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Engineering Mechanics

First Year Engineering

Semester – II

(Common to All Branches)

As per the new revised syllabus of Savitribai Phule Pune University w.e.f. academic year 2015-2016

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Engineering Mechanics

First Year Engineering (Semester – II)

(Common to All Branches)

As per the new revised syllabus of SPPU w.e.f. academic year 2015-2016

Dr. Kadam Madhav Punjaji, Prof. Dinesh W. Gawatre, Prof. Seham Khaleel.

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Preface

This Book 'Engineering Mechanics' is intended to be a textbook for students of First Year Engineering (F.E.) SPPU Pune. In most sciences, one generation years down what another has built and what one has established another undoes. In Engineering Mechanics, each generation adds a new story to the old structure. Keeping this in mind, this book is written to have a better introduction of the Engineering Mechanics. This book is presented with simple but exact explanation of subject matter, application of each topic to real life, engineering problems, large number of illustrative examples followed by well graded exercise. We have tried to be rigorous and precise in presenting the concepts in very simple manner. We hope that the students will not only learn some powerful concepts, but also will develop their ability to understand the concept and apply it properly to solve engineering problems. We feel that faculty member will also enjoy reading this book which is enriched with application of each topic.

Acknowledgment

I am grateful to the S.P.P.U. Pune, the examining body, whose 'Syllabus Draft' and Examination Questions have been included in this book for the purpose of illustration and right direction.

I extend my sincere thanks to Principal, Respected Dr. K.P.Patil Sir, Sinhgad Academy of Engineering, Pune for his creative suggestions and technical guidance, and our H.O.D [Department of Civil Engineering] Prof. R.B.Bajare, Sinhgad Academy of Engineering, Pune for his valuable suggestions.

I am thankful Dr. S.R. Parekar Sir, Head, Department of Civil Engineering, AISSMS College of Engineering, Pune for his valuable suggestions and guidance.

I owe an enormous debt of gratitude to my family members, my teachers, my colleagues, my student's for their kind co-operation and valuable guidance and special thanks to my wife Varsha for her motivation and encouragement to me every time.

I hope the book; an off-shoot of joint venture will cater all the requirement of students to crack the nut-shell of the subject. We are also thankful to **Gigatech Publishing House TEAM** for their continuous support, hard work and patience in preparing this book.

Author

Dinesh W.Gawatre

SYLLABUS

Unit - I : **(06 Hrs.)**

a) Principle of statics, force systems, resolution and composition of forces. Resultant of concurrent forces. Moment of a force, Varignon's theorem, resultant of parallel force system. Couple, Equivalent force couple system.

b) Resultant of general force system. Distributed forces. Centroid of plane lamina and wire bends.

Unit - II : **(07 Hrs.)**

a) **Kinematics :** Basic concepts, equations of motion for constant acceleration and motion under gravity. Variable acceleration and motion curves. Relative motion and dependant motion.

b) **Kinetics :** Newton's second law of motion and its application.

Unit – III : **(07 Hrs.)**

a) **Kinematics :** basic concepts, equation of motion in Cartesian co-ordinates. Path and polar co-ordinates. Motion of projectiles.

b) **Kinetics :** Newton's second law of motion in Cartesian and Path co-ordinates for curvilinear motion of a particle.

Unit – IV : **(06 Hrs.)**

a) Work, power, energy, conservative and non-conservative forces. Conservation of energy and work energy principle for motion of particle.

b) Impulse, momentum, directs central impact and coefficient of restitution. Conservation of momentum and Impulse momentum principle of particle.

Unit - V : **(07 Hrs.)**

a) Free body diagram, equilibrium of concurrent, parallel and general forces in a plane. Equilibrium of three forces in a plane. Types of beams : simple and compound beams, type of supports and reaction.

b) Resultant of concurrent and parallel forces in a space. Equilibrium of concurrent and parallel forces in a Space.

Unit - VI : **(07 Hrs.)**

a) **Two force members :** analysis of plane trusses by method of joint and method of section, cables subjected to point loads. Multi force member : plane frames.

b) **Friction :** Law's of friction, application of friction on inclined plane. Wedges and ladders friction, application to flat belt.

