DETAILED SOLUTIONS

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ESE 2023 : 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]**

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

DETAILED EXPLANATIONS

1. (d)

For ductile material under static loading, when the stresses in the vicinity of the discontinuity reaches the yield point, there is plastic deformation, resulting in a redistribution of stresses. This plastic deformation or yielding is local and restricted to a very small area in the component. There is no perceptible damage to the part as a whole.

3. (c)

Through bolts are used under the following conditions:

(a) The parts that are fastened have medium thickness and space is available to accommodate the bolt head and nut.

(b) The parts that are fastened are made of materials which are two weak to make durable threads and requires frequent dismantling and reassembly.

4. (c)

A castle nut is extensively used for joints that are subjected to vibrations. These are popular in the automobile industry.

6. (c)

When the thickness of the plates is less than 5 mm, it is not necessary to bevel the edges of the plates. The edges are square with respect to the plates. Therefore, the square butt joint is used.

8. (c)

For uniform wear theory, torque,

$$T = \frac{\pi \mu P_a d\left(D^2 - d^2\right)}{8}$$

or

$$T = \frac{\pi \mu P_a D^3}{8}\left[x\left(1 - x^2\right)\right] \qquad \left[\because x = \frac{d}{D}\right]$$

For maximum torque capacity,

$$\frac{dT}{dx} = 0$$

$$\Rightarrow \quad \frac{d\left[x(1 - x^2)\right]}{dx} = 0$$

or

$$1 - 3x^2 = 0$$

$$x = \frac{1}{\sqrt{3}} = 0.577$$

9. (d)

Given : C = 30 kN; L_{10h} = 8000 h, n = 300 rpm

$$\text{Bearing life, } L_{10} = \frac{60 n L_{10h}}{10^6} = \frac{60 \times 300 \times 8000}{10^6}$$

$$L_{10} = 144 \text{ million rev.}$$

$$\therefore \quad \text{Equivalent dynamic load, } P = \frac{C}{(L_{10})^{0.3}} = \frac{30000}{(144)^{0.3}} = \frac{30000}{4.4}$$

$$= 6818.18 \text{ N} \simeq 6.8 \text{ kN}$$

10. (c)

$$\text{Pressure on bearing, } P = \frac{W}{ld} = \frac{3.2 \times 1000}{50 \times 50} = 1.28 \text{ N/mm}^2$$

$$\therefore \quad \text{Temperature rise, } \Delta t = \frac{8.3P \times (CFV)}{FV} = \frac{8.3 \times 1.28 \times 3.2}{4.5}$$

$$\Delta t = 7.5°\text{C}$$

11. (d)

$$\text{Effective load, } P_{\text{eff}} = \frac{C_s}{C_v} \times P_t = \frac{1.5}{0.5} \times 1200 = 3600 \text{ N}$$

$$\text{Wear strength, } S_w = P_{\text{eff}} \times \text{FOS} = 3600 \times 2 = 7200 \text{ N}$$

$$\text{For pinion, } D_p = 5 \times 20 = 100 \text{ mm}$$

$$Q = \frac{2z_g}{z_g + z_p} = \frac{2 \times 40}{40 + 20} = \frac{4}{3}$$

Now, $S_w = bQD_pK$

$$\therefore \quad K = \frac{S_w}{bQD_p} = \frac{7200 \times 3}{40 \times 4 \times 100}$$

or $0.16\left(\frac{BHN}{100}\right)^2 = 1.35$

or $\text{BHN} = 100 \times \sqrt{\frac{1.35}{0.16}} = 100 \times 2.9$

$$\text{BHN} = 290$$

12. (c)

General equation for radial stress at a radius 'r' is

$$\sigma_r = \frac{\rho v^2}{10^6}\left(\frac{\mu + 3}{8}\right)\left(1 - \frac{r^2}{R^2}\right) \text{N/mm}^2$$

At $r = 0$, $\sigma_r = (\sigma_r)_{\max}$

$$\therefore \quad \sigma_{r\max} = \frac{\rho v^2}{10^6}\left(\frac{\mu + 3}{8}\right)$$

