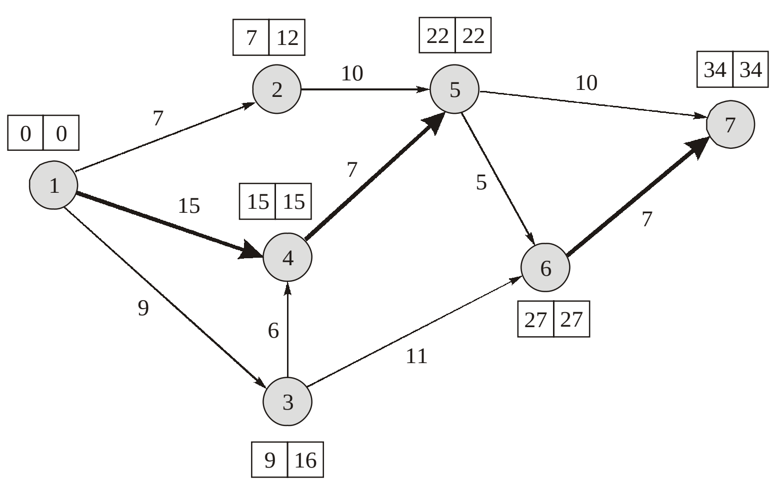
For small debris particle, spectrographic analysis or microscopic examination of oil samples after magnetic separation are commonly used technique. Another popular technique is SOAP analysis for Debris monitoring.

49. (c)

Given, MTBF = 60 hrs ; MTTR = 90 minutes = 1.5 hours

$$\text{Availability} = \frac{\text{MTBF}}{(\text{MTBF} + \text{MTTR})} = \frac{60}{61.5} = 0.976$$

50. (c)



Critical path = 1 - 4 - 5 - 6 - 7

51. (a)

Given, p = 3200 parts / day ; d = 1600 parts / day ; C_0 = Rs. 500 per setup ; C_h = Rs.10 unit / year; D = 320000 units

$$\text{Optimal lot size, } q_0 = \sqrt{\frac{2DC_o}{C_h}\left(\frac{p}{p-d}\right)}$$

$$= \sqrt{\frac{2 \times 320000 \times 500}{10}\left(\frac{3200}{1600}\right)}$$

$$= \frac{3200 \times 100}{40} = 8000 \text{ units}$$

Length of each production run, $t_p = \frac{8000}{p} = \frac{8000}{3200}$

$\Rightarrow \quad t_p = 2.5$ days

52. (d)

Quarter	Demand
1	546
2	528
3	532
4	526
5	534

Using moving average technique (n = 4)

$$F_6 = \frac{D_2 + D_3 + D_4 + D_5}{4} = \frac{528 + 532 + 526 + 534}{4}$$

$\Rightarrow \quad F_6 = 530$ units

53. (c)

- Ethanol is manufactured by the action of microorganisms on carbohydrates. The process is known as alcoholic fermentation.
- The concentration of ethanol is increase to 95% (by volume) by successive fractional distillation. The product is known as pure commercial alcohol and used as fuel in IC engines or other thermal applications. The remaining 5% water cannot be removed by simple distillation and special process (azeotropic distillation: co-distillation with a solvent such as benzene) is used to reduce water content to get 99.7% pure ethanol. This is known as absolute or anhydrous ethanol. This anhydrous ethanol is used for blending with gasoline.

54. (a)

Mass consumption per day = 2500 kg

Energy density = 18 MJ/kg

Energy consumption = 18000 × 2500 kJ/day

= 45×10^6 kJ/day

Power output = 750 kWh/day

= 750 × 3600 kJ/day

$$\therefore \quad \eta = \frac{750 \times 3600}{45 \times 10^6} \times 100$$

$\therefore \quad \eta = 6\%$

55. (d)

- The operating temperature of PAFC is 150°C – 200°C.
- The operating temperature for AFC is about 90°C.

