ME 245 : ENGINEERING MECHANICS AND THEORY OF MACHINES

LECTURE: BALANCING OF ROTATING MASSES

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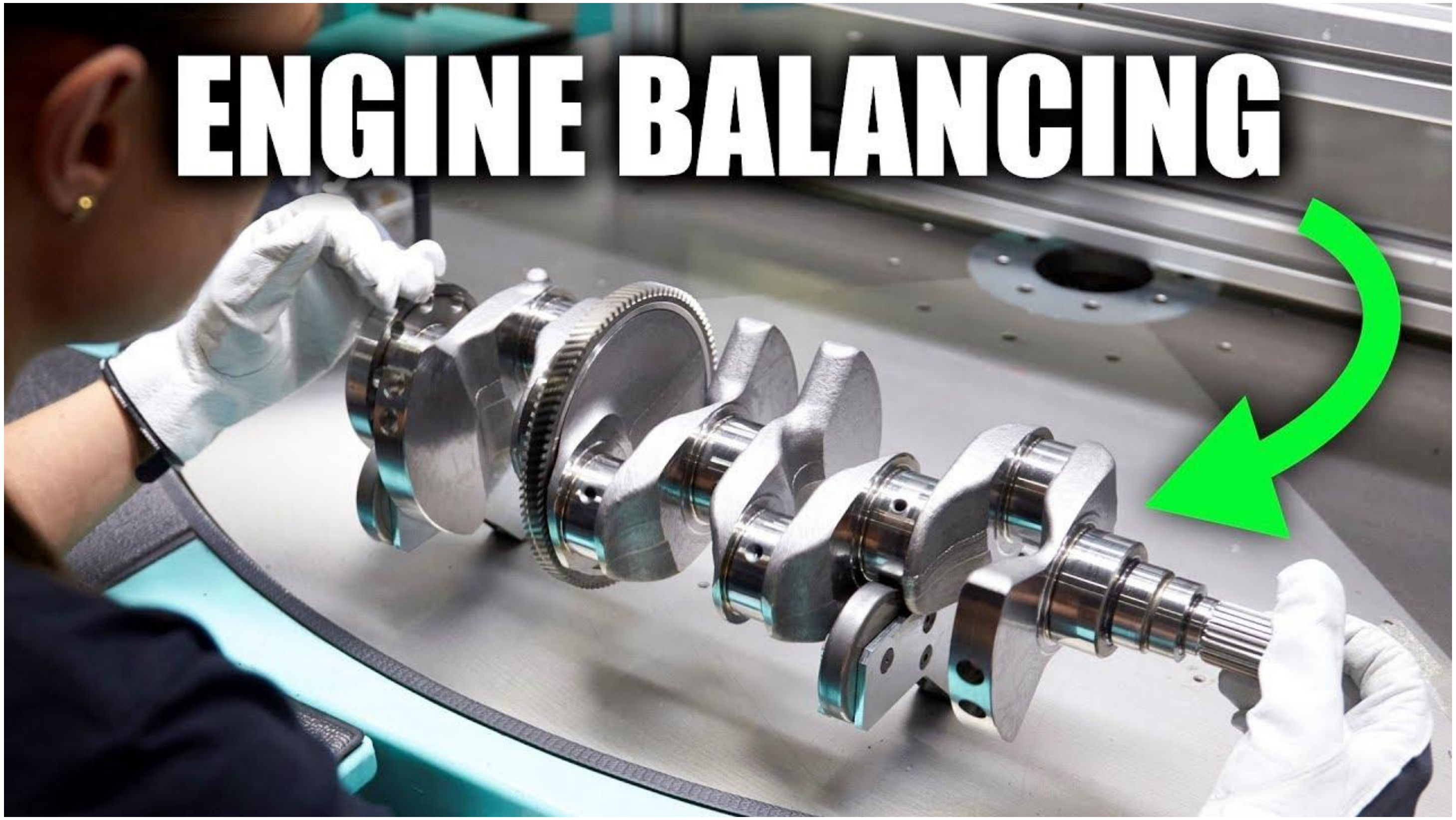
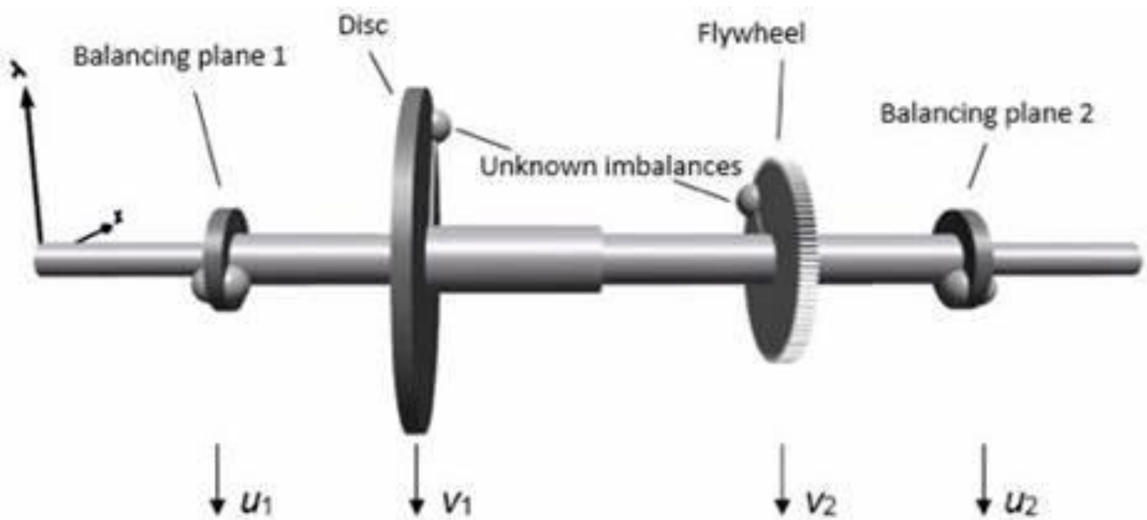