Recommended by SPPU Text Books and Reference Books

Text Books :

1. Vector Mechanics for Engineers by Beer & Johnston -- Mc Graw Hill
2. Engg. Mechanics : S. Timoscnko, Dtp. Young and J.V.Rao, - Tata Mc Graw Hill Education Pvt Ltd. New Delhi.
3. Engg. Mechanics by Basudeb Bhattacharyya - Oxford University Press,

Reference Books :

1. Engg. Mechanics by I.H. Shames & G.K.M. Rao---Pearson
2. Fundamentals of Engg. Mechanics by S. Rajasekaran & G. Sankarsubramanian :
   Vikas Publishing House Pvt. Ltd.
3. Engg. Mechanics by K. I. Kumar & Veenu Kumar.
   Tata Mc Graw Hill Education Pvt. Ltd. New Delhi
4. Engg. Mechanics by Soutas, Little, Inman-----India Edition---Cengage Learning.

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CONTENTS

◆◆◆

Unit 1 Forces and Force System

Moment

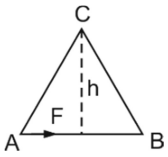
1. For triangle ABC the side AB represents magnitude of force and altitude of triangle represents moment arm from moment centre C then moment about C is ____.

(a) Area of triangle ABC (b) ½ area of triangle

(c) 2 area of triangle ABC (d) 3 area of triangle ABC

Ans.: (c)

Explanation :



$$\text{Moment about R} = F \times h$$

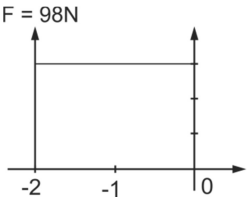
$$\text{Area of } \Delta ABC = \frac{1}{2} \times F \times h$$

2. A vertical force of F acting in second quadrant in –xy plane at (–2, 3) m. If F = 98 N, the magnitude of moment about origin is

(a) 196 Nm (b) 98 Nm (c) 294 Nm (d) 0 Nm

Ans.: (a)

Explanation :



$$\text{Moment} = F \cdot d$$

F = 38, d = – 2

$$m_e \text{ origin} = 98 \times (-2)$$

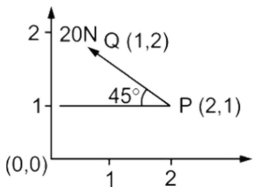
$$= \mathbf{-196\ N.m}$$

3. A force of 20 N acting through points P (2,1) and Q (1,2), its moment @ 0 (0,0) will be _____.

(a) 28.28N.m (b) 28N.m (c) 14.14N.m (d) -14.14N.m

Ans.: (a)

Explanation :



$$\text{Moment @ (0,0)} = 20 \cos 45 \times 1 + 20 \sin 45 \times 2$$

$$= 14.14 + 14.14$$

$$= \mathbf{28.28\ N.m}$$

4. A force of 200 N acting at A (4, 5) makes an angle 35° with the vertical, its moment about the origin is _____.

(a) -32.64N.m (b) 950.4N.m (c) 458.88N.m (d) 491.52N.m

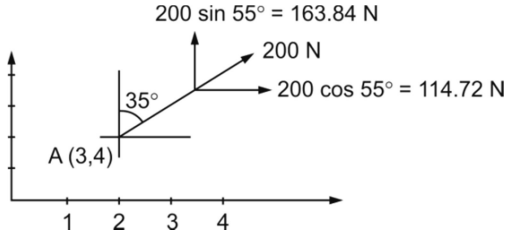
Ans.: (a)

Explanation :

$$\text{Moment of origin} = +114.72 \times 4 - 163.84 \times 3$$

$$= (114.72 \times 4) - (163.84 \times 3)$$

$$= \mathbf{-32.64\ N.m}$$

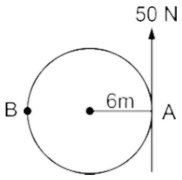


5. A force of 50 N acting tangentially to a circle of radius 6 m. Its moment about diametrically opposite point will be ____.

(a) 150 Nm (b) 600 Nm (c) 60 Nm (d) 300 Nm

Ans.: (b)

Explanation :



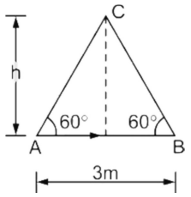
Moment about B = F × d
= 50 × 12
= **600 Nm**

6. A forces of 10 N each acting along sides of equilateral triangle of side 3 m. The moment of force system about apex of triangle is _____.