Here, $v = r\omega = 0.5 \times 30 = 15 \text{ m/s}$

$$\therefore \quad \sigma_{r\max} = \frac{8000 \times 15^2}{10^6} \times \left(\frac{0.3 + 3}{8}\right)$$

$$\sigma_{r\max} = 0.74 \text{ N/mm}^2$$

13. (c)

Permissible mean and amplitude stresses,

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{100 - 40}{2} = 30 \text{ N/mm}^2$$

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{100 + 40}{2} = 70 \text{ N/mm}^2$$

Factor of safety using Soderberg line,

$$\frac{\sigma_a}{s_e} + \frac{\sigma_m}{s_{yt}} = \frac{1}{FOS}$$

$$\therefore \quad \frac{30 \times FOS}{270} + \frac{70 \times FOS}{450} = 1$$

$$\therefore \quad FOS \times \left(\frac{30}{270} + \frac{70}{450} \right) = 1$$

$$FOS = 3.75$$

14. (d)

These can be engaged only when both shafts are stationary or rotate at very low speeds, because engagement of jaws at high speeds results in shock.

15. (c)

It has relatively poor heat dissipating capacity.

17. (d)

Lignite is the lowest grade of coal containing moisture as high as 30% and high volatile matter.

18. (a)

Induced draught fans handle hot combustion gases. Their power requirements are, therefore, greater than forced draught fans.

19. (c)

In cyclone furnace, due to higher forced draught fan pressures, higher power is consumed. The whirling motion of coal and air results in large volumetric heat release rate ranging from 4.7 to 8.3 MW/m^3 and high combustion temperature more than 1650°C, results in more oxides of nitrogen, NO_x which are pollutant.

20. (c)

Heat removal from the bed per fuel,

Q = Heat released – Heat carried away by the products

Q = 0.65 × 24000 – 15 × 1 × (850 – 30)

= 3300 kJ/kg fuel

$$\therefore \quad \text{Rate of heat removal, } \dot{Q} = 3300 \times \frac{7200}{3600} = 6600 \text{ kW}$$

21. (d)

The collection efficiency decreases with increasing

- cyclone diameter
- gas outlet duct diameter
- gas inlet area

22. (d)

$$\text{Condenser efficiency, } \eta = \frac{40-30}{60-30}\times 100 = 33.33\%$$

25. (c)

In the jet condenser, the height of the tail pipe is reduced by replacing it with a diffuser. The diffuser helps raising the pressure in a short distance than a tail pipe.

26. (b)

$$\eta_{Blade} = \frac{2\times \text{Work done per kg}}{v_1^2}$$

$$= \frac{2\times 50\times 10^3}{400^2} = 0.625$$

$$\therefore \quad \eta_{Stage} = \eta_{nozzle}\times \eta_{Blade}$$

$$\eta_{Stage} = 0.85 \times 0.625$$

$$\eta_{Stage} = 0.5312 \text{ or } 53.12\%$$

27. (c)