ENGINE BALANCING

Balancing of Rotating Masses



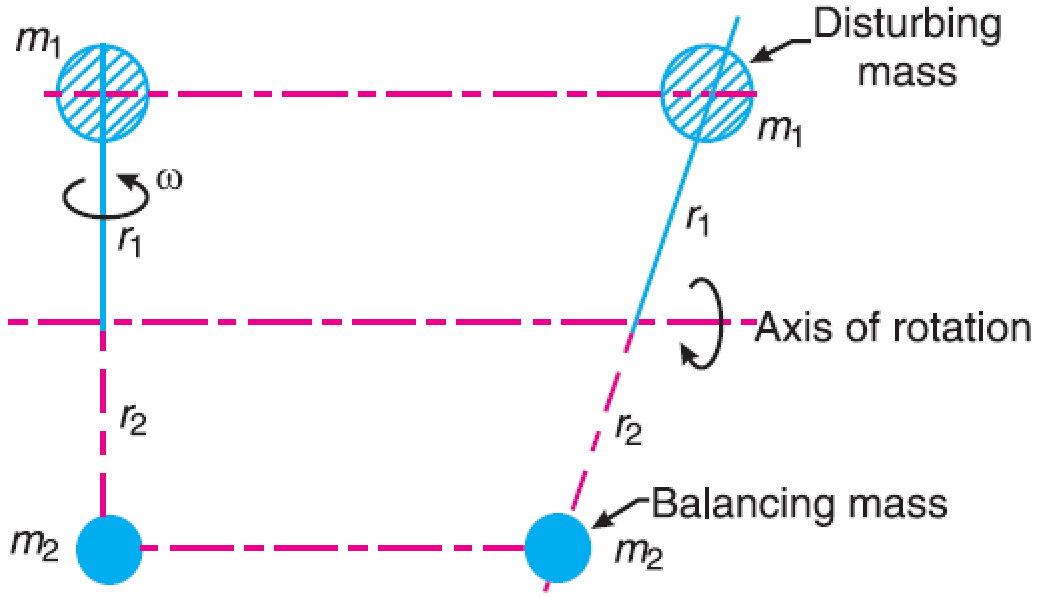
whenever a certain mass is attached to a rotating shaft, it exerts some centrifugal force, whose effect is to bend the shaft and to produce vibrations in it.

In order to prevent the effect of centrifugal force, another mass is attached to the opposite side of the shaft, at such a position so as to balance the effect of the centrifugal force of the first mass.

The following cases are important from the subject point of view:

1. Balancing of a single rotating mass by a single mass rotating in the same plane.
2. Balancing of a single rotating mass by two masses rotating in different planes.
3. Balancing of different masses rotating in the same plane.
4. Balancing of different masses rotating in different planes.

BALANCING OF A SINGLE ROTATING MASS BY A SINGLE MASS ROTATING IN THE SAME PLANE



$$m_1 . \omega^2 \cdot r_1 = m_2 \cdot \omega^2 \cdot r_2 \quad \text{or} \quad m_1 \cdot r_1 = m_2 \cdot r_2$$

BALANCING OF A SINGLE ROTATING MASS BY TWO MASSES ROTATING IN DIFFERENT PLANES

1. The net dynamic force acting on the shaft is equal to zero

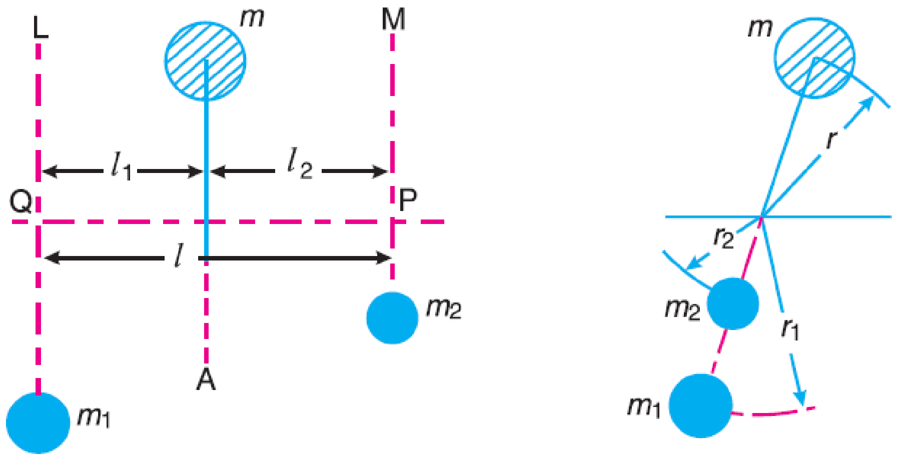
This is the condition for static balancing.

