Engineering Mechanics

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RECAP
Engineering Mechanics

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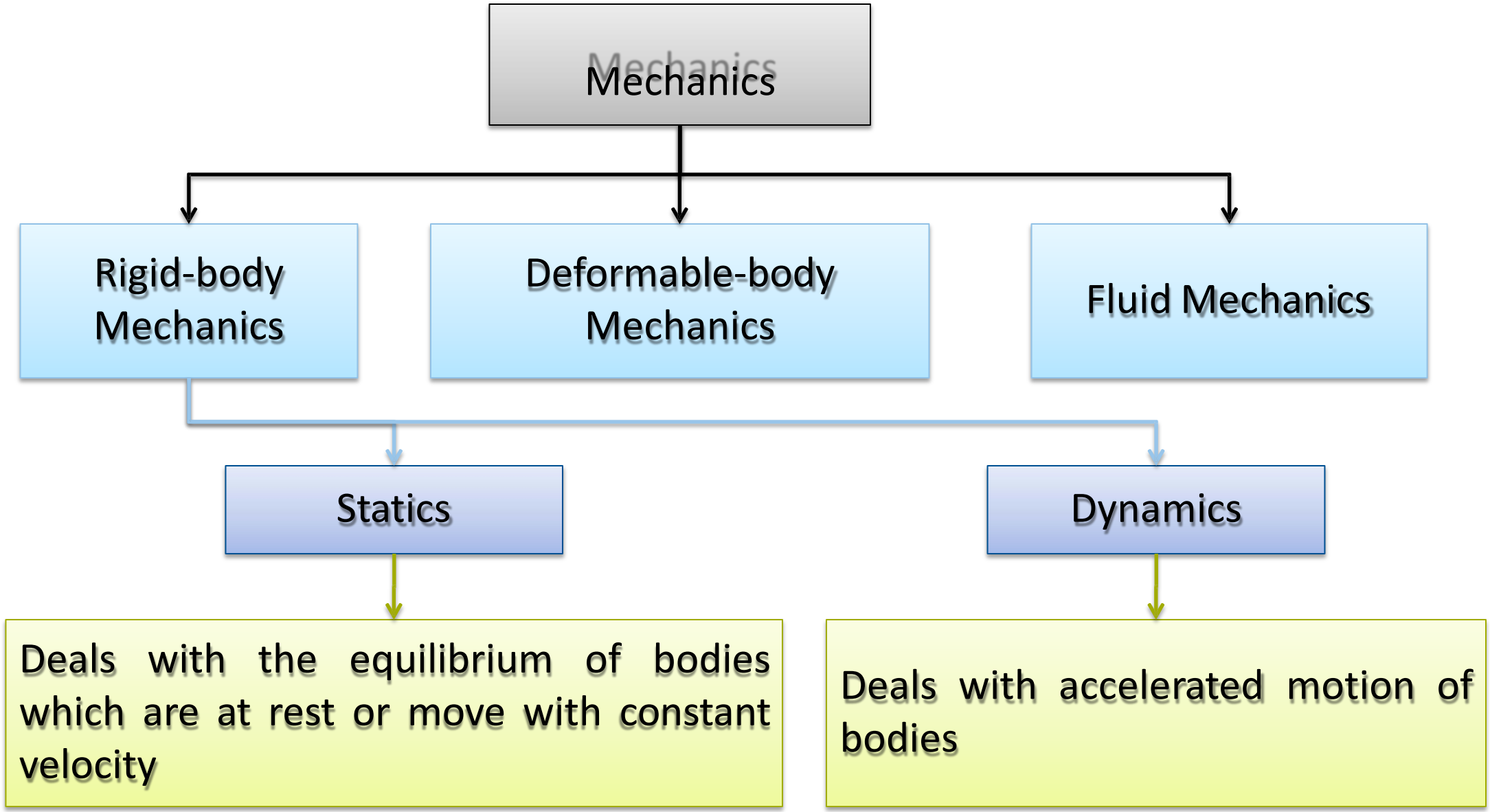
Definition

Mechanics is a branch of the physical sciences that is concerned with the state of rest or motion of bodies that are subjected to the action of forces.

OR in Simple words;

Mechanics is a branch of physics which deal with the effect of force or multiple forces acting on a body or a system of a body.


Mechanics
Rigid-body Mechanics
Deformable-body Mechanics
Fluid Mechanics
Statics
Dynamics
Deals with the equilibrium of bodies which are at rest or move with constant velocity
Deals with accelerated motion of bodies

Force Vectors

Definitions:

Scalar:

Any positive or negative physical quantity that can be completely specified by its magnitude. For instance, length, mass, time.

Vector:

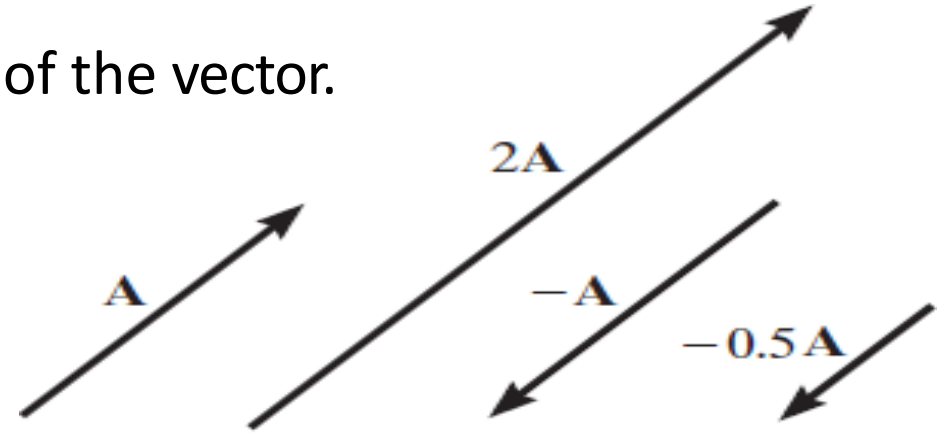
A vector is any physical quantity that requires both a magnitude and a direction for its complete description. For instance, force and moment. Graphically, a vector is shown by a line with an arrow. The length of the line represents the magnitude while the arrow head represents its sense of direction.