At maximum efficiency, for reaction turbine

$$\rho_{opt} = \cos\alpha = \frac{V_b}{V_1}$$

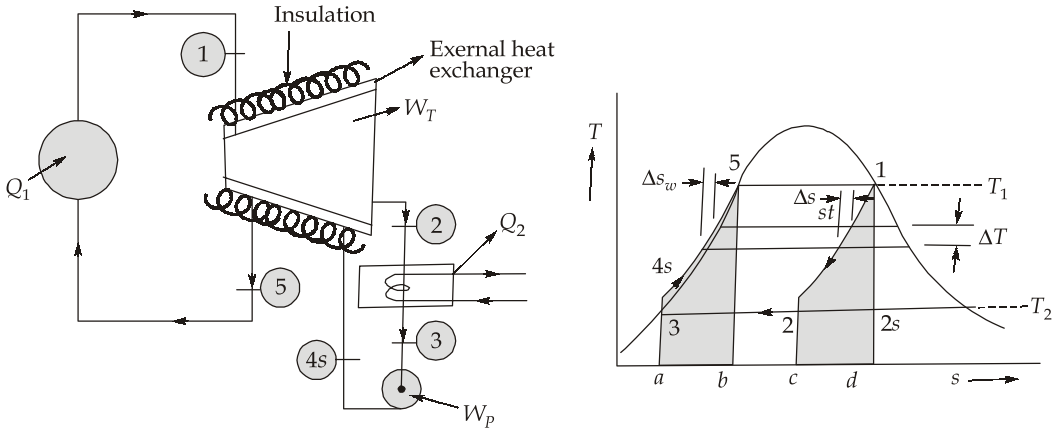
or

$$V_1 = \frac{V_b}{\cos\alpha} = 44.72\left(\frac{(\Delta h_s)_{stage}}{2}\right)^{1/2}$$

$$\therefore \quad \Delta h_{stage} = 2\left(\frac{V_b}{44.72\cos\alpha}\right)^2$$

28. (c)

- The moisture content of the steam in the turbine is high, which leads to excessive erosion of blades.
- Consider the ideal regenerative cycle, as shown in figure. The process 1-2 thus represents reversible expansion of steam in the turbine with reversible heat rejection to the surrounding liquid heated reversibly in the process 4s-5.



(a) (b)

Writing the steady flow energy equation for the turbine, we get

$$h_1 - w_T - h_2 + h_{4s} - h_5 = 0$$

$$\therefore \quad w_T = (h_1 - h_2) - (h_5 - h_{4s})$$

The pump work remains the same as in the rankine cycle, i.e.

$$w_p = h_{4s} - h_3$$

The net work output of the ideal regenerative cycle is thus less and hence its steam rate will be more, although it is more efficient, compared to the rankine cycle.

31. (a)

$$\text{For maximum blade efficiency, } \rho = \frac{\cos\alpha}{2} = \frac{\cos 30^\circ}{2}$$

$$= \frac{\sqrt{3}}{2\times 2} = 0.433$$

36. (d)

The compressive strength of brittle material is much higher than their tensile strength. Therefore, the failure criterion should show a difference in tensile and compressive strength. On this account, maximum principal stress theory is used for brittle materials. Also brittle materials do not yield and they fail by fracture.

37. (a)

For ductile components, due to homogeneous structure the stress analysis is more precise in case of static forces. Due to these reasons, the factor of safety is usually small in such cases. The recommended factor of safety is 1.5 to 2 based on the yield strength of the material.

38. (d)

$$\text{Economic order quantity, } Q^* = \sqrt{\frac{2C_0D}{C_H}} \times \sqrt{\frac{P}{P-d}}$$

$$Q^* = \sqrt{\frac{2 \times 1500 \times 300 \times 1000}{2}} \times \sqrt{\frac{2000}{2000-1000}}$$

$$Q^* = 30000 \text{ bearings}$$

$$\therefore \quad \text{Length of production cycle} = \frac{Q^*}{P} = \frac{30000}{2000} = 15 \text{ days}$$

39. (c)

$$\text{Arrival rate } \lambda = 8 \text{ per day}$$

$$\text{Service rate, } \mu = \frac{8 \times 60}{48} = 10 \text{ per day}$$

$$\therefore \quad \rho = \frac{\lambda}{\mu} = \frac{8}{10} = 0.8$$

$\therefore$ Expected number of T.V. sets in the system,

$$L_s = \frac{\rho}{1-\rho} = \frac{0.8}{1-0.8} = 4$$

40. (b)

Given : x_{BEP} = 5000 units, F = Rs.75000/-, v = Rs.25 per units

$$\therefore \quad x_{BEP} = \frac{F}{s-v}$$

$$\therefore \quad 5000 = \frac{75000}{s-25}$$

$$\therefore \quad s = 40/\text{- per unit}$$

$$\text{Now, volume of production, } \quad x = \frac{F+P}{s-v} = \frac{75000+25000}{40-25}$$

$$= 6666.67 \simeq 6667 \text{ units}$$

42. (c)

Routing is done to determine, how and where the work is to be done, what machines are to be used and it prescribes the path and sequence of operations to be followed.

46. (a)

The scale factor σ has non-zero positive (σ > 0) values and is called global scaling factor. σ > 1 is useful for reducing and 0 < σ < 1 is useful for enlarging and for robotic study σ = 1 is used.