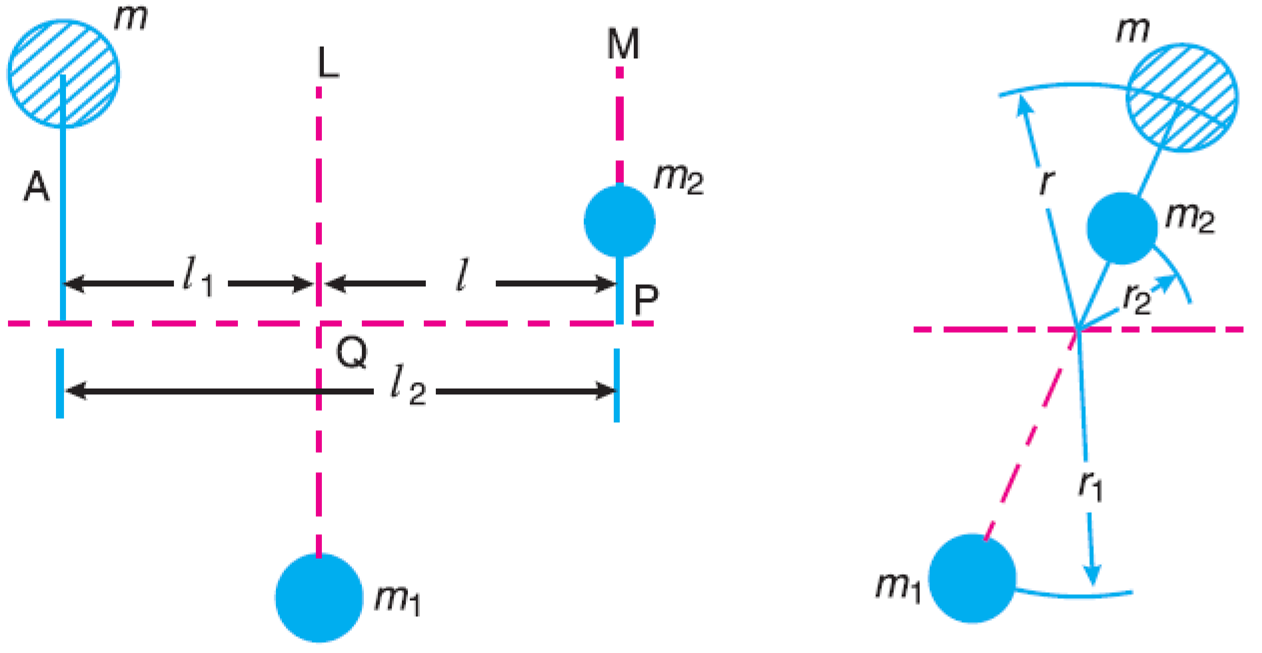
2. The net couple due to the dynamic forces acting on the shaft is equal to zero.

The conditions (1) and (2) together give dynamic balancing.

Consider a disturbing mass m lying in a plane A to be balanced by two rotating masses m_1 and m_2 lying in two different planes L and M as shown in Fig. 21.2. Let r, r_1 and r_2 be the radii of rotation of the masses in planes A, L and M respectively.

Let l_1 = Distance between the planes A and L,
l_2 = Distance between the planes A and M, and
l = Distance between the planes L and M.