Fuel Cell	Operating Temperature	Efficiency
PEMFC	40 - 60°C	48 - 58%
AFC	90°C	64%
PAFC	150 - 200°C	42%
MCFC	600 - 700°C	50%
SOFC	600 - 1000°C	60 - 65%

56. (c)

Given, $U_0 = 16 \text{ m/s}$; $R = \frac{D}{2} = 30 \text{ m}$; $\rho = 1.23 \text{ kg/m}^3$

For maximum axial thrust ($C_F = 1$ or $a = 0.5$)

$$(F_A)_{max} = \frac{1}{2}\rho A u_0^2$$

$$= \frac{1}{2} \times 1.23 \times \frac{\pi}{4} \times (60)^2 \times (16)^2$$

$$= 4.45 \times 10^5 \text{ N}$$

or $$(F_A)_{max} = 445 \text{ kN}$$

Section C : Theory of Machines - 2

57. (c)

Given : $N_1 = 720$ rpm; $p_1 = 15$ mm; $T_2 = 24$ (Pitch of wheel = Axial pitch of worm)

$$p_2 = \frac{\pi d_2}{T_2}$$

$$\Rightarrow \quad 15 = \frac{\pi d_2}{24}$$

$$\Rightarrow \quad d_2 = \frac{360}{\pi} \text{ mm}$$

$$\frac{N_2}{N_1} = \frac{\text{Lead}}{\pi d_2} = \frac{2p}{\pi d_2}$$

$$\Rightarrow \quad \frac{N_2}{720} = \frac{2 \times 15}{\pi \times \frac{360}{\pi}}$$

$$\Rightarrow \quad N_2 = 60 \text{ rpm}$$

58. (b)

The motion between two intersecting shafts is equivalent to the rolling of two cones, assuming no slipping. The gears are known as bevel gears.

- Straight bevel gears are used to connect shafts at right angles which runs at low speeds.
- Gears of the same size and connecting two shafts at right angles to each other are known as mitre gears.

59. (a)

Given, $G = 4$, $m = 6$; $t = 18$, $T = 18 \times 4 = 72$

$$\text{Path of approach} = 16 \text{ mm}$$

$$\omega_p r = \omega_g R = 2.16 \text{ m/s}$$

$$r = \frac{mt}{2} = \frac{6 \times 18}{2} = 54 \text{ mm}$$

$$\therefore \quad \omega_p \times 54 = 2.16 \times 10^3$$

$$\Rightarrow \quad \omega_p = 40 \text{ rad/s}$$

60. (b)

Given, $G = 4$, $m = 6$; $t = 18$, $T = 18 \times 4 = 72$

$$\text{Path of approach} = 16 \text{ mm}$$

$$\omega_p r = \omega_g R = 2.16 \text{ m/s}$$

$$R = \frac{mT}{2} = 216 \text{ mm}$$

$$\omega_g = \frac{2.16 \times 10^3}{216} = 10 \text{ rad/s}$$

$$\text{Velocity of sliding} = (\omega_p + \omega_g) \times \text{Path of approach}$$

$$V_{\text{sliding}} = (40 + 10) \times 16 = 800 \text{ mm/s} = 0.8 \text{ m/s}$$

61. (d)

The gears are interchangeable if they are standard ones. It is always a matter of convenience to have gears of standard dimensions which can be replaced easily when they are worn out. The gears are interchangeable if they have

- the same module,
- the same pressure angle,
- the same addendums and dedendums, and
- the same thickness.

62. (c)

Cycloidal Teeth's :

- Pressure angle varies from maximum at the beginning of engagement, reduces to zero at the pitch point and again increases to maximum at the end of engagement resulting in less smooth running of the gears.
- It involves double curve for the teeth, epicycloid and hypocycloid . This complicates the manufacture.

- Owing to difficulty of manufacture, these are costlier.
- Exact centre-distance is required to transmit a constant velocity ratio.
- Phenomenon of interference does not occur at all.
- In this, a convex flank always has contact with a concave face resulting in less wear.