Force Vectors

Vector Operations

Multiplication or Division of a Vector by a Scalar:

1. Multiplication of a vector by a positive scalar increase the magnitude of vector by that amount.
2. A negative scalar changes the direction of the vector.

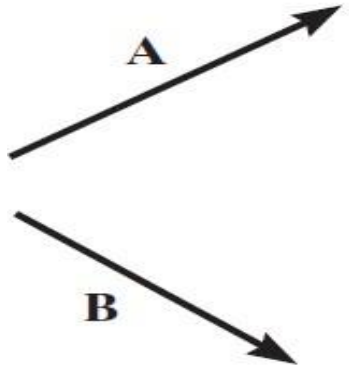


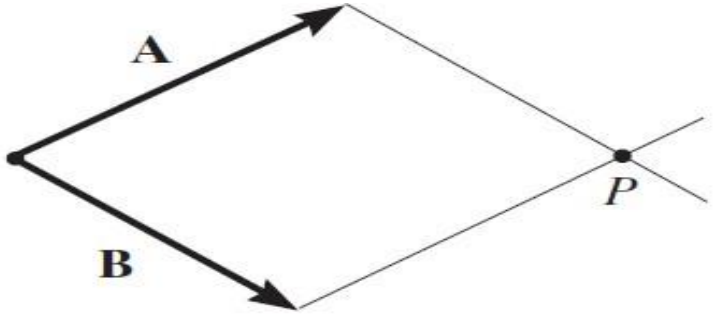
Scalar multiplication and division

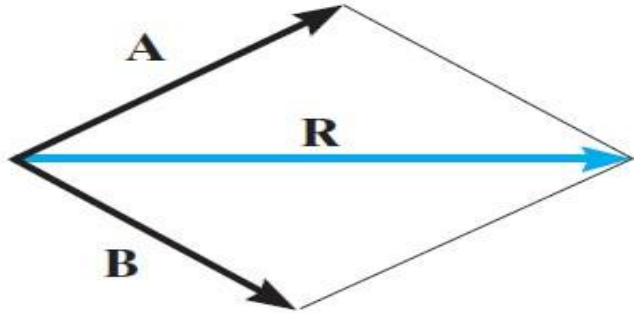
Force Vectors

Vector Addition:

1. Parallelogram Method:
    1. First join the tails of the vectors.
    2. From the head of B draw a line parallel to A. Draw another line from the head of A parallel to B. Both these lines intersect at point P to form the adjacent sides of a parallelogram.
    3. The diagonal of this parallelogram R, represents the resultant of A and B i.e. R = A+B



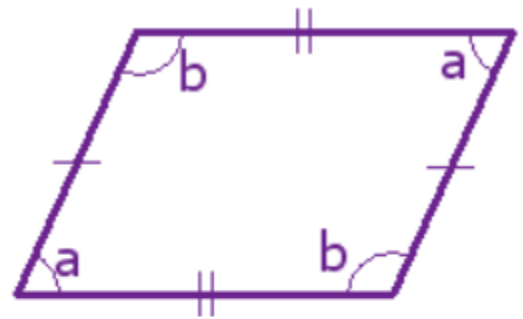




$\mathbf{R} = \mathbf{A} + \mathbf{B}$

Parallelogram law

A Parallelogram is a flat shape with opposite sides parallel and equal in length.



| *and* || *show equal sides*

- Opposite sides are parallel
- Opposite sides are equal in length
- Opposite angles are equal (angles "a" are the same, and angles "b" are the same)
- Angles "a" and "b" add up to 180°, so they are supplementary angles.

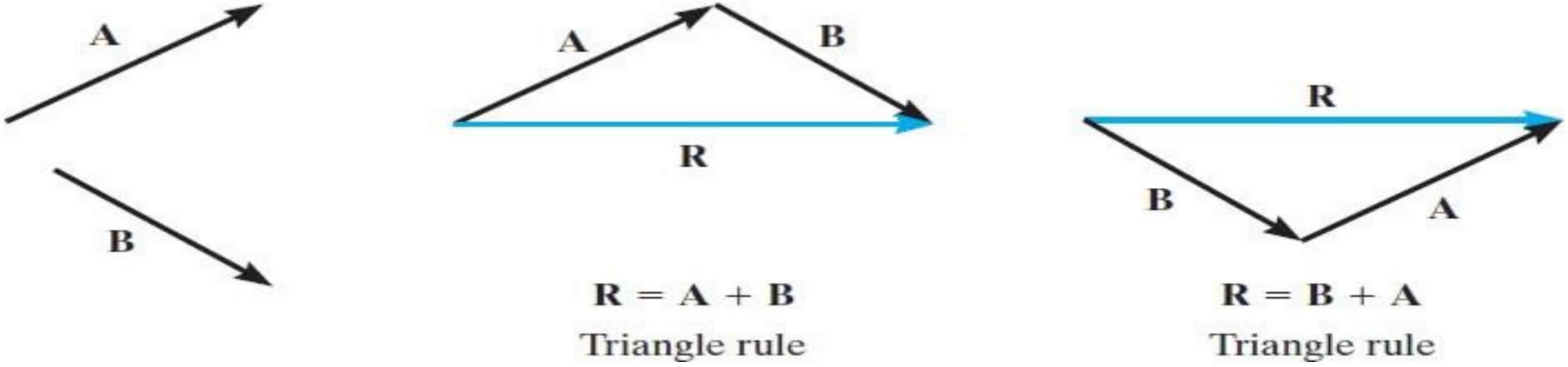
Force Vectors

Vector Addition:

2. Head to Tail Method (Triangle rule):

1. Draw the first vector A.
2. Draw the second vector B, such that the tail of B joins with the head of A.
3. The line joining the tail of first vector A to the head of last vector B forms the resultant vector R.

Vector addition is commutative i.e. R = A + B = B + A



R = A + B
Triangle rule

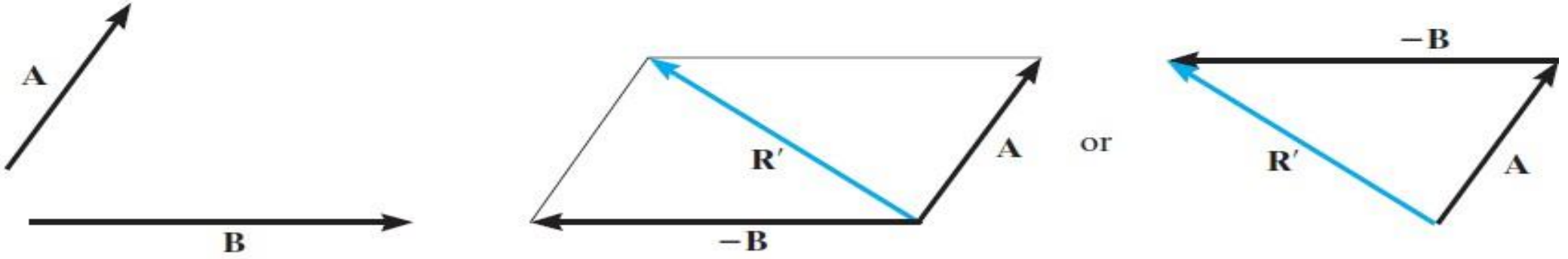
R = B + A
Triangle rule

Force Vectors

Vector Subtraction. The resultant of the *difference* between two vectors **A** and **B** of the same type may be expressed as

$$\mathbf{R}' = \mathbf{A} - \mathbf{B} = \mathbf{A} + (-\mathbf{B})$$

This vector sum is shown graphically in Fig. 2–6. Subtraction is therefore defined as a special case of addition, so the rules of vector addition also apply to vector subtraction.



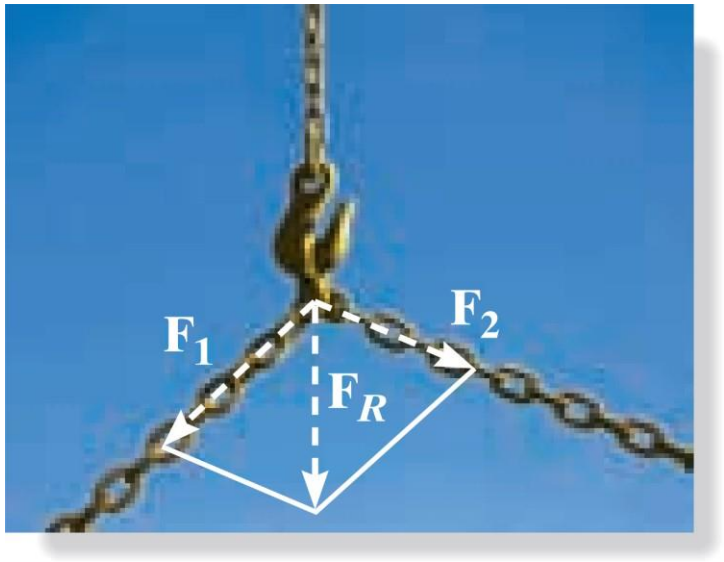
Parallelogram law

Triangle construction

Vector subtraction

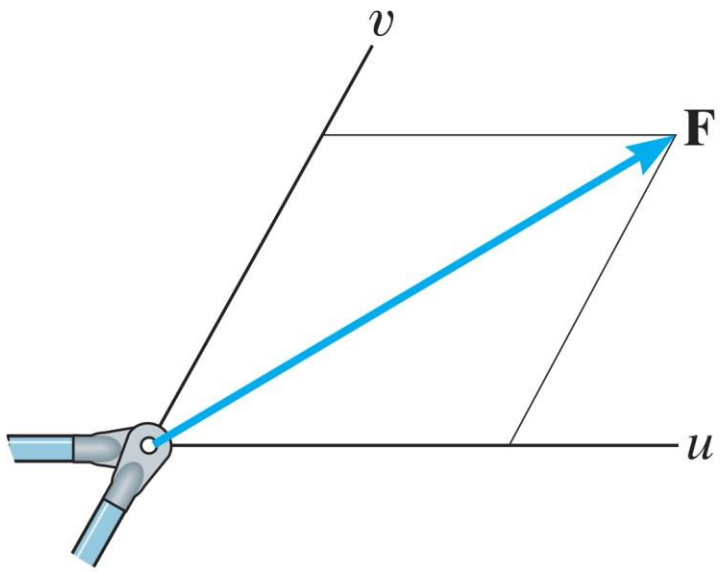
Vector Addition of Forces

Resultant of Force vectors



The parallelogram law must be used to determine the resultant of the two forces acting on the hook. (© Russell C. Hibbeler)