(a) 25.90 Nm (b) 60 Nm (c) 30 Nm (d) 12.95 Nm

Ans.: (a)

Explanation :



$\tan 60° = \frac{h}{1.5}$ ∴ h = 2.59 m

Moment at C = F·d = 10 × 2.59

= **25.90 N·m**

7. A door of width 1.8 m can rotate if a moment of 20 Nm is applied. The minimum force that can be applied to open it is ____.

(a) 20 N (b) 1.8 N (c) 11.11 N (d) None of these

Ans.: (c)

Explanation :

M = F·d

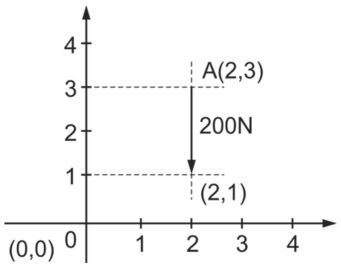
20 = F × 1.8

F = 11.11 N

8. A force of 200 N is acting through points A (2, 3) and B (2, 1). The moment of force about point O (0, 0) is

(a) 400 Nm (b) 200 Nm

(c) 600 Nm (d) 100 Nm



Ans.: (a)

Explanation : M_O = (200 × 2)

R = 400 Nm

9. Moment of a couple is

(a) Depends upon axis (b) Independent of a point

(c) Depends upon point (d) None of the above.

Ans.: (b)

Explanation :

Moment of couple : The moment of a couple is the product of the force and the arm of couple.

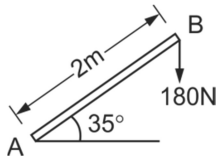
M = F × d

10. A lever AB = 2 m long is inclined at 35° with horizontal A forces of 180 N is acting at B vertically downwards. The moment about 'A' is

(a) 29.5 Nm (b) 295 Nm (c) 2950 Nm (d) 2.950 Nm

Ans.: (b)

Explanation :



Moment about A = F· d

= 180 × 2 cos 35°

= **295 Nm**

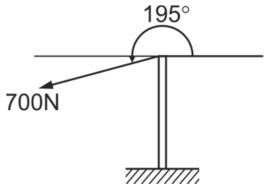
11. An electric pole is supported by a wire which exerts a pull of 700 N on the top of the pole. If the angle between the wire and the pole is 195° with + ve x– axis. What are the horizontal and vertical components?

(a) 181.17 N, 676.14 N (b) 676.14 N, 181.17 N

(c) 857.31 N, 181.17 N (d) 181.17, 857.31 N

Ans.: (a)

Explanation :



$F = 700$ N

$\theta = 270° - 195 = 75°$

$\Sigma F_x = F\cdot \cos\theta = 700 \times \cos 75° =$ **181.17 N**

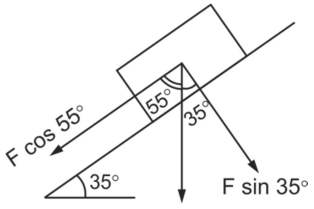
$\Sigma F_y = F\cdot \sin\theta = 700 \times \sin 75° =$ **676.14 N**

12. If a wooden block of weight W = 97 N placed on a rough surface inclined at an angle θ = 35° in anticlockwise direction with positive x– axis and is at rest, then assuming up the plane forces positive, the reaction offered by the surface is

(a) 97 N (b) 56 N (c) 80 N (d) 0 N

Ans.: (c)

Explanation :



Normal Reaction = F sin θ

= 37 × sin 55

= 79.45

≈ **80 N**

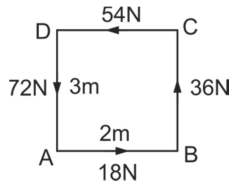
13. Four forces 18 N, 36 N, 54 N and 72 N are acting along sides AB, BC, CD and DA of a rectangle ABCD of side (2× 3) m. Their resultant forces is 150 N. Calculate position of resultant w.r.t. 'A'

(a) 1.56 m (b) 15.60 m (c) 156 m (d) 0.156 m

Ans.: (a)

Explanation :

Use Varignon′s theorem



$R \cdot x = (-36 \times 2) - (54 \times 3)$

$150 \times x = -72 - 162 \qquad 150 = -234$

$x = \frac{234}{150} =$ **1.56 m**

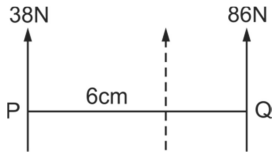
14. Two like parallel forces 38 N and 86 N are acting at a distance of 6cm. What is the Resultant and Position?

