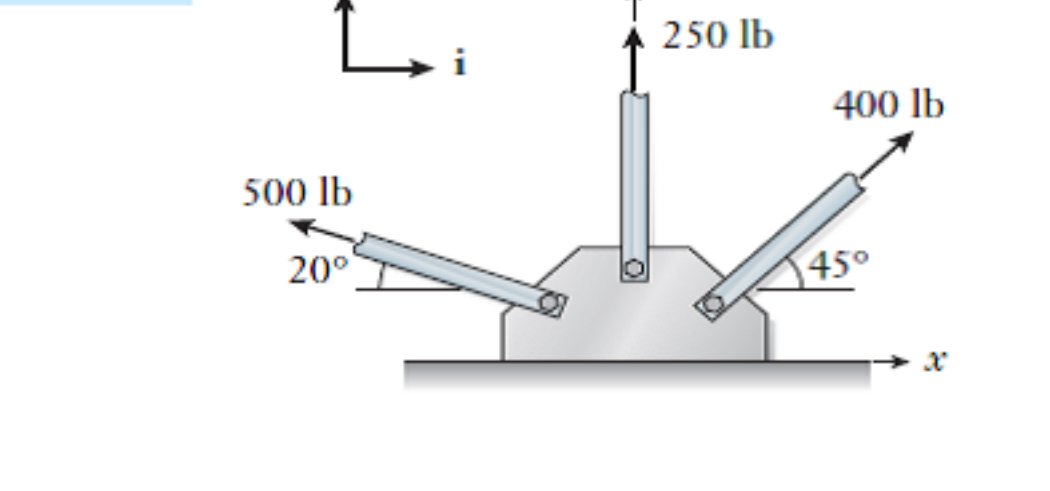


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Problem

Figure P4.6

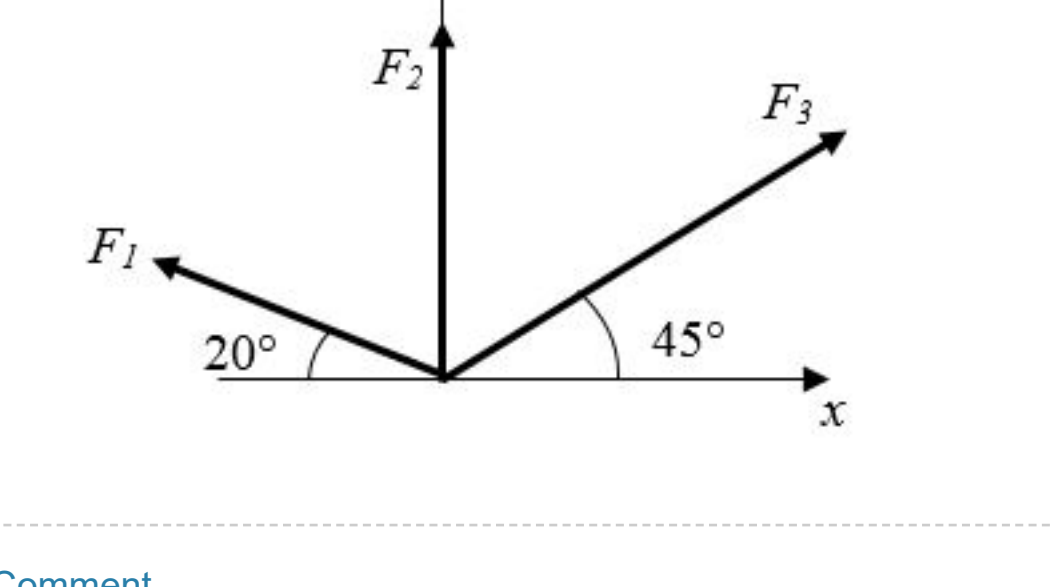


Step-by-step solution

Step 1 of 15

(a)

Figure showing force on gusset plate.



Comment

Step 2 of 15

Find the force F_1 vector representation as follows:

$$F_1 = (F_1 \cos \theta_1) \mathbf{i} + (F_1 \sin \theta_1) \mathbf{j}$$

Here, the angle made by the force F_1 with horizontal is θ_1 .

Substitute 500 lb for F_1 and 20° for θ_1 .

$$F_1 = (-500 \times \cos 20^\circ) \mathbf{i} + (500 \times \sin 20^\circ) \mathbf{j}$$
$$= (-469.85 \text{ lb}) \mathbf{i} + (171.01 \text{ lb}) \mathbf{j}$$

Comment

Step 3 of 15

Find the force F_2 vector representation as follows:

$$F_2 = (F_2 \cos \theta_2) \mathbf{i} + (F_2 \sin \theta_2) \mathbf{j}$$

Here, the angle made by the force F_2 with horizontal is θ_2 .