63. (d)

Given, $t = 40$, $T = 120$

$$\omega_p = \frac{2\pi \times 900}{60} = 30\pi \text{ rad/s}$$

$$\because \quad G = \frac{T}{t} = 3$$

$$\omega_g = \frac{\omega_p}{G} = 10\pi \text{ rad/s}$$

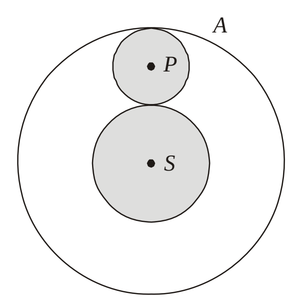
$$P = T_1\omega_1 = T_2\omega_2$$

$$\Rightarrow \quad 40 \times 30\pi = T_2 \times 10\pi$$

$$T_2 = 120 \text{ Nm}$$

64. (c)

Given, $T_A = 60$; $T_P = 15$



$\because$ All gears are in mesh.

$$\therefore \quad m_A = m_P\,,\; m_P = m_S$$

$$\therefore \quad r_S + 2r_P = r_A$$

$$\Rightarrow \quad T_S + 2T_P = T_A$$

$$\Rightarrow \quad T_S = 60 - 2 \times 15$$

$$\Rightarrow \quad T_S = 30$$

65. (c)

Given, $r = 100$ mm $= 0.1$ m ; $R = 60$ kg, $m = 48$ kg, $c = \frac{3}{4}$; $b = 300$ mm $= 0.3$ m

$$Bb = (m + cR)r$$

$$\Rightarrow \quad B \times 0.3 = \left(48 + \frac{3}{4} \times 60\right) \times 0.1$$

$$\Rightarrow \quad B = 31 \text{ kg}$$

66. (c)

In a cycloidal motion of cam follower:

$$\text{Maximum acceleration, } a_{max} = 2\pi h\left(\frac{\omega}{\phi}\right)^2$$

$$\text{Maximum velocity, } v_{max} = 2h\left(\frac{\omega}{\phi}\right)$$

$$\Rightarrow \quad \frac{a_{max}}{v_{max}} = \frac{2\pi h\left(\frac{\omega}{\phi}\right)^2}{2h\left(\frac{\omega}{\phi}\right)} = \pi\left(\frac{\omega}{\phi}\right)$$

67. (a)

$$\text{Unbalanced secondary force, } F_s = mR\omega^2 \frac{\cos 2\theta}{n}$$

$$\text{Also,} \quad mR\omega^2 \frac{\cos 2\theta}{n} = m \times (r)(2w)^2 \cos 2\theta \quad (\because \text{ Balancing crank speed} = 2\omega)$$

$$\therefore \quad \text{Balancing radius, } r = \frac{R}{4n} = \frac{R}{4 \times \frac{L}{R}} = \frac{R^2}{4L}$$

68. (a)

- Pitch curve is the curve drawn by the trace point assuming that the cam is fixed, and the trace point of the follower rotates around the cam.
- The smallest circle drawn tangent to the pitch curve is known as the prime circle.
- Base circle is the smallest circle tangent to the cam profile (contour) drawn from the centre of rotation of a radial cam.
- In automobile engines, a spherical-faced follower is used.

69. (b)

Given, $m = 2 \times 10^3$ kg ; $k = 0.3$ m ; $N = 2100$ rpm ; $R = 200$ m, $V = 36$ kmph $= 10$ m/s

$$\omega_p = \frac{V}{R} = \frac{10}{200} = 0.05 \text{ rad/s}$$

$$I = mk^2 = 2 \times 10^3 \times (0.3)^2 = 180 \text{ kgm}^2$$

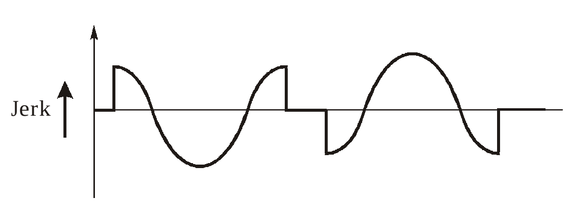
$$C = I\omega\omega_p = I\frac{2\pi N}{60}\omega_p$$

$$\Rightarrow \quad C = 180 \times \frac{2\pi \times 2100}{60} \times 0.05 = 630\pi \text{ Nm}$$