48. (d)

The position of the origin of frame {1} with respect to frame {2} is given by

$$^2D_1 = -^1R_2{}^T . {}^1D_2$$

49. (d)

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. This advantage is very important at high speeds and high precision.

51. (c)

$$\text{Voltage output, } E = \frac{ktF}{A}; \qquad \text{where } k = \text{voltage sensitivity}$$

$$\therefore \quad 100 = \frac{0.05 \times 2 \times 10^{-3} \times F}{5 \times 5 \times 10^{-6}}$$

$$\therefore \quad F = 25 \text{ N}$$

52. (d)

The following are the applications of Hall effect transducers:

1. Displacement measurement
2. Current measurement
3. Magnetic flux measurement
4. Fluid level measurement

53. (c)

Low pass filters pass only low frequencies and reject all high frequencies above the cut-off frequencies.

55. (d)

Program counter (PC) is a 16 bit special purpose register and is used to hold the memory address of the next instruction to be executed.

59. (c)

$$\text{Torque coefficient, } C_{T\max} = \frac{C_{P_{\max}}}{\lambda}, \text{ where } \lambda \text{ is tip speed ratio}$$

$$\therefore \quad \lambda = \frac{\omega r}{v} = \frac{2\pi \times 30}{60} \times \frac{40}{20}$$

$$= 6.28$$

$$\therefore \quad C_{T\max} = \frac{0.593}{6.28} = 0.094$$

60. (c)

Various zones	Operating temperature
Drying zone	Upto 350°C
Pyrolysis zone	350 - 600°C
Oxidation zone	1000 - 1200°C
Reduction zone	700 - 1000°C

61. (b)

In single basin, double effect scheme, power is generated on both flood and ebb. Two-way (reversible) hydraulic turbines are used.

65. (a)

The dedendum of given gear must be greater than addendum on mating gear.

66. (d)

- A contact ratio indicates that one tooth pair is contacting 80% of the time and two pairs 20% of time.
- With high contact ratio load is transferred between several tooth pairs which increases load carrying capacity.

67. (a)

Centre distance between gears should be same

$$T_A + T_B = T_C + T_D$$
$$30 + 80 = 20 + T_D$$
$$T_D = 90$$
$$\frac{N_D}{N_A} = \frac{T_A \times T_C}{T_B \times T_D}$$
$$\frac{N_D}{120} = \frac{30 \times 20}{80 \times 90}$$
$$N_D = 10 \text{ rpm}$$

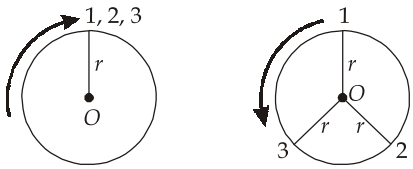
69. (b)

$$\omega = \frac{2\pi \times 600}{60} = 20\pi \text{ rad/s}$$
$$V_{amx} = \frac{2\omega S}{\theta_0} = \frac{2 \times 20\pi \times 20 \times 180}{\pi \times 150} = 960 \text{ mm/s}$$

70. (a)

Unbalanced force due to reciprocating masses varies in direction but is constant in magnitude.

71. (d)



$$\text{Maximum primary force} = 3 \times \frac{m}{2} \times r\omega^2$$
$$= 3 \times \frac{2}{2} \times \frac{50}{1000} \times \left(\frac{2\pi \times 1800}{60}\right)^2$$
$$= 5.3 \text{ kN}$$

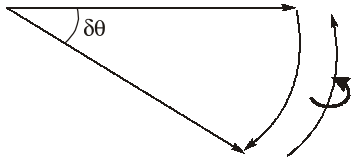
72. (c)

$$C = I\omega\omega_p$$

$$= 40 \times 200 \times \frac{270}{50} \times \frac{5}{18}$$

$$= 12000 \text{ Nm}$$

73. (c)



Effect of gyroscopic couple is to turn ship towards port.

74. (a)

By convexing surface of cam pressure angle decreases which reduces lateral pressure or $F\sin\alpha$.

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