Components of Force Vectors (splitting force vector)



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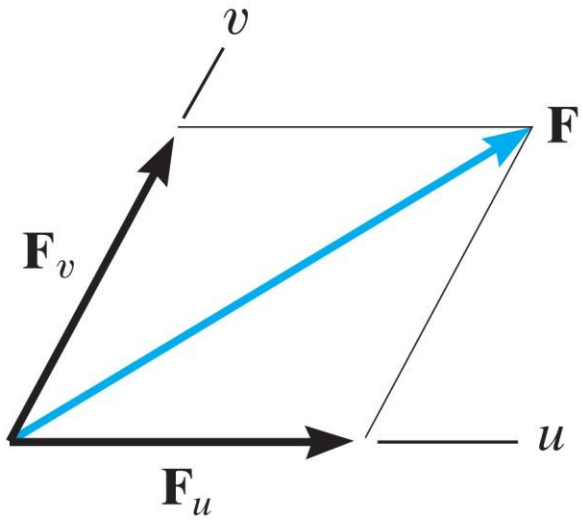
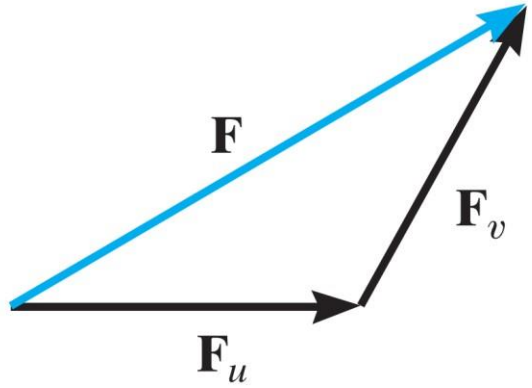
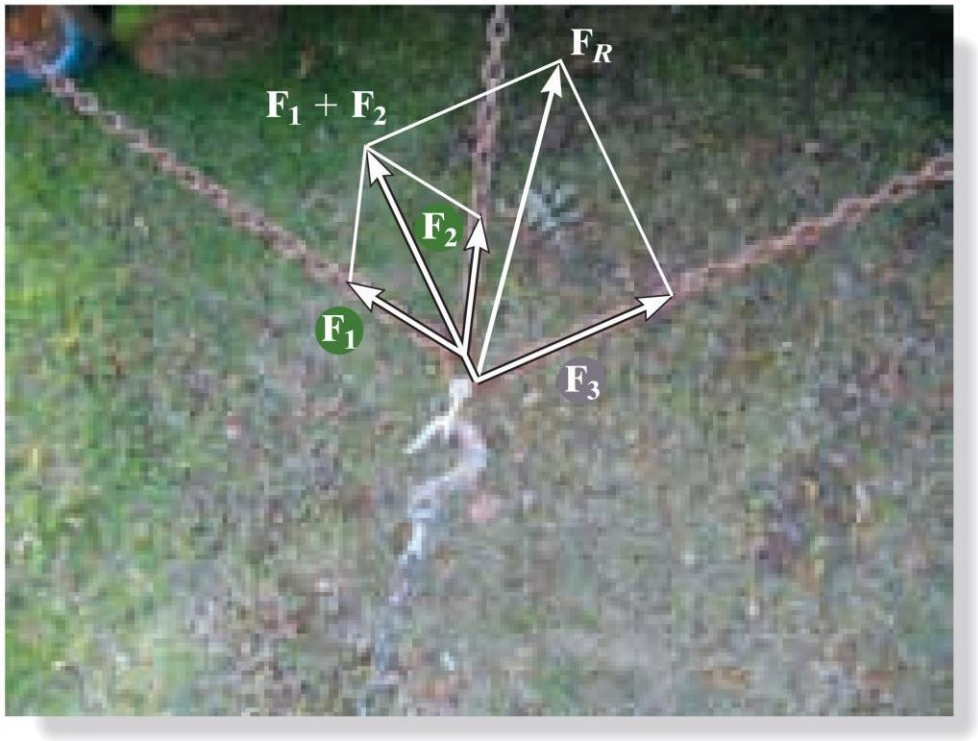


