



**RPSC AEn-2024
Main Test Series**

**MECHANICAL
ENGINEERING**

Test 15

Test Mode : • Offline • Online

Subject : Full Syllabus Test [Paper-I]

DETAILED EXPLANATIONS

1. Solution:

The main objective of labour laws is to protect workers from exploitation, ensure industrial peace, improve working conditions, and promote social and economic justice.

2. Solution:

The automated guided vehicle (AGV) is a programmable mobile vehicle without the need of human intervention. An AGV is a vehicle equipped with automatic guidance equipment either electromagnetic or optical.

3. Solution:

(i) Queue Length : The average number of customers in the queue waiting to get service. This excludes the customers being served.

(ii) System Length : The average number of customers in the system including those waiting as well as those being served.

4. Solution:

It is the number of nearest neighboring atoms surrounding a given atom.

5. Solution:

An alloy is a metallic substance composed of two or more elements.

A composite material is a combination of two or more materials having compositional variations and depicting properties distinctively from those of the individual materials of the composite.

6. Solution:

Powder metallurgy is a manufacturing process in which metal powders are compacted and sintered to produce components.

Advantage: Near-net shape production with minimum material wastage.

7. Solution:

Injection molding: Molten plastic is injected into a closed mold cavity.

Compression molding: Heated plastic is compressed in a mold to shape.

8. Solution:

Top-down approach: Bulk material is reduced to nanoscale (e.g., ball milling).

Bottom-up approach: Nanomaterials are built atom-by-atom (e.g., chemical vapor deposition).

9. Solution:

A beam made up of two or more different materials assumed to be rigidly connected together behaving like a single unit, is known as composite beam.

10. Solution:

Following assumptions are made for a circular shaft subjected to torsion :

(i) The twist along the length of shaft is uniform throughout.

(ii) The material of shaft is uniform throughout.

11. Solution:

The chances of bursting the cylinder longitudinally are more than those for circumferential failure of the cylinder. Therefore, it is necessary to strengthen the cylinder longitudinally.

12. Solution:

The moment of inertia of a lamina about any axis in the plane of lamina equals the sum of moment of inertia about a parallel centroid axis in the plane of lamina and the product of the area of lamina and square of the distance between the two axes.

13. Solution:

Core is a sand shape or form which makes the contour of a casting for which no provision has been made in the pattern for moulding.

14. Solution:

Resistance welding process includes following methods:

(a) Spot welding

(b) Seam welding

(c) Projection welding

(d) Percussion welding

(e) Flash butt welding

(f) Resistance butt welding

(g) High frequency resistance welding

15. Solution:

Mechanical working of metals above the recrystallisation temperature, but below the melting point is known as hot working whereas; below the recrystallisation temperature is known as cold working.

16. Solution:

- It should be cheap
- It should be non-toxic
- It should be easily available.
- It should dry quickly
- N_2 , CO_2 , He, etc are normally used as carrier gas.

17. Solution:

When the addendum of a mating gear (say pinion) goes beyond the base circle of the other gear (say wheel) the tip of the tooth on the pinion will then undercut the tooth on the wheel at the root. This phenomenon is called interference.

18. Solution:

Radial cam: In this cam, the follower reciprocates (or) oscillates in a direction perpendicular to the cam axis.

Cylindrical cams: In this the follower reciprocates (or) oscillates in a direction parallel to the cam axis.

19. Solution:

Pre stressing of leaf springs is obtained by a difference of radii of curvature known as nipping.

The initial gap can be adjusted so that under maximum load conditions the stress in all the leaves will be same or, if desired the stress in the full length leaves may be less.

20. Solution:

Completely Reversed Loading - Shafts carrying pulleys

Repeated Loading - Gears, Chain

Fluctuating Loading - Vehicle springs, Engine valve springs

Alternating Loading - IC engine connecting rods

21. Solution:

F.W. Taylor proposed scientific management to improve efficiency through systematic study of work. Its key principles include science, not rule of thumb; harmony between management and workers; cooperation rather than conflict; and development of workers to their maximum efficiency. Taylor emphasized time study, standardization of tools, proper selection and training of workers, and incentive wage systems. The approach aimed at increasing productivity while ensuring mutual prosperity of both workers and management.

