C. Newton's Laws

First Law

A particle remains at rest or continues to move in a straight line with constant speed if there are no unbalanced forces acting on it.

→ Statics, usually with $v = 0$.

Second Law

The acceleration of a particle is proportional to the vector sum of forces acting on it, and in the direction of this vector sum.

→ Acceleration is a vector

→ Forces are vectors

→ Direction and magnitude

→ Dynamics

Third Law

The forces of action and reaction between interacting bodies are equal in magnitude, opposite in direction and colinear.

D. Newtonian Gravitation

Gravitatial force between two particles

$$\boxed{F = \frac{G m_1 m_2}{r^2}}$$

→ F, mutual force of attraction

→ G, universal gravitational constant

→ m_1, m_2, masses of the two particles

→ r, distance between the centers of the particles

Weight on earth:

$$\boxed{W = \frac{G m m_E}{r^2}}$$

$\underline{m_2 \rightarrow m_E}$

→ W, weight

→ m, mass of object

→ m_E, mass of earth

→ r, separation distance

Acceleration due to gravity: $\underline{W = ma}$

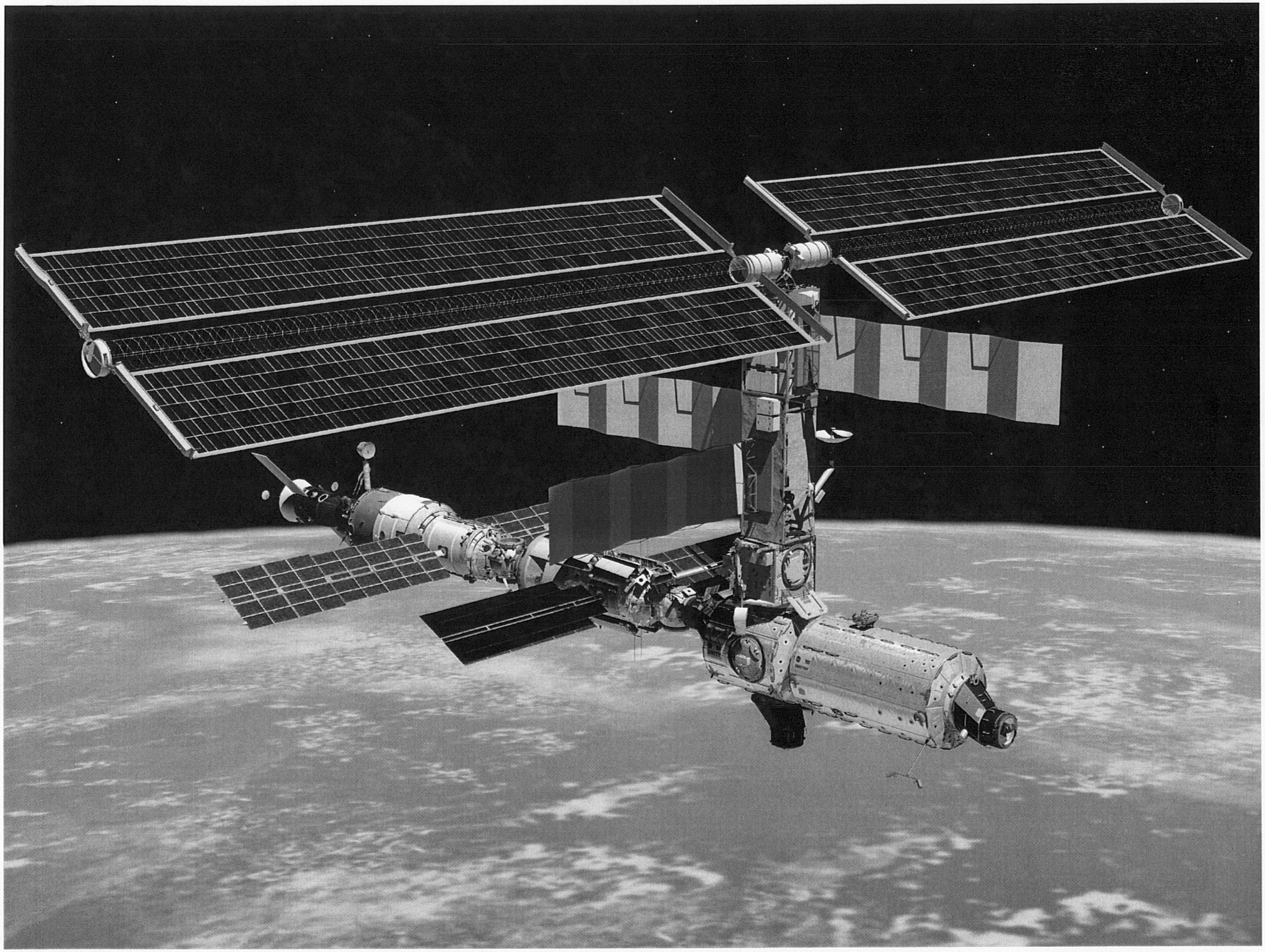
$$\boxed{a = \frac{G m_E}{r^2}}$$

Using that $\underline{a = g \text{ @ } r = R_E}$

Then

$$\boxed{a = g \frac{R_E^2}{r^2}}$$

6.1



6,2

Study Questions

1. Does the weight of an object depend on its location?
2. If you know an object's mass, how do you determine its weight at sea level?

Example 12.3

Determining an Object's Weight

In its final configuration, the International Space Station (Fig. 12.5) will have a mass of approximately 450,000 kg.

(a) What would be the weight of the ISS if it were at sea level?

(b) The orbit of the ISS is 354 km above the surface of the earth. The earth's radius is 6370 km. What is the weight of the ISS (the force exerted on it by gravity) when it is in orbit?

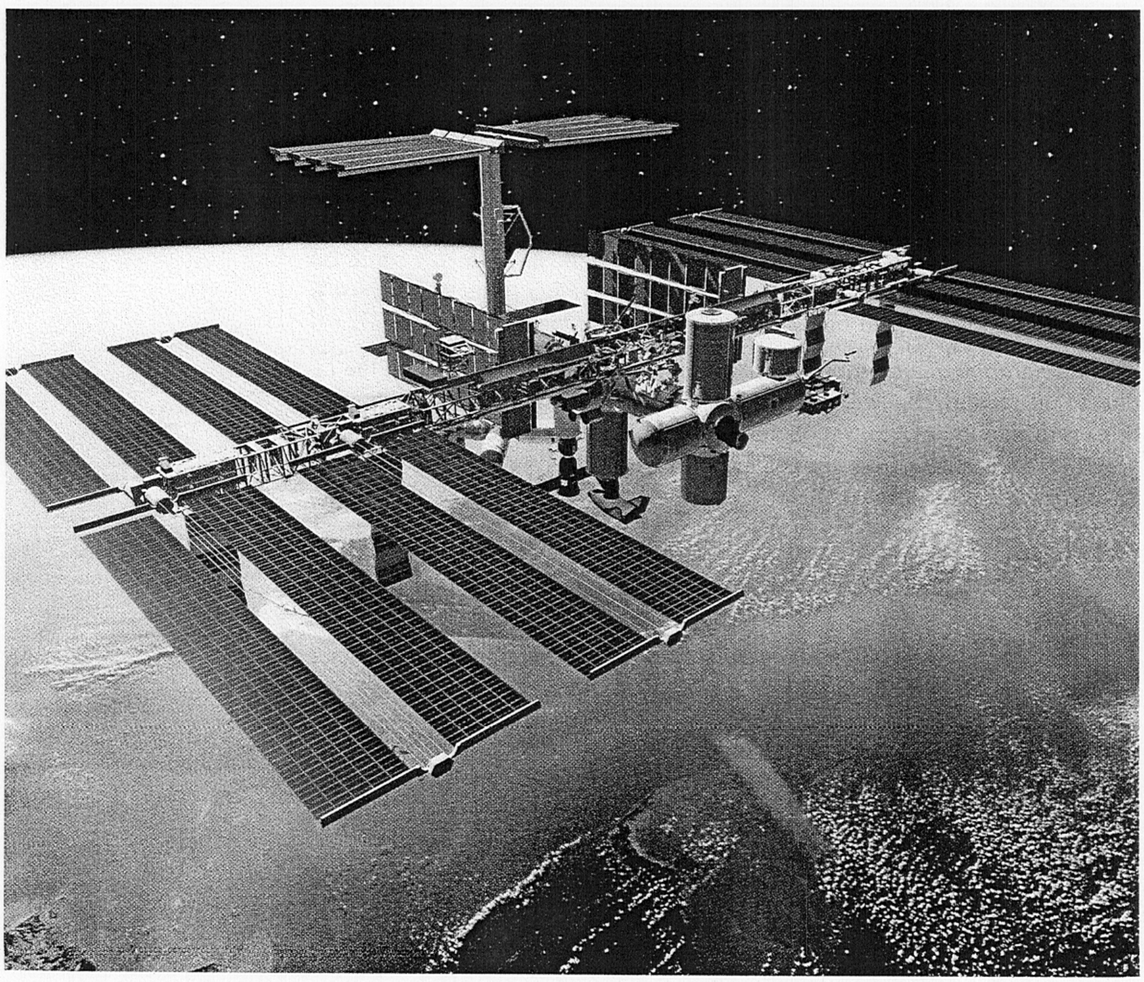


Figure 12.5
International Space Station.