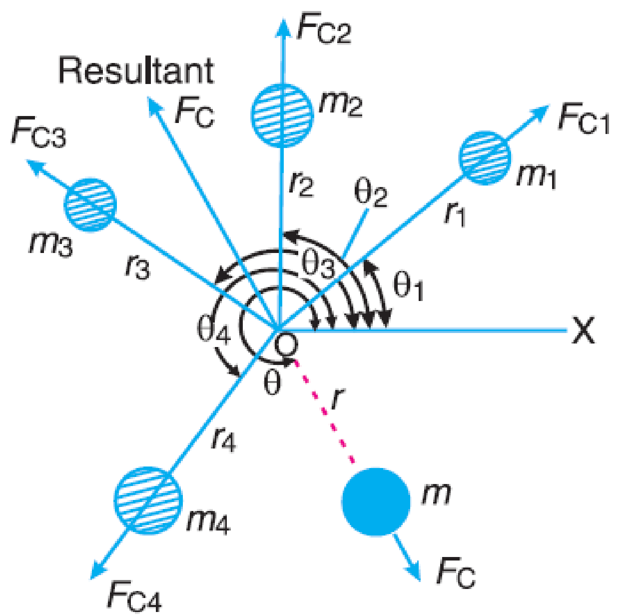


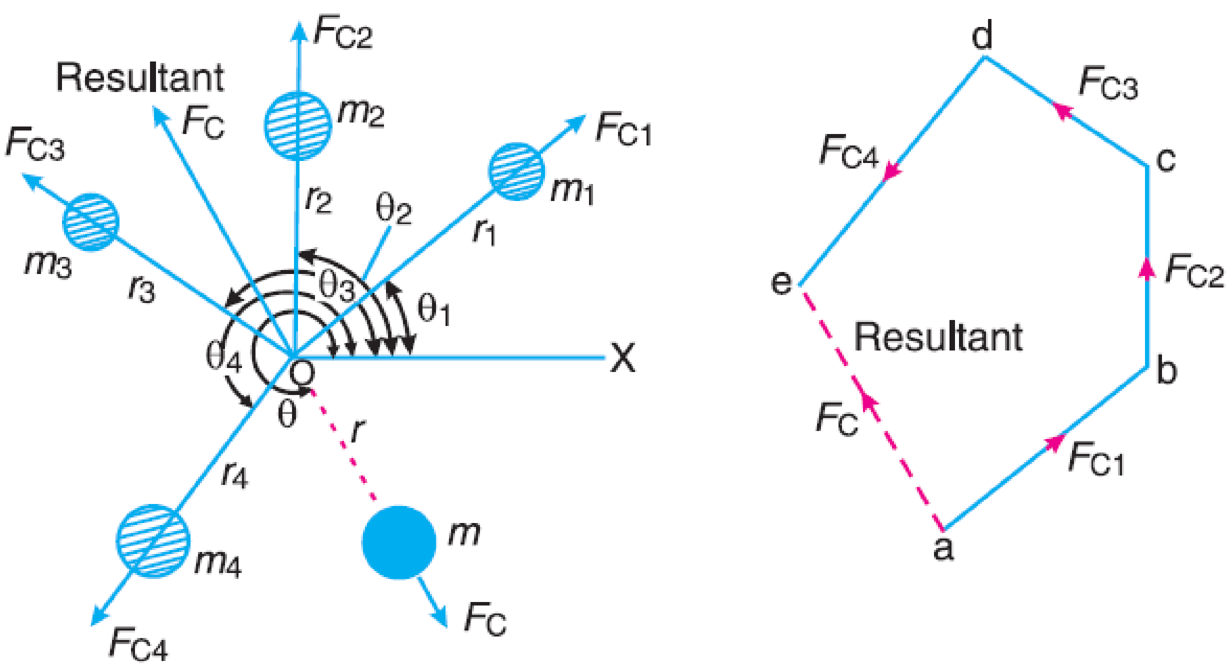


m
L
M
A
m_2
l_1
l
P
Q
l_2
m_1
m
r
m_2
r_2
r_1
m_1

BALANCING OF SEVERAL MASSES ROTATING IN THE SAME PLANE

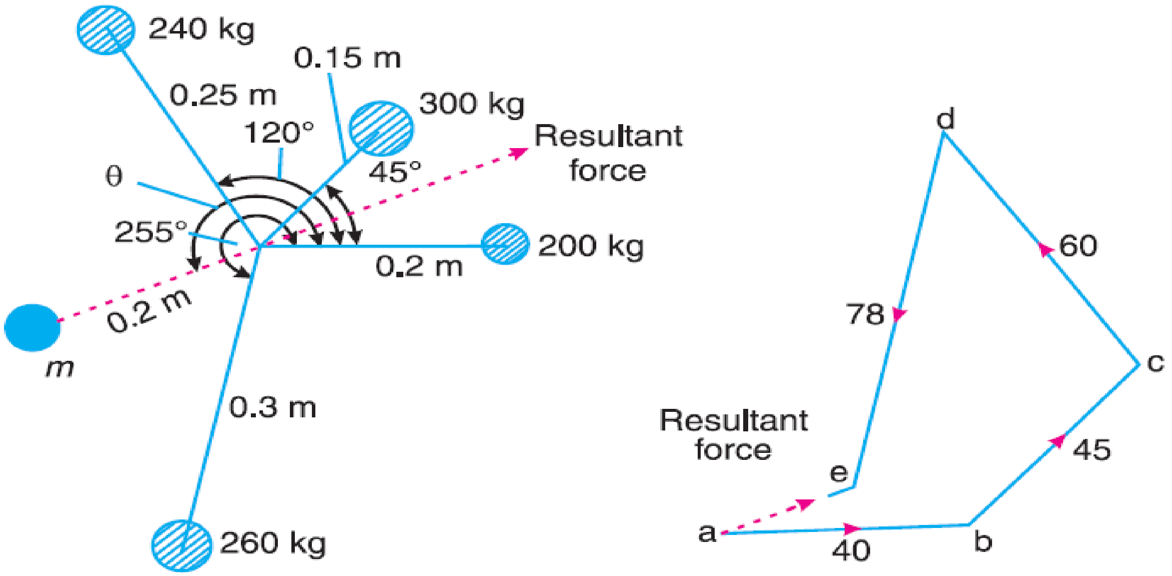
Consider any number of masses (say four) of magnitude m_1, m_2, m_3 and m_4 at distances of r_1, r_2, r_3 and r_4 from the axis of the rotating shaft. Let $\theta_1, \theta_2, \theta_3$ and θ_4 be the angles of these masses with the horizontal line *OX*, as shown in Fig. 21.4 (*a*). Let these masses rotate about an axis through *O* and perpendicular to the plane of paper, with a constant angular velocity of ω rad/s.





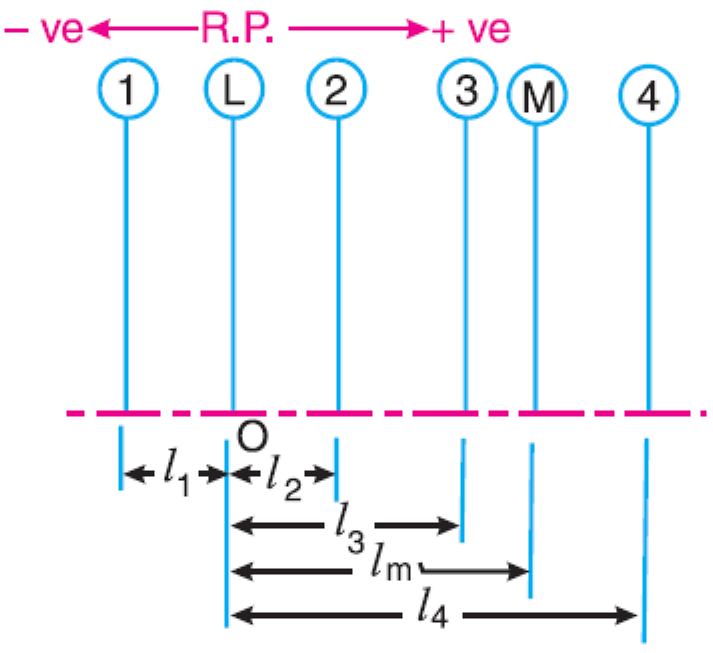
(*a*) Space diagram. (*b*) Vector diagram.

Four masses m_1, m_2, m_3 and m_4 are 200 kg, 300 kg, 240 kg and 260 kg respectively. The corresponding radii of rotation are 0.2 m, 0.15 m, 0.25 m and 0.3 m respectively and the angles between successive masses are 45°, 75° and 135°. Find the position and magnitude of the balance mass required, if its radius of rotation is 0.2 m.