22. Solution:

Various steps in value analysis are:

1. **Orientation:** This phase involves identification of the problem very clearly, selection of projects, formation of teams, laying down objective and target and in-depth training of all the team members.
2. **Information gathering:** After completion of orientation, all the information like drawing and technical specification manufacturing processes, detailed cost breakup is gathered.
3. **Functional analysis:** This step involves analysis and identification of functions.
4. **Creation of alternative:** This is the essence of value engineering. All the possible alternatives are generated. This can be achieved by application of brain storming and other creativity technique in order to generate a large number of ideas.
5. **Evaluation:** In this phase the possible alternatives developed are analysed. The cost of each idea is estimated. Critical evaluation of all point are carried out.
6. **Investigation /development:** The shortlisted ideas are investigated and in depth analysis is done to arrive at optimum and practical solution.
7. **Implementation:** as a result of all these steps, a definite specific and tangible solution acceptable to all is reached and implemented.
8. **Follow up:** this is the final step which compares the result with original expectation and suggest corrective actions.

23. Solution:**I. Contributions of Walter A. Shewhart:**

- (a) Statistical process control (SPC) (b) Shewhart cycle (c) Control charts

II. Contributions of W. Edward Deming :

- (a) Deming cycle (b) 14 points for transforming management
(c) 7 deadly diseases (d) Deming profound knowledge

III. Contributions of Joseph M. Juran:

- (a) Pareto principle
(b) Juran trilogy or quality trilogy. This trilogy is composed of three managerial processes which are given below:
(i) Quality planning (ii) Quality control (iii) Quality improvement

IV. Contributions of Philip B. Crosby

- (a) Concept of zero defect (b) Quality is free (c) Cost of poor quality

24. Solution:

Time study: A work measurement technique for recording the times and rates of working of the elements of a specified job carried out under specified conditions and for analyzing the data so as to determine the time necessary for carrying out the job at the defined level of performance.

Work sampling: A technique in which a large number of observations are made over a period of time of one or group of machines, processes or workers. Each observation records what is happening at that instant and the percentage of observations recorded for a particular activity, or delay, is a measure of the percentage of time during which that activities delay occurs.

Applications of time study:

The reason for which time study may be done:

1. The job in question is new one or not previously carried out.
2. Change in the method of the existing time-standard.
3. Complaints received from workers or unions regarding the time standard.
4. Change in management policy.

Application of Work- Sampling:

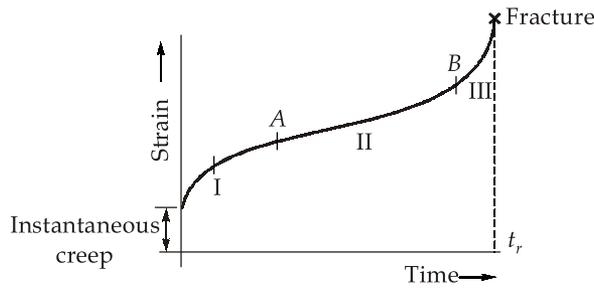
1. Activity and delay sampling: To measure the activities and delays of workers or machine.
2. Performance sampling.
3. Work measurement.

25. Solution:

The combination of a slip plane and its directions of slip is known as a **slip system**. The slipping of one plane of atoms over an adjacent plane (slip planes) under shear stress causes plastic deformation. The significance of slip system is that metals with slip systems of 5 or above are ductile, whereas those with the slip systems below 5 are not. In body-centered cubic crystals, there are 48 possible slip systems. Therefore metals with BCC structures generally have good strength and moderate ductility. In FCC crystals, there are 12 slip systems. These metals generally have moderate strength and good ductility. The Hexagonal close packed crystal has 3 slip systems and so it has a low probability of slip. Therefore, metals with HCP structure are generally brittle at room temperature.

26. Solution:

Creep is the term used to describe the tendency of a material to move or to deform permanently to relieve stresses. Material deformation occurs as a result of long term exposure to levels of stress that are below the yield or ultimate strength of the material.



Creep is more severe in materials that are subjected to heat for long periods and near melting point. The rate of this damage is a function of the material properties and the exposure time, exposure temperature and the applied load (stress). Depending on the magnitude of the applied stress and its duration, the deformation may become so large that a component can no longer perform its function - for example creep of a turbine blade will cause the blade to contact the casing, resulting in the failure of the blade. A creep curve shows the variation of the extension of a metal with time under different stresses. A typical creep curve under constant nominal stress and constant temperature, is shown in the figure.