(a) 416 N, 1.24 cm from Q (b) 124 N, 4.16 cm from Q

(c) 124 N, 4.16 cm from P (d) 416 N, 1.24 cm from P

Ans.: (c)

Explanation :



$$R = 38 + 86 = 124 \text{ N}$$

Use Varignon′s theorem

$$R \cdot x = \Sigma M_p$$

$$124\ x = 86 \times 6 = 516$$

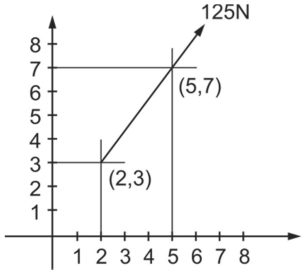
$$\mathbf{x = 4.16 \text{ cm}}$$

15. A force of magnitude 125 N is directed from point A (2, 3) to B (5, 9). The x and y components are

(a) –100 N, 75 N (b) 100 N, 75 N (c) 75 N, 100 N (d) 100 N, – 75 N

Ans.: (c)

Explanation :



$$\tan\theta = \frac{y_2 - y_1}{x_2 - x_1} = \frac{7-3}{5-2} = \frac{4}{3} = 1.34$$

$$\theta = 53.26°, F = 125 \text{ N}$$

$F_x = F\cos\theta$, $F_x = 125 \cos\theta$**= 75 N**

$F_y = F \sin\theta$, $F_y = 125 \sin\theta$**= 100 N**

16. A force of magnitude 125 N is directed from A(2, 3) to B (– 5, –7). The x and y components are

(a) –83.05 N, 93.41 N (b) – 93.41 N, 83.05 N

(c) 83.05 N, 93.41N (d) 93.41 N, 83.05 N

Ans.: (c)

Explanation : $\tan\theta = \frac{y_2 - y_1}{x_2 - x_1} = \frac{-7-2}{-5-3} = \frac{-9}{-8} = 1.125$

$$\theta = 48.36°$$

$F_x = F\cos\theta = 125 \times \cos 48.36°$**= 83.05 N**

$F_y = F \sin\theta = 125 \times \sin 48.36°$**= 93.41 N**

17. A force of 20 N is acting along a line having slope $\frac{3}{4}$. Calculate Resultant.

(a) 16 N (b) 20 N (c) 12 N (d) 28 N

Ans.: (b)

Explanation :

$$\text{Slope } \tan\theta = \frac{3}{4}$$

$$\theta = 36.86°$$

$F_x = f\cos\theta = 20 \cos 36.86° = 16$

$F_y = f \sin\theta = 20 \sin 36.86° = 12$

$$\mathbf{R = 20 \text{ N}}$$

18. The moment of a force about any point is geometrically equal to ____ area of triangle where base represents the force and height represents the perpendicular distance.

(a) Half (b) Twice (c) Same (d) thrice

Ans.: (b)

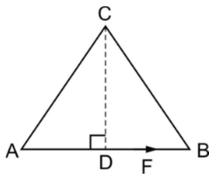
Explanation : $Me_C = F \times d = Fd$

$$A(\Delta ACB) = \frac{1}{2} AB \times CD$$

$= \frac{1}{2} \times F \times d = \frac{1}{2} \times F\ d$

i.e $= \frac{1}{2} M_c$

i.e $\mathbf{M\ e_c = 2\ A\ (\Delta\ ABC)}$



19. If the arm of couple is doubled, its moment will

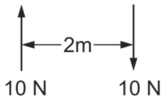
(a) Be halved (b) Remains same

(c) Be doubled (d) None of the above

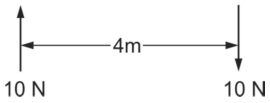
Ans.: (c)

Explanation :

Case – I) M = 10 ×2 = 20 Nm



Case – II) M = 10 ×4 = 40 Nm



20. A force of 200 N acting download tangentially to a drum of radius 0.75 m, must be transferred parallel to itself to its centre 0. The moment which should accompany it for equivalent effect is

(a) 150 Nm (b) – 150 Nm (c) – 75 Nm (d) 75 N.m

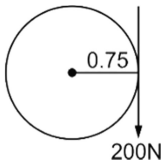
Ans.: (b)

Explanation :

$M = f \cdot d$

$M_0 = 200 \times 0.75$

$= 150$ Nm



∴ **Equivalent effect = 150 Nm↺**

Resultant

21. Find the magnitude of two unlike parallel forces P & Q acting at a distance 2m apart. Which is equivalent to a force of 600 N acting at a distance of 600 mm?