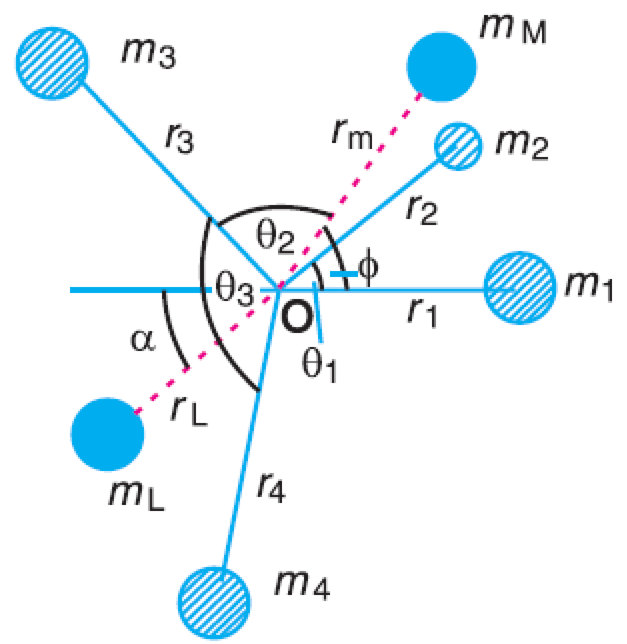


(*a*) Space diagram. (*b*) Vector diagram

BALANCING OF SEVERAL MASSES ROTATING IN DIFFERENT PLANES

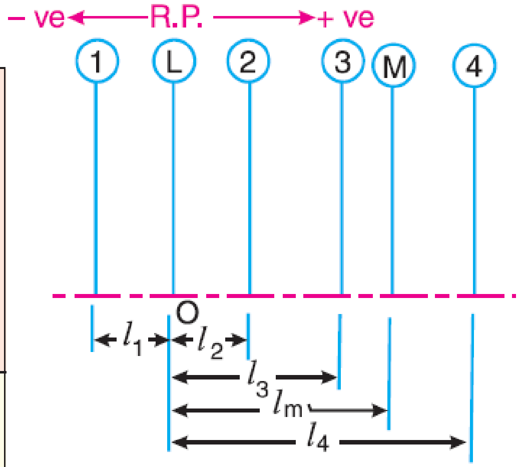


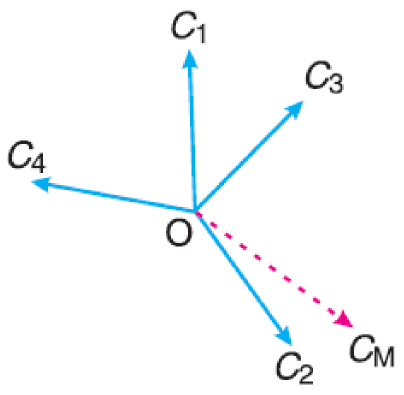
(*a*) Position of planes of the masses.



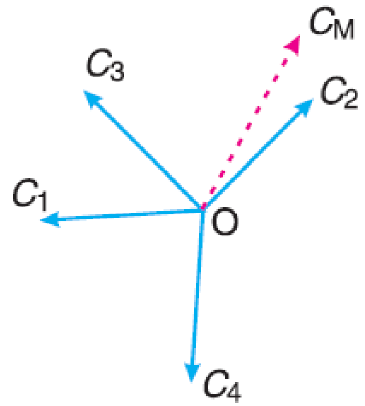
(*b*) Angular position of the masses.

Plane (1)	Mass (m) (2)	Radius(r) (3)	Cent.force ÷ ω^2 (m.r) (4)	Distance from Plane L (l) (5)	Couple ÷ ω^2 (m.r.l) (6)
1	m_1	r_1	$m_1.r_1$	$-l_1$	$-m_1.r_1.l_1$
L(R.P.)	m_L	r_L	$m_L.r_L$	0	0
2	m_2	r_2	$m_2.r_2$	l_2	$m_2.r_2.l_2$
3	m_3	r_3	$m_3.r_3$	l_3	$m_3.r_3.l_3$
M	m_M	r_M	$m_M.r_M$	l_M	$m_M.r_M.l_M$
4	m_4	r_4	$m_4.r_4$	l_4	$m_4.r_4.l_4$

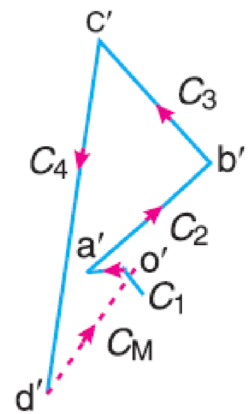




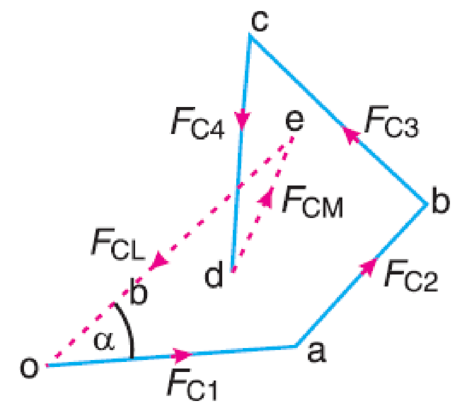
(*c*) Couple vector.



(*d*) Couple vectors turned counter clockwise through a right angle.