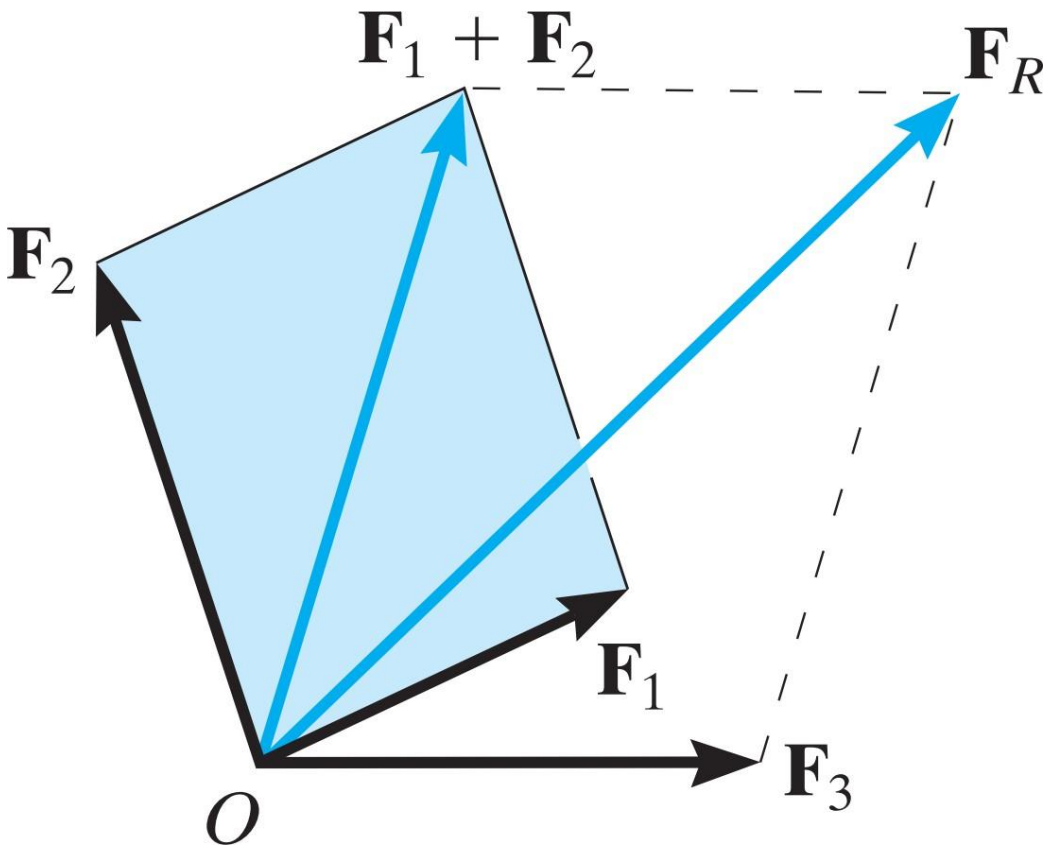
(b)



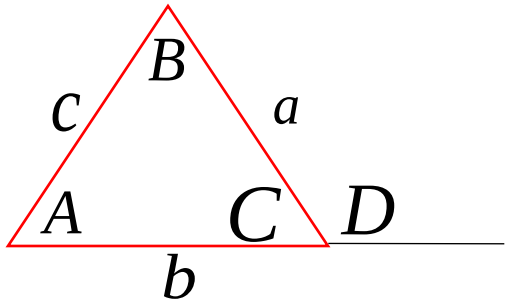
(c)

Addition of Several Forces



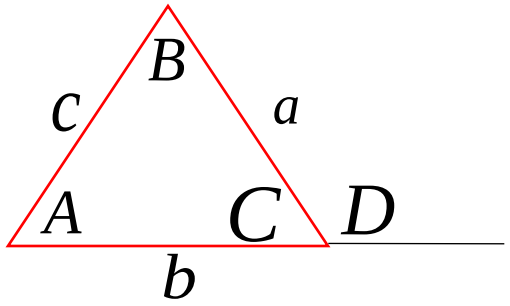


Sine Law



$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

Cosine Law



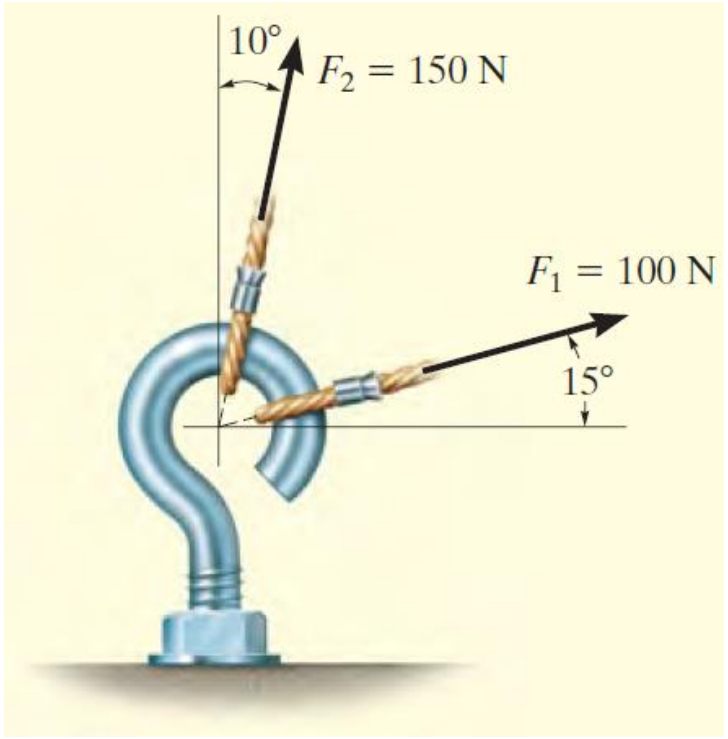
$$c^2 = a^2 + b^2 - 2ab\cos C$$

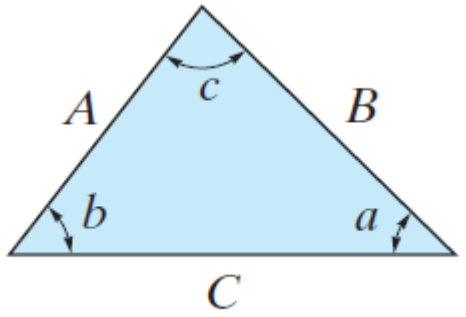
$$c^2 = a^2 + b^2 + 2ab\cos D$$

Lecture 1 – Force Vectors

Learning Exercise 1:

The screw eye in the following figure is subjected to two forces F_1 and F_2. Determine the magnitude and the direction of the resultant force.