(a) 600 N (b) 360 N (c) 300 N (d) 1 N

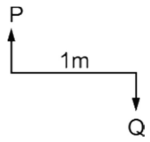
Ans.: (b) Explanation :

$P = Q = P$

∴ $P \times 1 = 600 \times 0.6$

$= 360$ N

P = 360 N



22. Four forces P = 150 N (East), Q = 200 N (North), R = 200 N (South) and S = 150 N (West) are acting on member, their resultant is _____.

(a) 0 N (b) 500 N (c) 400 N (d) 300 N

Ans.: (a)

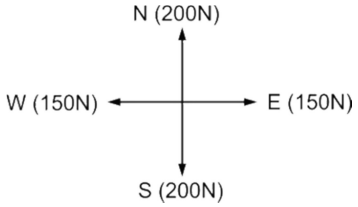
Explanation :

$\Sigma F_x = 150 - 150 = 0$

$\Sigma F_y = 200 - 200 = 0$

$R = \sqrt{(\Sigma Fx)^2 + (\Sigma Fy)^2}$

$= \mathbf{0}$



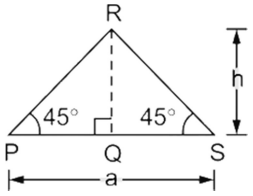
23. The centre of gravity of an isosceles triangle with base a and sides b is ____ from its base.

(a) $\sqrt{\frac{4b^2 - a^2}{6}}$ (b) $\sqrt{\frac{4a^2 - b^2}{6}}$ (c) $\sqrt{\frac{4b^2+a^2}{6}}$ (d) $\sqrt{\frac{4a^2+b^2}{6}}$

Ans.: (a)

Explanation :

In $\Delta PQR = 90°$



$$b^2 = \left(\frac{a}{2}\right)^2 + h^2 \qquad b^2 = \frac{a^2}{4} + h^2$$

$$h^2 = b^2 - \frac{a^2}{4} \qquad h^2 = \frac{4b^2 - a^2}{4}$$

$$h = \sqrt{\frac{4b^2 - a^2}{2}}$$

C.G. from bottom h/3

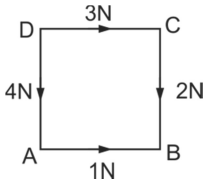
$$\text{C.G.} = \sqrt{\frac{4b^2 - a^2}{2 \times 3}} = \sqrt{\frac{\mathbf{4b^2 - a^2}}{\mathbf{6}}}$$

24. Forces of magnitudes 1 N, 2 N, 3 N and 4 N are acting along sides AB, CB, DC and DA of a rectangle respectively. The magnitude of resultant is

(a) 7.21 N (b) 4 N (c) 6 N (d) 0N

Ans.: (a)

Explanation:



$$\Sigma F_x = 1 + 3 = 4 \text{ N}$$

$$R = \sqrt{4^2 + (-6^2)}$$

$$R = 7.21 \text{ N}$$

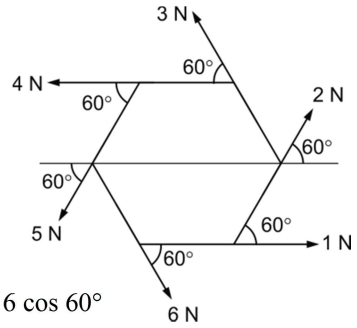
$$\therefore \quad \Sigma F_y = -2 - 4 = \mathbf{-6\ N}$$

25. If forces of 1N, 2 N, 3 N, 4 N, 5 N and 6 N act at in order along the sides of regular hexagon, then the resultant is _____.