27. Solution:

(i) Maximum bending moment = 300 kNm

$$\text{Section modulus, } z = \frac{bd^2}{6} = \frac{100 \times 150^2}{6}$$

$$\sigma_{\max} = \frac{M_{\max}}{z} = \frac{300 \times 10^6 \times 6}{100 \times 150^2} = 800 \text{ MPa}$$

(ii) Bending formula is given by

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

$$\frac{E}{R} = \frac{M}{I}$$

$$R = \frac{EI}{M} = \frac{E(bd^3)}{12M} = \frac{200 \times 10^3 \times 100 \times 150^3}{12 \times 300 \times 10^6} = 18750 \text{ mm}$$

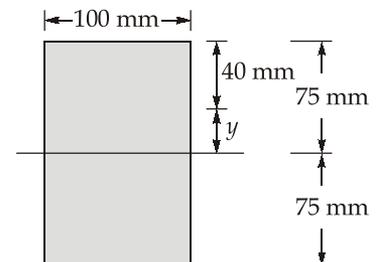
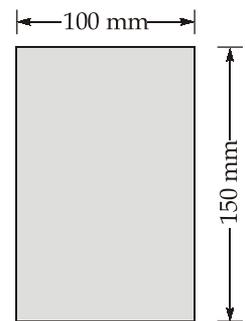
Radius of curvature = 18.75 m

$$y + 40 = 75$$

$$y = 35 \text{ mm}$$

(iii)
$$\sigma' = \frac{My}{I} = \frac{300 \times 10^6 \times 35 \times 12}{100 \times (150)^3}$$

$$\sigma = 373.33 \text{ MPa}$$



28. Solution:

Machining time is given by

$$t = \frac{L}{fN} \text{ min.}$$

where $\rightarrow L$ is in mm; f is in mm/rev; N is rpm

Cutting speed, $v = \pi DN$ m/min

$$N = \frac{v}{\pi D} = \frac{14}{3.14 \times 25 \times 10^{-3}} = 178.34 \text{ rpm}$$

Length of tool travel = work thickness + length of approach and over travel

$$= 60 + 5 = 65 \text{ mm}$$

$$t = \frac{65}{0.3 \times 178.34} = 1.215 \text{ minute}$$

29. Solution:

- It increase productivity
- It reduces number of rejected components
- Close tolerance is possible
- The tool material need not be harder than work piece material as in conventional machining
- Harder and difficult to machine materials can be machined by this process.
- The machined surfaces do not have any residual stresses.

30. Solution:

$$k_{eq} = \frac{2k_1k_2}{k_1 + 2k_2}$$

D' Alembert's principle state that the resultant force acting on a body along with the inertia force is zero, then the body will be in static equilibrium.

i.e. $F + F_I = 0$

$$F_I = \text{Inertia force} = m.a$$

Also $ma + k_{eq}x = 0$

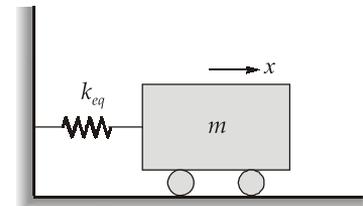
$$m\ddot{x} + k_{eq}x = 0 \quad \dots(i)$$

The solution is $x = A \sin \omega_n t ; A\omega \cos \omega_n t = \dot{x}$

$$\ddot{x} = -A\omega_n^2 \sin \omega_n t$$

From (i) we get

$$m(-A\omega_n^2 \sin \omega_n t) + kA \sin \omega_n t = 0$$



$$-m\omega_n^2 + k = 0$$

$$\Rightarrow \omega_n = \sqrt{k_{eq}/m}$$

$$\omega_n = \sqrt{\frac{2k_1k_2}{m(k_1 + 2k_2)}}$$

31. Solution:

External radius, $r_1 = 20$ cm Internal radius, $r_2 = 15$ cm

Coefficient of friction, $\mu = 0.08$

Total axial load, $W = 30$ kN

Intensity of pressure, $P = 3.5$ bar = 3.5×10^5 N/m²

Speed, $N = 420$ rpm

We have to use uniform pressure theory because it is to determine loss of power due to friction,