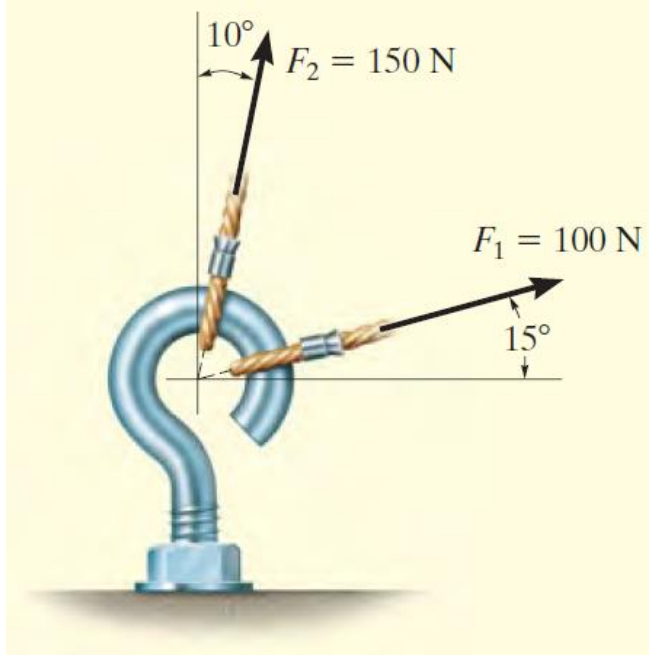


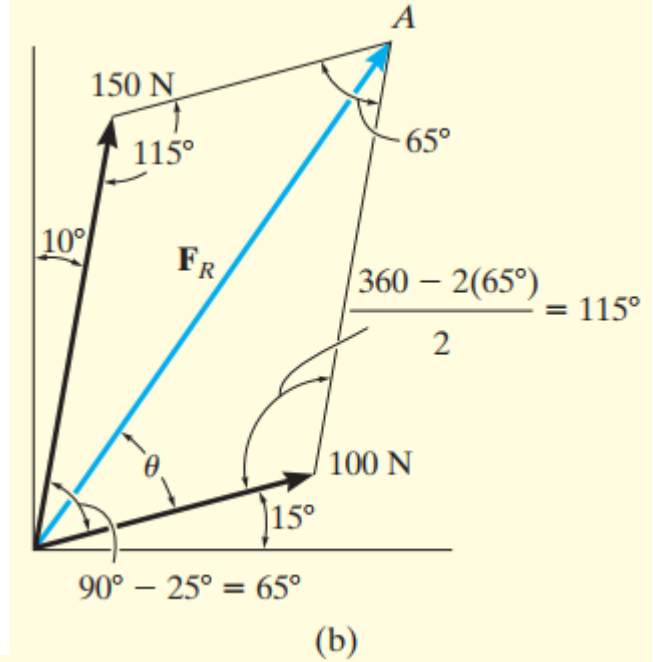
Cosine law:

$$C = \sqrt{A^2 + B^2 - 2AB\cos c}$$

Sine law:

$$\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c}$$





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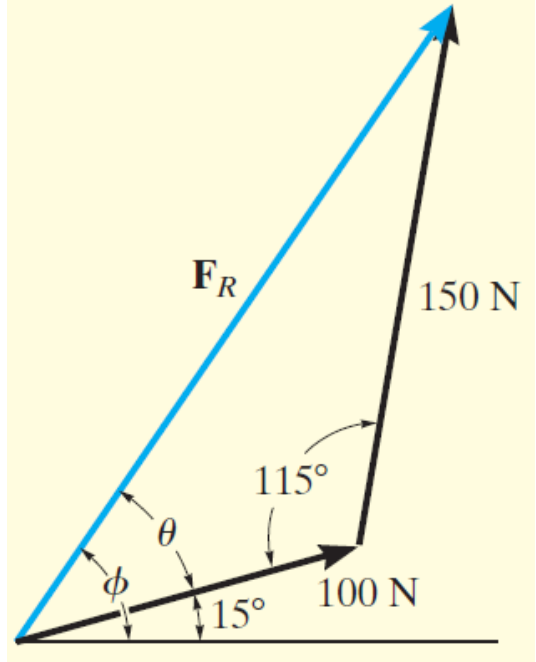


Using the law of cosines

$$F_R = \sqrt{(100\text{ N})^2 + (150\text{ N})^2 - 2(100\text{ N})(150\text{ N})\cos 115°}$$