Substitute 250 lb for F_2 and 90° for θ_2 .

$$F_2 = (250 \times \cos 90^\circ) \mathbf{i} + (250 \times \sin 90^\circ) \mathbf{j}$$
$$= (0) \mathbf{i} + (250 \text{ lb}) \mathbf{j}$$
$$= (250 \text{ lb}) \mathbf{j}$$

Comment

Step 4 of 15

Find the force F_3 vector representation as follows:

$$F_3 = (F_3 \cos \theta_3) \mathbf{i} + (F_3 \sin \theta_3) \mathbf{j}$$

Here, the angle made by the force F_3 with horizontal is θ_3 .

Substitute 400 lb for F_3 and 45° for θ_3 .

$$F_3 = (400 \times \cos 45^\circ) \mathbf{i} + (400 \times \sin 45^\circ) \mathbf{j}$$
$$= (282.84 \text{ lb}) \mathbf{i} + (282.84 \text{ lb}) \mathbf{j}$$

Comment

Step 5 of 15

Find the resultant force vector using the following relation:

$$R = F_1 + F_2 + F_3$$

Substitute $(-469.85 \text{ lb}) \mathbf{i} + (171.01 \text{ lb}) \mathbf{j}$ for F_1 , $(250 \text{ lb}) \mathbf{j}$ for F_2 and $(282.84 \text{ lb}) \mathbf{i} + (282.84 \text{ lb}) \mathbf{j}$ for F_3 .

$$R = [(-469.85 \text{ lb}) \mathbf{i} + (171.01 \text{ lb}) \mathbf{j}] + [(250 \text{ lb}) \mathbf{j}] + [(282.84 \text{ lb}) \mathbf{i} + (282.84 \text{ lb}) \mathbf{j}]$$
$$= (-469.85 + 282.84) \mathbf{i} + (171.01 + 250 + 282.84) \mathbf{j}$$
$$= (-187.01 \mathbf{i} + 703.85 \mathbf{j}) \text{ lb}$$

Comment

Step 6 of 15

Calculate the magnitude of resultant force.

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

Substitute -187.01 lb for R_x and 703.85 lb for R_y .

$$R = \sqrt{(-187.01)^2 + (703.85)^2}$$
$$= 728.27 \text{ lb}$$

Comment

Step 7 of 15

Find the angle of resultant force relative to x-axis as follows:

$$\theta = \tan^{-1} \left(\frac{R_y}{R_x} \right)$$

Substitute -187.01 lb for R_x and 703.85 lb for R_y .

$$\theta = \tan^{-1} \left(\frac{703.85}{-187.01} \right)$$
$$= 180 - \tan^{-1} \left(\frac{703.85}{187.01} \right)$$
$$= 104.88^\circ$$

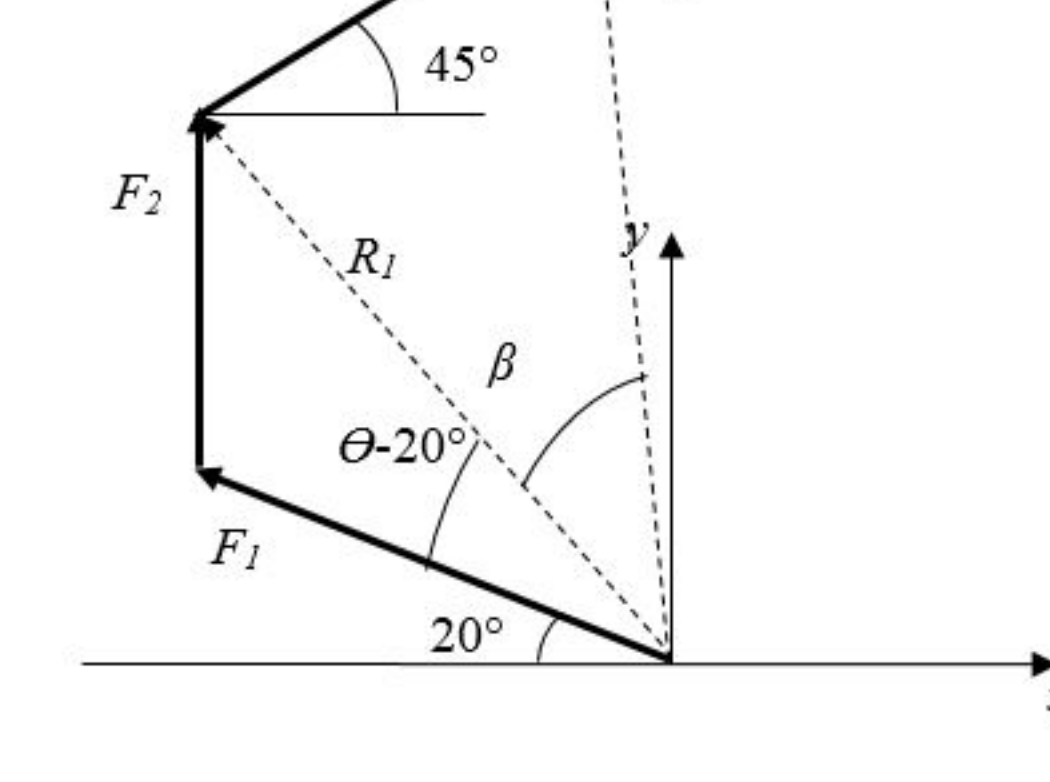
Therefore, the resultant of two forces in vector algebra method is 728.27 lb in magnitude and its angle relative to x-axis is 104.88° .