$$\text{Friction moment, } M_t = \left(\frac{2}{3}\right) \frac{\mu W (r_1^3 - r_2^3)}{(r_1^2 - r_2^2)} = \frac{2}{3} \times \frac{0.08 \times 30 \times 10^3 (20^3 - 15^3)}{(20^2 - 15^2) \times 100}$$

$$= \frac{2}{3} \times 0.08 \times 300 \times \frac{4625}{175} = 422.85 \text{ N.m}$$

$$\text{Power lost in friction} = \frac{422.85 \times 2\pi \times 420}{60} = 18598.22 \text{ W or } 18.59 \text{ kW}$$

$$\begin{aligned} \text{Load per collar} &= P \times \pi (r_1^2 - r_2^2) = \frac{3.5 \times 10^5 \times \pi (400 - 225)}{10^4} \\ &= 35\pi(175) = 19242.25 \text{ N} \end{aligned}$$

$$\text{Number of collars} = \frac{\text{Total load}}{\text{Load per collar}} = \frac{30000}{19242.25} = 1.56 \approx 2 \text{ collars}$$

32. Solution:

(i) $\phi = 14.5^\circ$, $m = 5$ mm, $t_p = 15$, $T_g = 60$, $A_G = m = 1$ m, $G = \text{Gear ratio} = 4$

$$\text{Minimum number of teeth on gear} = \frac{2A_G}{m \sqrt{1 + \frac{1}{G} \left(2 + \frac{1}{G}\right) \sin^2 \phi - 1}}$$

$$= \frac{2}{\sqrt{1 + \frac{1}{4} \left(2 + \frac{1}{4}\right) \sin^2 (14.5^\circ) - 1}}$$

$$= \frac{2}{0.01747} = 114.42 \text{ teeth} \approx 115 \quad \text{so, interference will occur}$$

(ii) In order to eliminate interference the number of teeth on gear is equal to 60.

$$\therefore 60 = \frac{2}{\sqrt{1 + \{0.25(2.25)\sin^2 \phi\} - 1}}$$

$$\Rightarrow \sqrt{1 + 0.5625\sin^2 \phi} - 1 = 0.03333$$

$$1 + 0.5625 \sin^2 \phi = 1.067$$

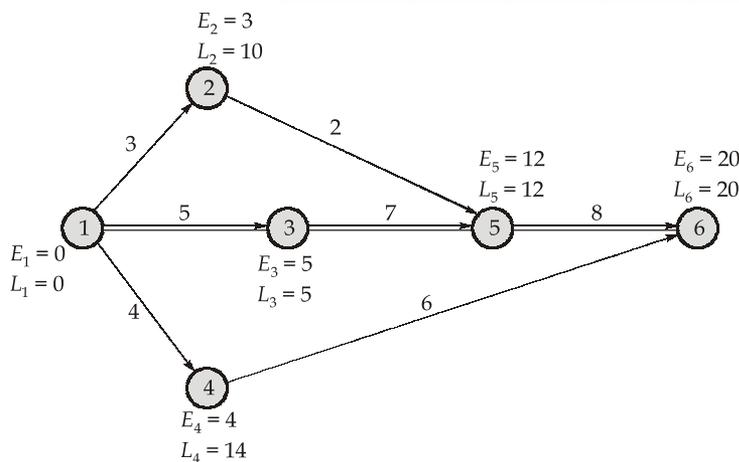
$$\sin^2 \phi = 0.120$$

$$\sin \phi = 0.347$$

$$\phi = 20.31^\circ$$

33. Solution:

Activity Sequence	Time duration (weeks)			$t_e = \frac{t_0 + 4t_m + t_p}{6}$	$\sigma^2 = \left(\frac{t_p - t_0}{6}\right)^2$
	t_0	t_m	t_p		
1 - 2	2	2	8	$\frac{2 + 4 \times 2 + 8}{6} = 3$	1
1 - 3	2	5	8	$\frac{2 + 5 \times 4 + 8}{6} = 5$	1
1 - 4	3	3	9	$\frac{3 + 4 \times 3 + 9}{6} = 4$	1
2 - 5	2	2	2	$\frac{2 + 4 \times 2 + 2}{6} = 2$	0
3 - 5	3	6	15	$\frac{3 + 4 \times 6 + 15}{6} = 7$	4
4 - 6	3	6	9	$\frac{3 + 4 \times 6 + 9}{6} = 6$	1
5 - 6	4	7	16	$\frac{4 + 4 \times 7 + 16}{6} = 8$	4