$$= \sqrt{10\,000 + 22\,500 - 30\,000(-0.4226)} = 212.6\text{ N}$$

$$= 213\text{ N} \qquad \textit{Ans.}$$

Applying the law of sines to determine θ,

$$\frac{150\text{ N}}{\sin\theta} = \frac{212.6\text{ N}}{\sin 115°}$$

$$\sin\theta = \frac{150\text{ N}}{212.6\text{ N}}(\sin 115°)$$

$$\theta = 39.8°$$

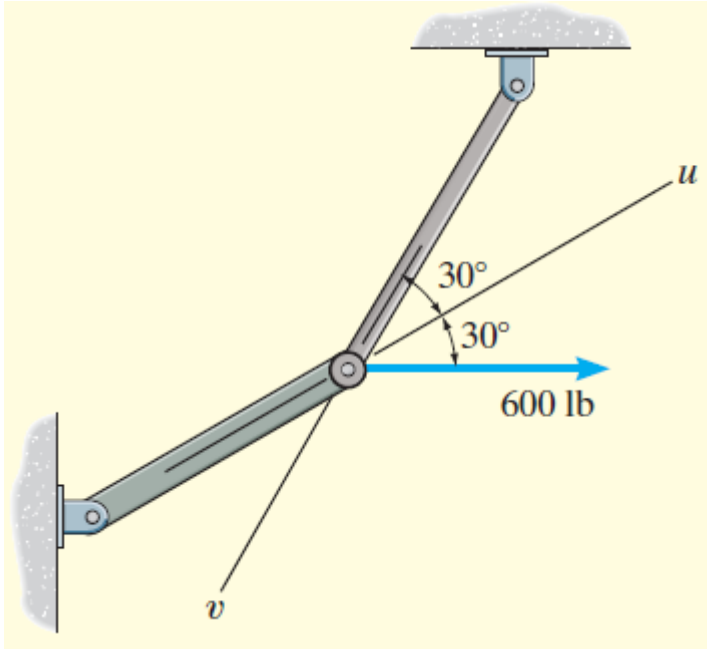
Thus, the direction ϕ (phi) of $\mathbf{F}_R$, measured from the horizontal, is

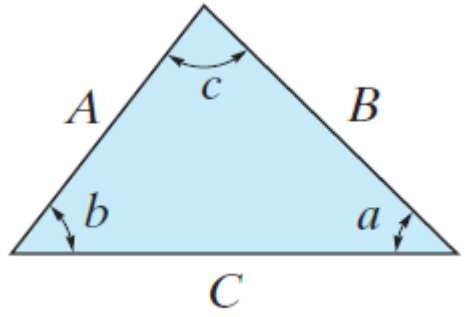
$$\phi = 39.8° + 15.0° = 54.8° \qquad \textit{Ans.}$$

Lecture 1 – Force Vectors

Learning Exercise 2:

Resolve the horizontal 600lb force in the following figure into components along the u and v axes and determine the magnitude of these components.



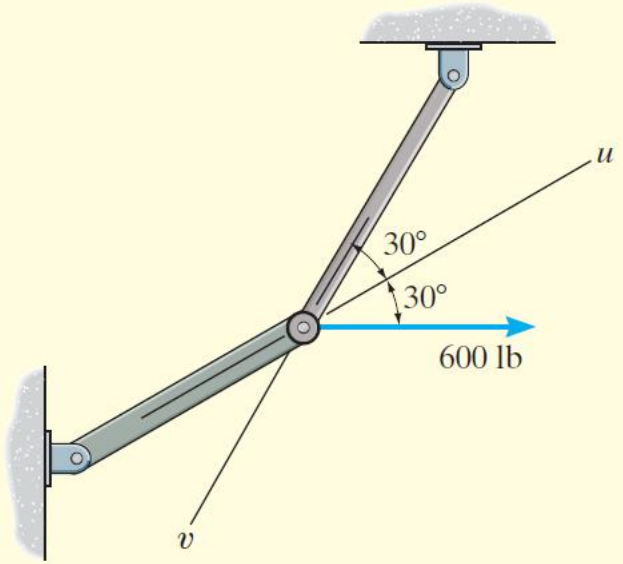


Cosine law:

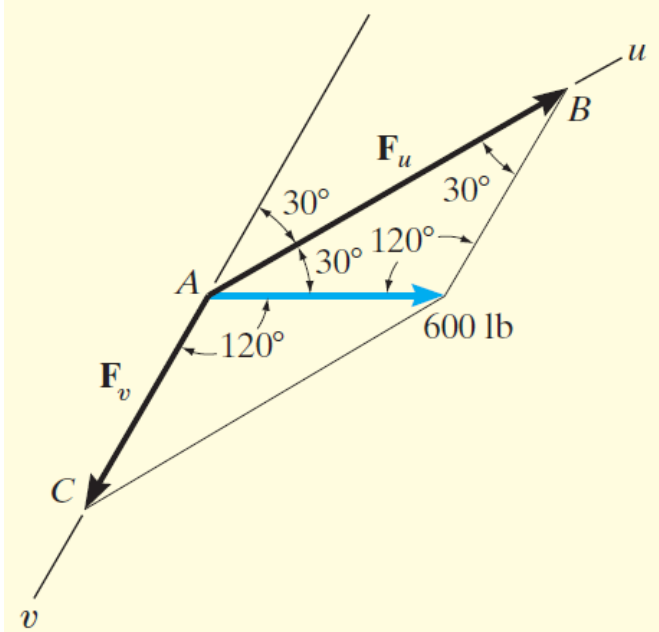
$$C = \sqrt{A^2 + B^2 - 2AB\cos c}$$

Sine law:

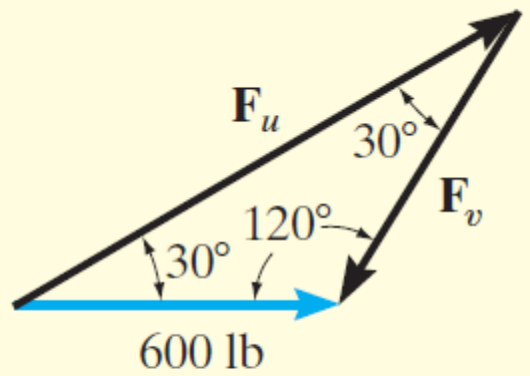
$$\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c}$$



(a)



(b)



(c)

The vector addition using the triangle rule is shown in Fig. 2–12*c*. The two unknowns are the magnitudes of $\mathbf{F}_u$ and $\mathbf{F}_v$. Applying the law of sines,