(a) 0 (b) 6 N (c) 12 N (d) 18 N

Ans.: (b)

Explanation :



Interior angles $= (2n - 4)\ 90$

$= (2 \times 6 - 4) \times 90$

$= 720$

Each angle $= \frac{720}{6}$

$= 120°$

$\Sigma F_x = 1 + 2\cos 60° - 3\cos 60° - 4 - 5\cos 60° + 6\cos 60°$

$= -3$ N

$\Sigma F_y = 2\sin 60° + 3\sin 60° - 5\sin 60° - 6\sin 60°$

$= -5.19$ N

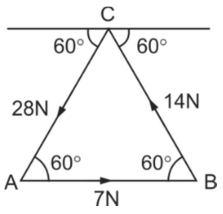
Resultant (R) $= \sqrt{\Sigma Fx^2 + \Sigma Fy^2} = \sqrt{(-3)^2 + (-5.19)^2} = \mathbf{6\ N}$

26. Three forces 7 N, 14 N and 28 N act along three sides of an equilateral triangle AB, BC and CA. Side AB being horizontal. The resultant of system is

(a) 18.15 N (b) 31.77 N (c) 23.71 N (d) 71.31 N

Ans.: (a)

Explanation :



$\Sigma F_x = 7 - 14\cos 60 - 28\cos 60° = -14$ N

$\Sigma F_y = 14\sin 60° - 28\sin 60$

$= -12.12$ N

$R = \sqrt{(-14)^2 + (-12.12)^2} = \mathbf{18.51}$

27. The resultant of two perpendicular forces of magnitude F each will be

(a) $\sqrt{2}$ P (b) $\sqrt{2P}$ (c) $2\sqrt{P}$ (d) P

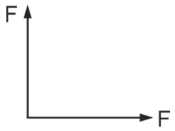
Ans.: (a)

Explanation :

$R^2 = f_1^2 + f_2^2 + 2f_1f_2\cos\theta$

$f_1 = f_2 = f$

And $\theta = 90°$



$R^2 = f^2 + f_1^2 + 2f \cdot f \cdot \cos 90°$

$R^2 = f_1^2 + f^2$

$R^2 = 2f^2$

$\mathbf{R = \sqrt{2} \cdot f = \sqrt{2}\ P}$

28. Two forces act an angle of 130°. If the greater force is 60 N and their resultant is perpendicular to the smaller force, the smaller force is _____.

(a) 0 N (b) 38.57N (c) 300 N (d) 25 N.

Ans.: (b)

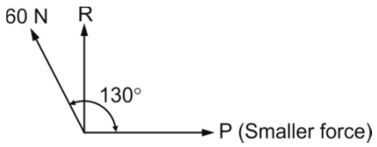
Explanation :

$\Sigma F_x = P - 60\cos 50° = 0$

$= 38.57$ N

$\therefore$ Smaller force $= 38.57$ N

R = is along 90°



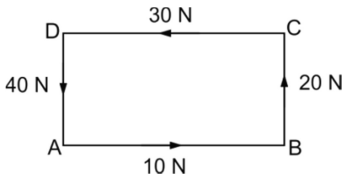
$\therefore \quad \mathbf{\Sigma F_y = 0}$

29. Forces 10 N, 20 N, 30 N and 40 N act along sides of a rectangle. Their resultant force will be _____.

(a) 28.28 N (b) 40 N (c) 100 N (d) 32.32 N

Ans.: (a)

Explanation :



$\Sigma F_x = 10 - 30 = -20$

$\Sigma F_y = 20 - 40 = -20$

$R = \sqrt{(20)^2 + (20)^2}$

$\mathbf{R = 28.28\ N}$

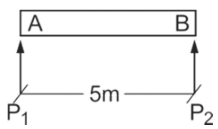
30. Two parallel forces P_1 and P_2 act on rigid body at points A and B lying on a straight line such that AB = 6 m. Resultant of these two forces at a point C lying on AB such that AB = 2 : 3_____.