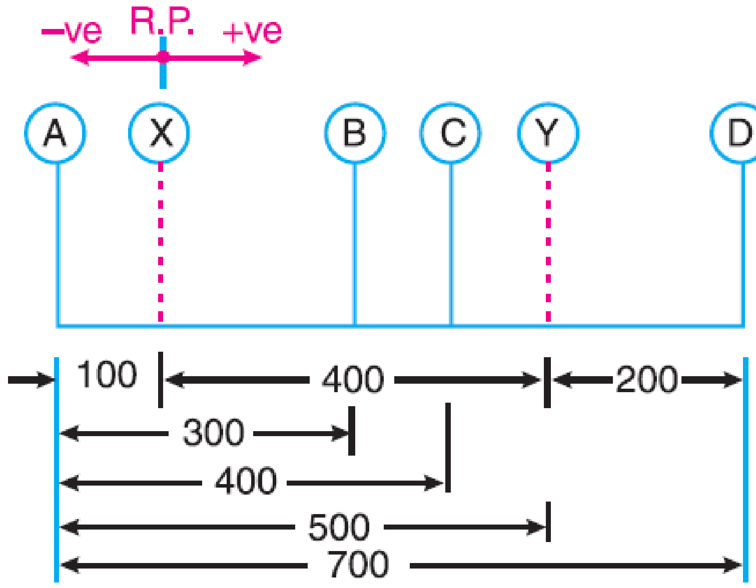
(*e*) Couple polygon.



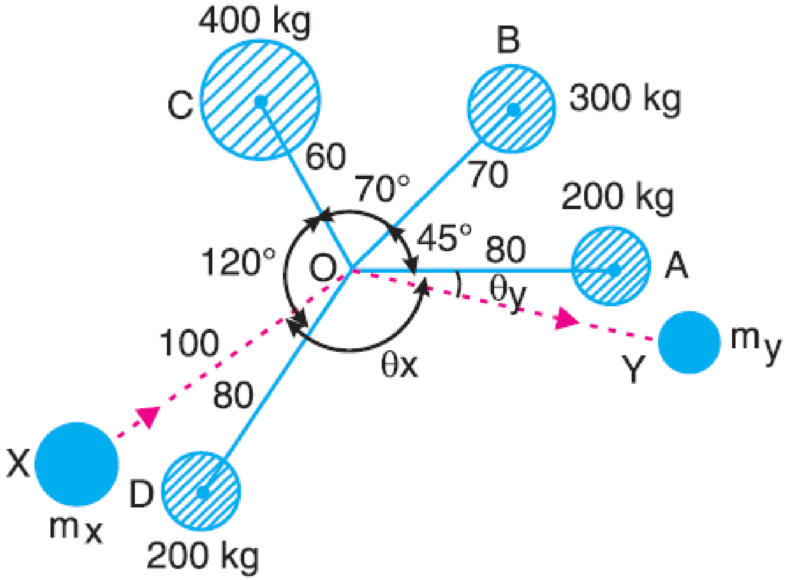
(*f*) Force polygon.

A shaft carries four masses A, B, C and D of magnitude 200 kg, 300 kg, 400 kg and 200 kg respectively and revolving at radii 80 mm, 70 mm, 60 mm and 80 mm in planes measured from A at 300 mm, 400 mm and 700 mm. The angles between the cranks measured anticlockwise are A to B 45°, B to C 70° and C to D 120°. The balancing masses are to be placed in planes X and Y. The distance between the planes A and X is 100 mm, between X and Y is 400mm and between Y and D is 200 mm. If the balancing masses revolve at a radius of 100 mm, find their magnitudes and angular positions.

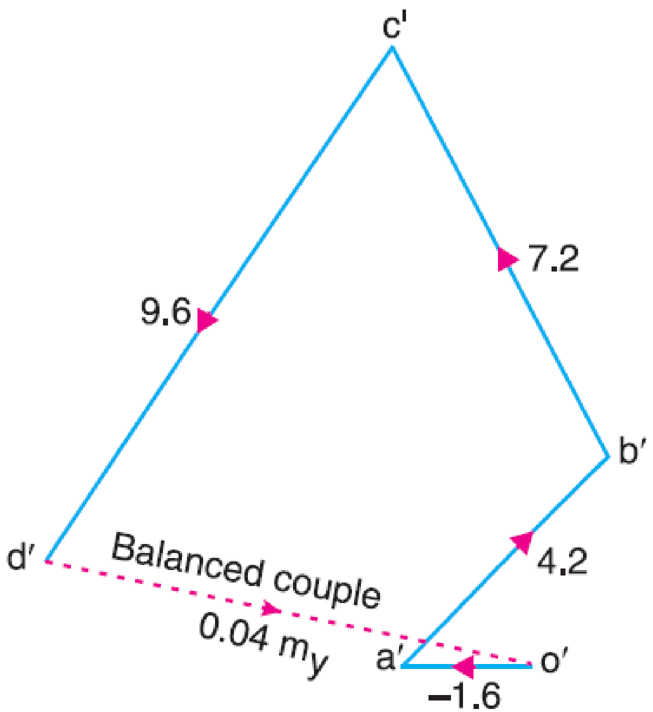
Plane *(1)*	*Mass (m)* *kg* *(2)*	*Radius (r)* *m* *(3)*	*Cent.force* $\div \omega^2$ *(m.r) kg-m* *(4)*	*Distance from* *Plane x(l) m* *(5)*	*Couple* $\div \omega^2$ *(m.r.l) kg-m*^{2} *(6)*
A	200	0.08	16	– 0.1	– 1.6
X(*R.P.*)	m_X	0.1	0.1 m_X	0	0
B	300	0.07	21	0.2	4.2
C	400	0.06	24	0.3	7.2
Y	m_Y	0.1	0.1 m_Y	0.4	0.04 m_Y
D	200	0.08	16	0.6	9.6