$$\text{or} \quad C = 1979 \text{ Nm}$$

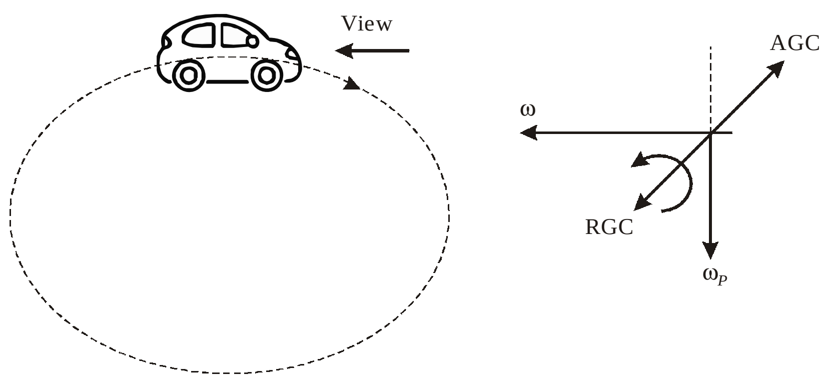
70. (c)

Cycloidal motion of the follower:



It is observed that there are 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.

71. (a)



Effect of RGC = Raise the front and lower the rear

72. (d)

Given, N = 240 rpm ; Total rise, h = 25 mm = 0.025 m; $\theta_0 = 120° = \frac{2\pi}{3}$

$$\therefore \quad \omega = \frac{2\pi N}{60} = 8\pi \text{ rad/s}$$

$$\Rightarrow \quad \frac{2\pi}{3} = 8\pi \times t$$

$$\Rightarrow \quad t = \frac{1}{12} \text{sec}$$

Also,
$$t = \frac{h}{V_r}$$

$$\Rightarrow \quad \frac{1}{12} = \frac{0.025}{V_r}$$

$$\Rightarrow \quad V_r = 0.3 \text{ m/s}$$

73. (c)

Given, $G = 3$, $m = 3$ mm

$$R + r = 240 \text{ mm}, \phi = 20°$$

$$R + r = \frac{m}{2}(T + t)$$

$$\Rightarrow \quad 240 = \frac{3}{2}(T + t)$$

$$\Rightarrow \quad T + t = 160$$

$\because \quad \frac{T}{t} = 3$

$\Rightarrow \quad T = 3t$

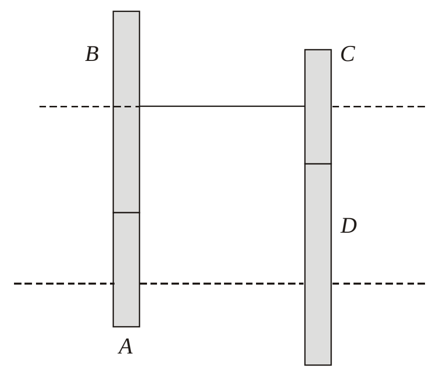
$\therefore \quad t = 40$ and $T = 120$

$$R = \frac{mT}{2} = \frac{3}{2} \times 120 = 180 \text{ mm}$$

$$R_b = R\cos\phi = 180 \cos(20°) \text{ mm}$$

74. (b)

Given, $T_A = 24$, $T_B = 64$, $T_D = 72$



$$r_A + r_B = r_C + r_D$$

$\because \quad m_A = m_B = m_C = m_D$

$\Rightarrow \quad T_A + T_B = T_C + T_D$

$\Rightarrow \quad 24 + 64 = T_C + 72$

$\Rightarrow \quad T_C = 16$

$$\text{Velocity ratio} = \frac{T_B}{T_A} \times \frac{T_D}{T_C}$$

$$= \frac{64}{24} \times \frac{72}{16} = 12$$

75. (b)

- When an annular wheel is added to the epicyclic gear train, the combination is usually referred as sun and planet gear.
- When an epicyclic gear train consist of a number of epicyclic gears (sun and planet gears) in series such that the pin of the arm of the first epicyclic gear drives an element of another epicyclic gear, it is known as a compound epicyclic gear.

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