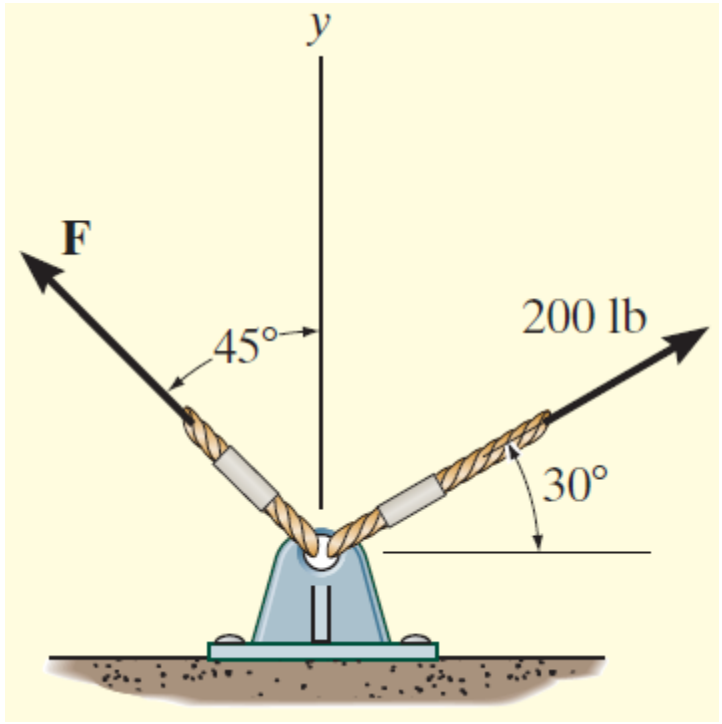
$$\frac{F_u}{\sin 120^\circ} = \frac{600\ \text{lb}}{\sin 30^\circ} \qquad F_u = 1039\ \text{lb} \quad \textit{Ans.}$$

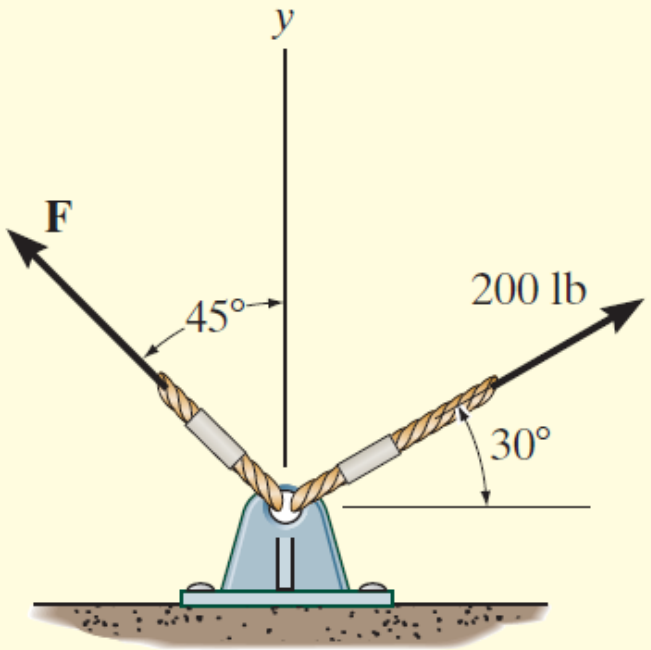
$$\frac{F_v}{\sin 30^\circ} = \frac{600\ \text{lb}}{\sin 30^\circ} \qquad F_v = 600\ \text{lb} \quad \textit{Ans.}$$

Lecture 1 – Force Vectors

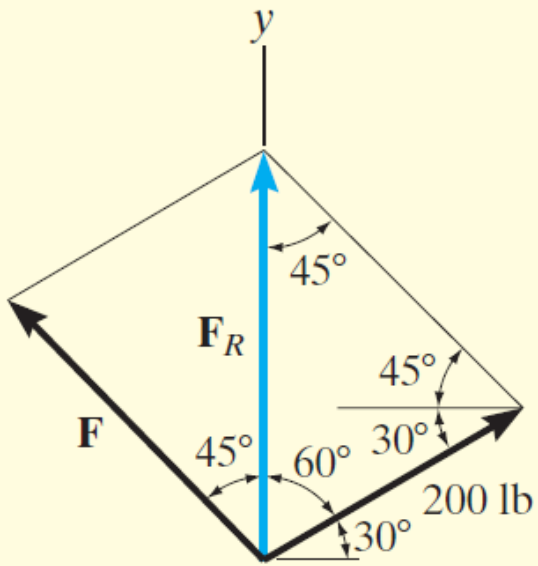
Learning Exercise 3:

Determine the magnitude of the component force F in the following figure and the magnitude of the resultant force F_R if the force F_R is directed along the positive y-axis.

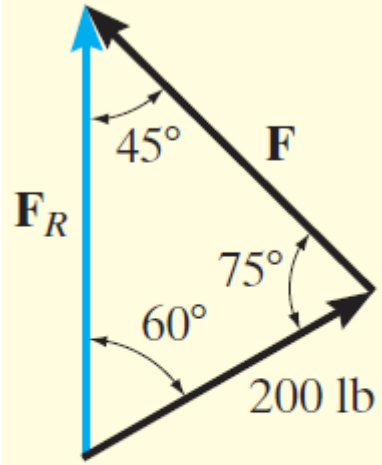




(a)



(b)



(c)

$$\frac{F}{\sin 60^\circ} = \frac{200 \text{ lb}}{\sin 45^\circ}$$

$$F = 245 \text{ lb} \qquad \textit{Ans.}$$

$$\frac{F_R}{\sin 75^\circ} = \frac{200 \text{ lb}}{\sin 45^\circ}$$

$$F_R = 273 \text{ lb} \qquad \textit{Ans.}$$

Home Assignment

- Example 2.4