Comment

Step 8 of 15

(b)

Figure showing force diagram of the forces on Gusset plate.



Comment

Step 9 of 15

Resultant of three forces is determined using vector polygon method in two steps. First resultant of Forces F_1 and F_2 is determined and it is resultant $1 R_1$. Then resultant of R_1 and F_3 gives the resultant of three forces R .

From law of cosines find the resultant of two forces,

$$R_1 = \sqrt{F_1^2 + F_2^2 - 2F_1F_2 \cos \alpha}$$

Substitute 500 lb for F_1 , 250 lb for F_2 and 110° for α .

$$R_1 = \sqrt{F_1^2 + F_2^2 - 2F_1F_2 \cos \alpha}$$
$$= \sqrt{500^2 + 250^2 - 2 \times 500 \times 250 \times \cos 110^\circ}$$
$$= 630.87 \text{ lb}$$

The resultant of two forces is 630.87 lb .

Comment

Step 10 of 15

From law of sines find the forces and its included angles as follows:

$$\frac{R_1}{\sin(90^\circ + 20^\circ)} = \frac{F_2}{\sin(\theta - 20^\circ)}$$
$$\sin(\theta - 20^\circ) = \frac{F_2}{R_1} \sin 110^\circ$$
$$\theta = 20^\circ + \sin^{-1} \left(\frac{250}{630.87} \sin 110^\circ \right)$$
$$= 41.86^\circ$$

Angle of resultant force R_1 relative to -x-axis is 41.86° .

Comment

Step 11 of 15

From law of cosines find the resultant of two forces R_1 and F_3 .

$$R = \sqrt{R_1^2 + F_3^2 - 2R_1F_3 \cos \alpha_2}$$

Substitute 630.87 lb for R_1 , 400 lb for F_3 and 86.86° for α_2 .

$$R = \sqrt{R_1^2 + F_3^2 - 2R_1F_3 \cos \alpha_2}$$
$$= \sqrt{630.87^2 + 400^2 - 2 \times 630.87 \times 400 \times \cos 86.86^\circ}$$
$$= 728.26 \text{ lb}$$

Comment

Step 12 of 15

The angle between F_3 and R_1 is as follows:

$$\gamma = 180^\circ - (110^\circ + (\theta - 20^\circ))$$
$$\gamma = 180^\circ - (110^\circ + (41.86^\circ - 20^\circ))$$
$$= 48.14^\circ$$

Comment

Step 13 of 15

Calculate the angle opposite to the Resultant R .

$$\delta = (90^\circ - 48.14^\circ) + 45^\circ$$
$$= 86.86^\circ$$

Comment

Step 14 of 15

From law of sines calculate the angle β .

$$\frac{R}{\sin 86.86^\circ} = \frac{F_3}{\sin \beta}$$
$$\sin \beta = \frac{F_3}{R} \sin 86.86^\circ$$

Substitute 400 lb for F_3 and 728.26 lb for R .

$$\beta = \sin^{-1} \left(\frac{400}{728.26} \sin 86.86^\circ \right)$$
$$\beta = 33.26^\circ$$

Comment

Step 15 of 15

Find the angle of resultant force relative to -x-axis.

$$\beta + \theta = 33.26 + 41.86$$
$$= 75.12^\circ$$

Find the angle of resultant force relative to the positive x-axis.

$$180^\circ - (\beta + \theta) = 180^\circ - 75.12^\circ$$
$$= 104.88^\circ$$

Therefore, the resultant of two forces in vector polygon method is 728.26 lb and the angle made is relative to x-axis is 104.88° .

Magnitude and direction of resultant force from both methods are exactly matching.

Comment

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7

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