(a) like parallel forces (b) unlike parallel forces

(c) both (a) and (b) (d) perpendicular forces

Ans.: (a)

Explanation :



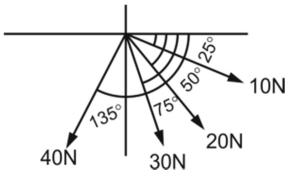
$\therefore$ Both force P_1 and P_2 vertical so Resultant also vertical

31. Four forces 10N, 20N, 30N and 40N (all tensile) act at a point at angles of 25°, 50°, 75° and 100° clockwise from +ve X-axis. The sum of components of all forces along axis parallel to X-axis is

(a) 36.64N (b) 87.91N (c) -36.64N (d) -87.91N

Ans.: (a)

Explanation :

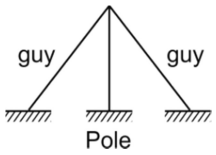


$\Sigma F_x = 10\cos 25° + 20\cos 50° + 30\cos 75° + 40\cos 80°$

$= 9.07 + 12.86 + 7.76 + 6.95$

$= \mathbf{36.64N}$

32. The guy wire of two vertical electrical pole makes 40° with horizontal and subjected to 40 kN force. What will be the horizontal component of force?



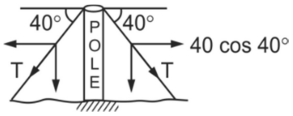
As shown in Fig.

(a) 30.64 kN (b) 0kN

(c) 33.56 kN (d) 25.68 kN

Ans.: (b)

Explanation :



$T = 40$ kN

$\theta = 40°$

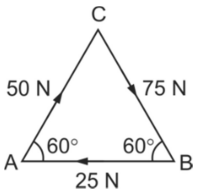
$\Sigma F_x = -40\cos 40° + 40\cos 40° = \mathbf{0}$

33. Three forces 25 N, 50 N and 75 N act along AB, BC and CA respectively along the sides of an equilateral triangle. AB being horizontal. The resultant of the force system is _____.

(a) 37.50 N (b) 21.66 N (c) 43.30 N (d) 59.16 N

Ans.: (c)

Explanation :



$\Sigma F_x = 0 = -25 + 50\cos 60° + 75\cos 60°$

$= 37.5$ N

$\Sigma F_y = 50\sin 60° - 75\sin 60°$

$= -21.66$ N

$R = \sqrt{(37.5)^2 + (-21.66)^2}$

$\mathbf{R = 43.30\ N}$

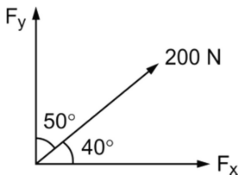
34. The components of force of 200 N in direction inclined to it at 40° and 50° on opposite sides are ____.

(a) 128.55 N and 153.20 N (b) 153.20 N & 125.55 N

(c) –128.55 N and –153.20 N (d) –153.20 N & –128.55 N

Ans.: (b)

Explanation :



$\alpha = 40° \beta = 50° \alpha + \beta = 40° + 50° = 90°$

$F_x = F\left(\frac{\sin\beta}{\sin(\alpha+\beta)}\right) = 200\left[\frac{\sin 50}{\sin 90}\right] = \mathbf{153.20\ N}$

$F_y = F\left(\frac{\sin\alpha}{\sin(\alpha+\beta)}\right) = 200\left[\frac{\sin 40}{\sin 90}\right] = \mathbf{125.55\ N}$

35. Three forces 20 N, 30 N and 40 N act along sides of equilateral triangle taken in order. 20 N force is acting horizontally towards right. Their resultant is _____.

(a) 20 N (b) 17.32 N (c) 30 N (d) 40 N

Ans.: (b)

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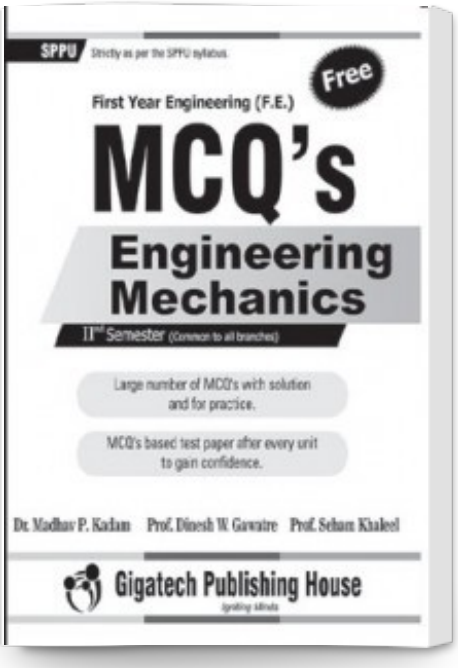

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