Network Diagram

Expected project length = 20 weeks

Critical path = 1 - 3 - 5 - 6

Various path	Length of the path
1 - 2 - 5 - 6	$3 + 2 + 8 = 13$ Weeks
1 - 3 - 5 - 6	$5 + 7 + 8 = 20$ Weeks
1 - 4 - 6	$4 + 6 = 10$ Weeks

Activity	Variance (σ^2)	Standard deviation
1 - 3	1	1
3 - 5	4	2
5 - 6	4	2
	$\Sigma\sigma^2 = 9$	

Variance of project length = 9

Standard deviation of project length = $\sqrt{9} = 3$ Weeks

34. Solution:

$$\Sigma F_V = 0$$

$$R_A + R_B = 10 + 16$$

$$\Sigma M_A = 0$$

$$24R_B - 2.5 - (10 \times 8) - (2 \times 8 \times 12) = 0$$

$$R_B = 11.4375 \text{ kN}$$

$$R_A = 14.5625 \text{ kN}$$

SF in AE [x from A]

$$S_x = R_A = 14.5625 \text{ kN}$$

$$S_A = S_E = 14.5625 \text{ kN}$$

SF in ED [x from E]

$$S_x = R_A - 10 - 2x$$

$$= 4.5625 - 2x$$

$$S_E = 4.5625 \text{ kN}$$

$$S_D = -11.4375 \text{ kN}$$

For $S_x = 0$,

$$x = 2.28125 \text{ m}$$

SF in DB [x from B]

$$S_x = -R_B = -11.4375$$

$$S_D = S_B = -11.4375 \text{ kN}$$

BM in AE [x from A]

$$M_x = R_A x = 14.5625x$$

$$M_A = 0$$

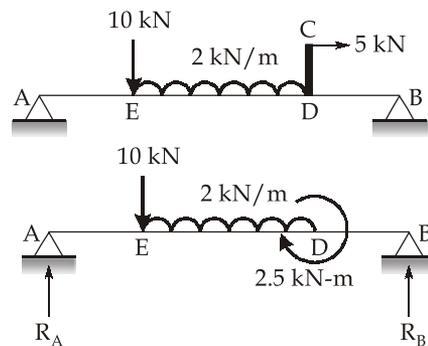
$$M_E = 116.5 \text{ kNm}$$

BM in ED [x from E]

$$M_x = R_A(x + 8) - 10x - \frac{2x^2}{2} = 116.5 + 4.5625x - x^2$$

$$M_E = 116.5 \text{ kNm}$$

$$M_D = 89 \text{ kNm}$$



$$M_{\max} = 121.70 \text{ kNm}$$

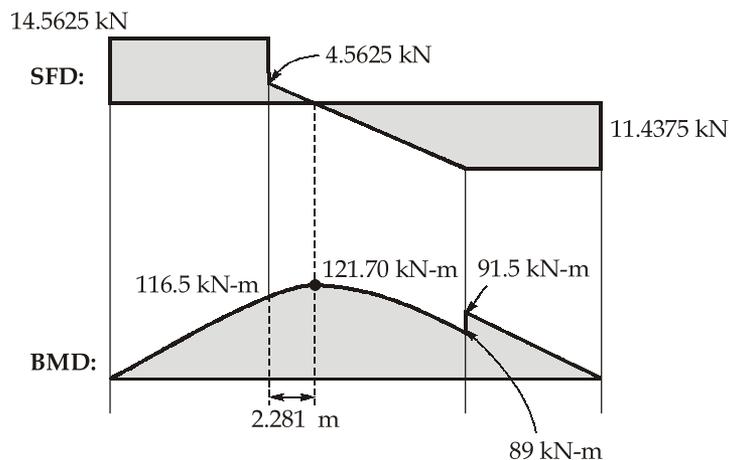
BM in DB [x from B]

$$M_x = R_B x = 11.4375x$$

$$M_B = 0$$

$$M_D = 91.5 \text{ kNm}$$

Maximum bending moment = 121.7 kNm



35. Solution:

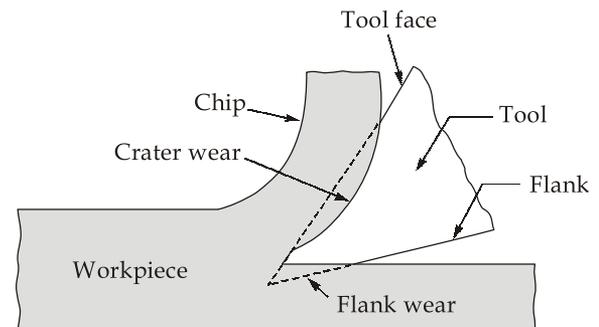
Face wear (Crater wear):