6.3

Strategy

(a) The weight of an object at sea level is given by Eq. (12.6). Because the mass is given in kilograms, we will express g in SI units: $g = 9.81\ \text{m/s}^2$.
(b) The weight of an object at a distance r from the center of the earth is given by Eq. (12.5).

Solution

(a) The weight at sea level is

$$\begin{aligned} W &= mg \\ &= (450{,}000)(9.81) \\ &= 4.41 \times 10^6\ \text{N}. \end{aligned}$$

(b) The weight in orbit is

$$\begin{aligned} W &= mg\frac{R_\text{E}^2}{r^2} \\ &= (450{,}000)(9.81)\frac{(6{,}370{,}000)^2}{(6{,}370{,}000 + 354{,}000)^2} \\ &= 3.96 \times 10^6\ \text{N}. \end{aligned}$$

Discussion

Notice that the force exerted on the ISS by gravity when it is in orbit is approximately 90% of its weight at sea level.

Problems

12.1 Express the fractions $\frac{1}{3}$ and $\frac{2}{3}$ to three significant digits.

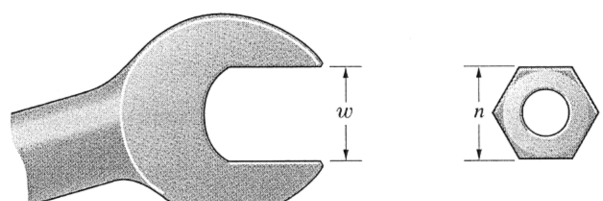
12.2 What is the value of e (the base of natural logarithms) to five significant digits?

12.3 A machinist drills a circular hole in a panel with radius $r = 5$ mm. Determine the circumference C and the area A of the hole to four significant digits.

12.4 The opening in a soccer goal is 24 ft wide and 8 ft high. Use these values to determine its dimensions in meters to three signifi-cant digits.

12.5 The central span of the Golden Gate Bridge is 1280 m long. What is its length in miles to three significant digits?

12.6 Suppose that you have just purchased a Ferrari F355 coupe and you want to know whether you can use your set of SAE (U.S. Customary unit) wrenches to work on it. You have wrenches with widths $w = 1/4$ in., $1/2$ in., $3/4$ in., and 1 in., and the car has nuts with dimensions $n = 5$ mm, 10 mm, 15 mm, 20 mm, and 25 mm. Defining a wrench to fit if w is no more than 2% larger than n, which of your wrenches can you use?



P12.6

12.7 The orbital velocity of the International Space Station is 7690 m/s. Determine its velocity in km/hr and in mi/hr to three significant digits.

12.8 High-speed "bullet trains" began running between Tokyo and Osaka, Japan, in 1964. If a bullet train travels at 240 km/hr, what is its velocity in mi/hr to three significant digits?

$\boxed{\text{2. Vectors}}$

A. History of Vector Notation

B. Scalars and Vectors

Scalar - a quantity having only magnitude, described by a real number

- Temperature, pressure, weight

Vector - a quantity having magnitude and direction

- velocity, force, displacement

Notation

scalar → plain letters, T, P, W

vector → bold letters (text), $\mathbf{V}$

→ over bar/over arrow (written), $\bar{V}$, $\vec{V}$, $\vec{V}$

→ historically, under bar, $\underline{V}$

→ why, typesetting ⇒ bold

Vector magnitude → non-bold letter, v (some texts written)

→ Absolute value, $|\vec{v}|$ (text & written)