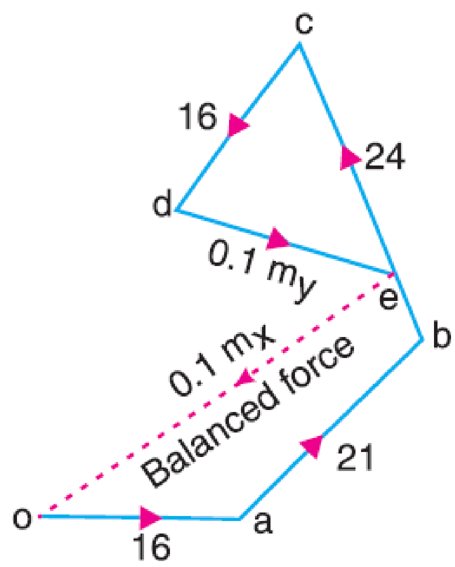
−ve
R.P.
+ve
A
X
B
C
Y
D
100
400
200
300
400
500
700



400 kg
B
C
300 kg
60
70°
70
200 kg
45°
80
120°
O
A
θy
100
θx
m y
Y
80
X
D
m x
200 kg



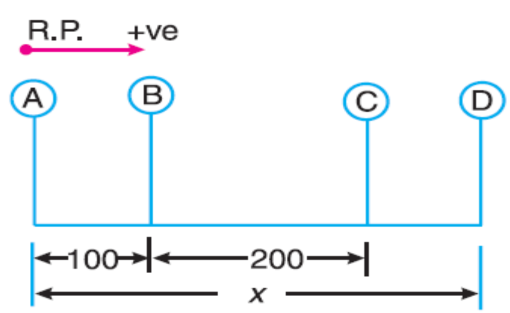
(*c*) Couple polygon.

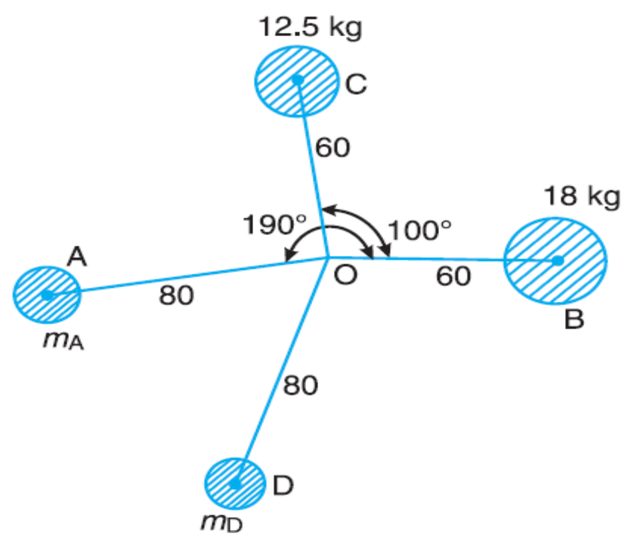


(*d*) Force polygon.

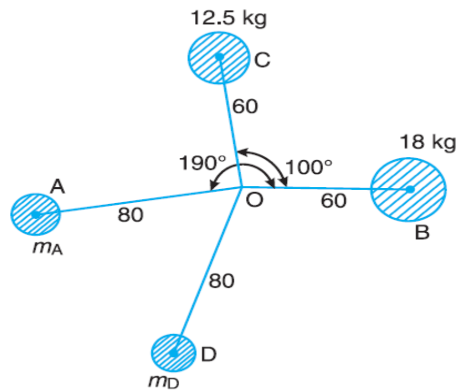
A shaft carries four masses in parallel planes A, B, C and D in this order along its length. The masses at B and C are 18 kg and 12.5 kg respectively, and each has an eccentricity of 60 mm. The masses at A and D have an eccentricity of 80 mm. The angle between the masses at B and C is 100° and that between the masses at B and A is 190°, both being measured in the same direction. The axial distance between the planes A and B is 100 mm and that between B and C is 200 mm. If the shaft is in complete dynamic balance, determine :

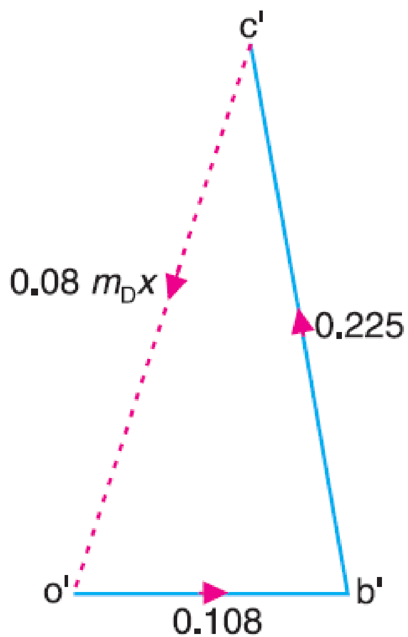
1. The magnitude of the masses at A and D ; 2. the distance between planes A and D ; and 3. the angular position of the mass at D.



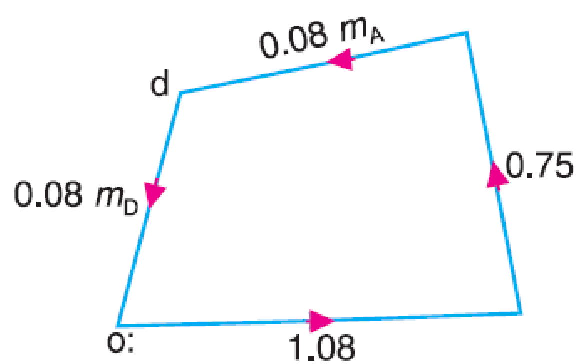


Plane (1)	***Mass*** ***(m) kg*** (2)	***Eccentricity*** ***(r) m*** (3)	***Cent. force*** $\div \omega^2$ ***(m.r) kg-m*** (4)	***Distance from plane A(l)m*** (5)	***Couple*** $\div \omega^2$ ***(m.r.l) kg-m²*** (6)
A (R.P.)	m_A	0.08	$0.08\ m_A$	0	0
B	18	0.06	1.08	0.1	0.108
C	12.5	0.06	0.75	0.3	0.225
D	m_D	0.08	$0.08\ m_D$	x	$0.08\ m_D \cdot x$