- On the face of the tool there is a direct contact of tool with the chip. Wear takes the form of cavity or crater, which has its origin above the cutting edge. With time, cavity goes on widening. This is prominent in ductile materials. The crater occurs on the rake face of the tool at the point of impingement of the chip with tool and does not actually reach the cutting edge but ends near the nose and on the periphery which serves as the focal points of development of crack and extends to the cutting edge causing a rapid rupture. It leads to weakening of tool, increase in cutting temperature, friction and cutting forces. The tool life due to crater wear can be determined by fixing the ratio of width of crater to its depth.

Flank wear (Edge wear):

- This wear is also called "wearland". Work and tool are in contact at cutting edge only. Usually wear first appears on the clearance face of the tool in the form of a wear land, and is mainly the result of friction and abrasion.

- Adhesion is also a factor because welding of the tool to the work material causes a built-up edge which is torn away, taking particles of the tool material with it. Thermal cracking, due to thermal shock, is also a cause of breakdown of small particles, leading to flank or edge wear.



- Flank wear starts at cutting edge and then starts widening along the clearance face. It is independent of cutting conditions and tool/work materials. Crater wear is prominent in ductile metals, but the flank wear becomes predominant in materials having brittle and flaky chip and discontinuous chip. It is important even in ductile materials if surface finish is the main criteria.
- While all other modes of tool failure can be effectively reduced by changing speed, feed or depth of cut, the flank wear is a progressive form of deterioration which will ultimately result in failure inspite of best precautions.

Given data: $V_1 = 50$ m/min; $T_1 = 45$ min; $V_2 = 100$ m/min; $T_2 = 10$ min

$$VT^n = \text{constant} = C$$

$$V_1 T_1^n = V_2 T_2^n$$

$$50(45)^n = 100(10)^n$$

$$4.5^n = 2$$

On taking log both sides,

$$n \ln 4.5 = \ln 2$$

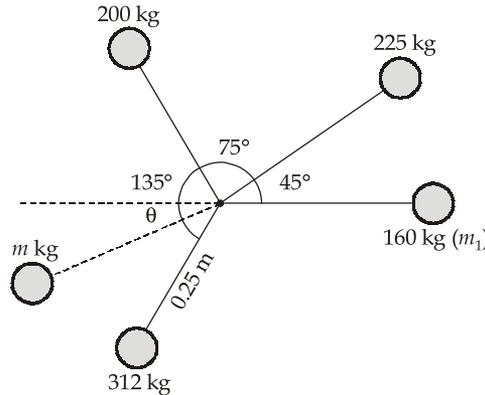
$$n = \frac{\ln 2}{\ln 4.5} = 0.46$$

36. Solution:

Let the balancing mass be m , $r = 0.25$ m

Then the angle which the balancing mass makes with m_1 is θ .

Given: $m_1 = 160$ kg, $r_1 = 0.25$ m, $m_2 = 225$ kg, $r_2 = 0.2$ m,
 $m_3 = 200$ kg, $r_3 = 0.3$ m, $m_4 = 312$ kg, $r_4 = 0.25$ m