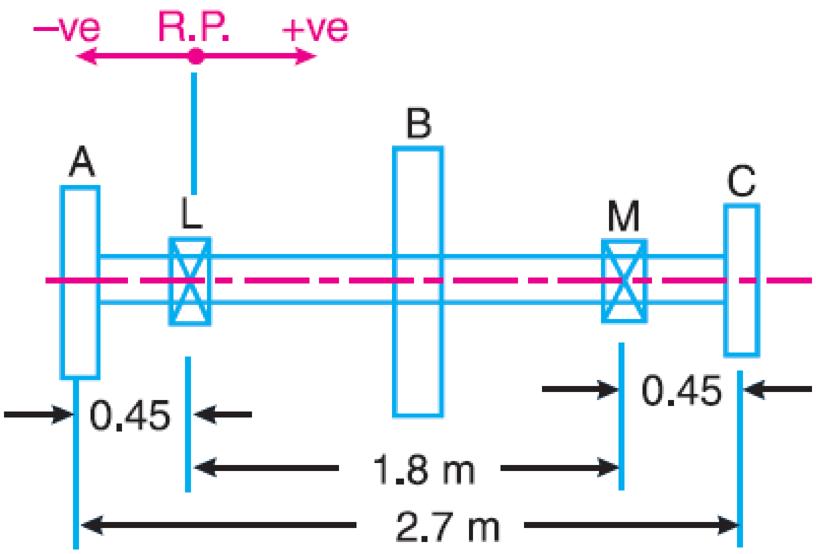


(c) Couple polygon.

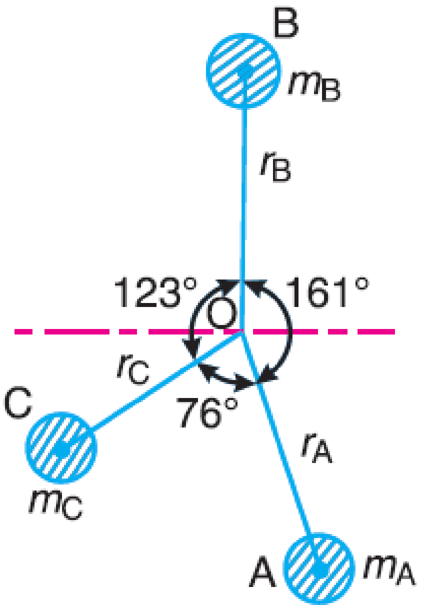


(*d*) Force polygon.

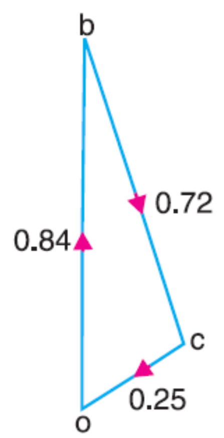
A shaft is supported in bearings 1.8 m apart and projects 0.45 m beyond bearings at each end. The shaft carries three pulleys one at each end and one at the middle of its length. The mass of end pulleys is 48 kg and 20 kg and their centre of gravity are 15 mm and 12.5 mm respectively from the shaft axis. The centre pulley has a mass of 56 kg and its centre of gravity is 15 mm from the shaft axis. If the pulleys are arranged so as to give static balance, determine :***1. relative angular positions of the pulleys, and 2. dynamic forces produced on the bearings when*** *the shaft rotates at 300 r.p.m.*



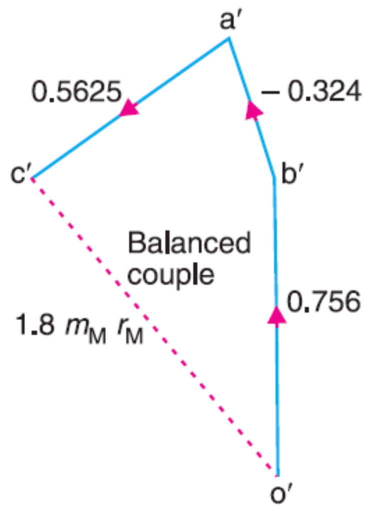
(*a*) Position of shaft and pulleys.



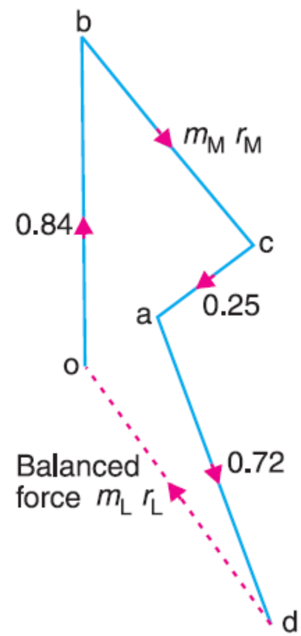
(*b*) Angular position of pulleys.



(*c*) Force polygon.



(*d*) Couple polygon.



(*e*) Force polygon.

8. A 3.6 m long shaft carries three pulleys, two at its two ends and third at the mid-point. The two end pulleys has mass of 79 kg and 40 kg and their centre of gravity are 3 mm and 5 mm respectively from the axis of the shaft. The middle pulley mass is 50 kg and its centre of gravity is 8 mm from the shaft axis. The pulleys are so keyed to the shaft that the assembly is in static balance. The shaft rotates at 300 r.p.m. in two bearings 2.4m apart with equal overhang on either side. Determine : 1. the relative angular positions of the pulleys, and 2. dynamic reactions at the two bearings.