Since the magnitude of centrifugal forces are proportional to the product of each mass and its radius, therefore

$$m_1 r_1 = 160 \times 0.25 = 40 \text{ kg.m}, m_2 r_2 = 225 \times 0.2 = 45 \text{ kg.m}$$

$$m_3 r_3 = 200 \times 0.3 = 60 \text{ kg.m}, m_4 r_4 = 312 \times 0.25 = 78 \text{ kg.m}$$

$$\begin{aligned} \Sigma H = 0 &= m_1 r_1 \cos \theta_1 + m_2 r_2 \cos \theta_2 + m_3 r_3 \cos \theta_3 + m_4 r_4 \cos \theta_4 - m r \cos \theta \\ &= 40 \cos 0^\circ + 45 \cos 45^\circ + 60 \cos 120^\circ + 78 \cos 255^\circ \\ &= 40 + 31.8 - 30 - 20.2 = 21.6 \text{ kg.m} \end{aligned}$$

$$\begin{aligned} \Sigma V = 0 &= m_1 r_1 \sin \theta_1 + m_2 r_2 \sin \theta_2 + m_3 r_3 \sin \theta_3 + m_4 r_4 \sin \theta_4 - m r \sin \theta \\ m r \sin \theta &= 40 \sin 0^\circ + 45 \sin 45^\circ + 60 \sin 120^\circ + 78 \sin 255^\circ \\ &= 0 + 31.8 + 52 - 75.3 = 8.5 \text{ kg.m} \end{aligned}$$

$$R = \sqrt{(m r)^2 (\cos^2 \theta + \sin^2 \theta)} = \sqrt{(21.6)^2 + (8.5)^2} = 23.2 \text{ kg.m} = m r$$

$$m = \frac{23.2}{0.25} = 92.8 \text{ kg}$$

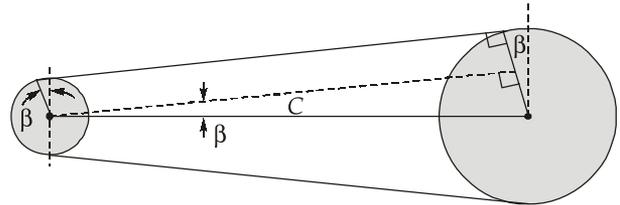
$$\tan \theta = \frac{\Sigma V}{\Sigma H} = \frac{8.5}{21.6} = 0.3935 \text{ or } \theta = 21.48^\circ$$

Since θ is the angle of the resultant R from the horizontal mass of 160 kg, therefore the angle of balancing mass from the horizontal mass of 160 kg.

$$\theta = 180 + 21.48 = \mathbf{201.48^\circ}$$

37. Solution:

- Given: $C = 2000 \text{ mm}$
 Power transmitted, $P = 10 \times 10^3 \text{ W}$
 Dia of larger pulley, $D_2 = 480 \text{ mm}$
 Dia of smaller pulley, $D_1 = 200 \text{ mm}$
 Thickness of belt, $t = 8 \text{ mm}$
 Density of belt, $\rho = 950 \text{ kg/m}^3$
 Friction coefficient, $\mu = 0.3$
 $N_1 = 1000 \text{ RPM}$



$$\tan \beta = \frac{D_2 - D_1}{2C} = \frac{480 - 200}{2 \times 2000} = 0.07$$

$$\beta = 4^\circ$$

Lap angle on smaller pulley

$$\theta = \pi - 2\beta = 172^\circ = 3 \text{ radian}$$

$$\frac{T_1}{T_2} = e^{0.3 \times 3} = 2.45$$

Now, Velocity $V = \omega r = \frac{2\pi N}{60} \times (R_1 + t/2) = \frac{2\pi 1000}{60} \times \left(100 + \frac{8}{2}\right) \times 10^{-3} = 10.89 \text{ m/s}$

$$(T_1 - T_2)V = 10 \times 10^3$$

$$(2.45 T_2 - T_2) \times 10.89 = 10 \times 10^3$$

$$T_2 = 633.3 \text{ N}$$

$$T_1 = 1551.56 \text{ N}$$

$$\text{Centrifugal tension} = T_c = (\rho V^2) \times (\text{Area}) = 950 \times 10.89^2 \times b \times t$$

$$= 950 \times 10.89^2 \times b \times 8 \times 10^{-3} = 901.29b$$

$$T_c = 901.3 b$$

$$T = T_1 + T_c$$

$$\sigma_{\max} = \frac{T}{b \times t}$$

$$\frac{1551.56 + 901.3b}{0.008b} = 2.2 \times 10^6$$

$$b = 92.9 \text{ mm}$$

Length of belt, $L = R_1(\pi - 2\beta) + R_2(\pi + 2\beta) + 2C \cos \beta$
 $= 100(\pi - 2\beta) + 240(\pi + 2\beta) + 2 \times 2000 \times \cos \beta$
 $= 5077.945 \text{ mm}$