→ $v = |\vec{v}|$

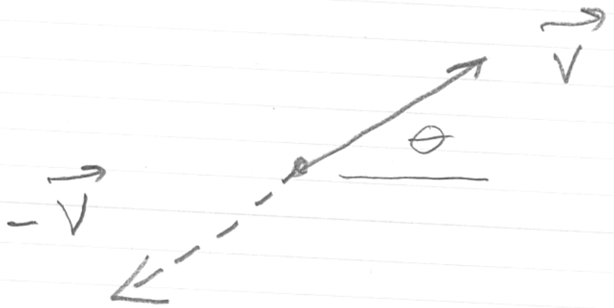
<u>Vector Representation</u>

Line segment with arrowhead

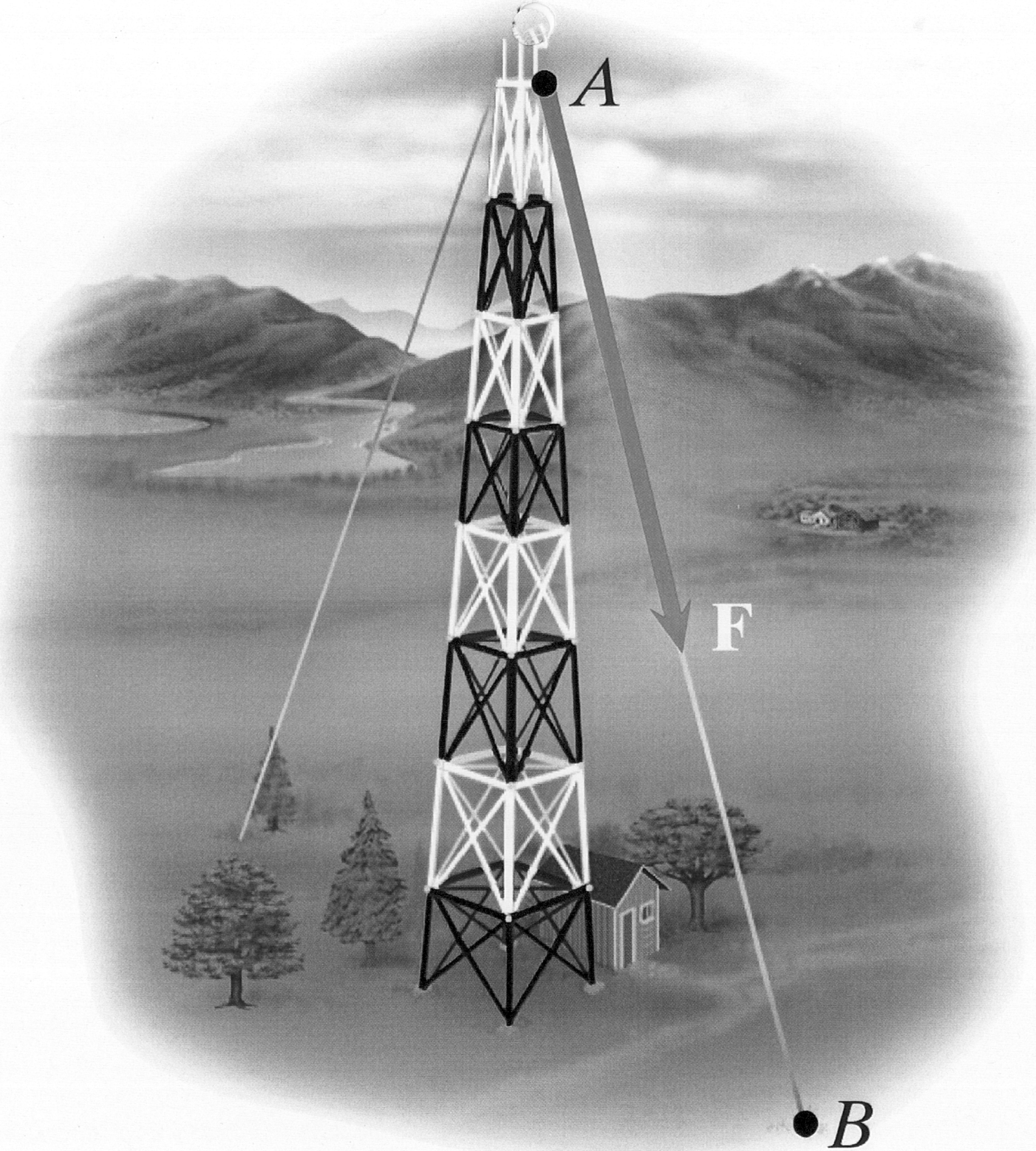
<u>length</u> $\propto$ magnitude

<u>arrowhead</u> indicates sense

Negitive sign "flips" arrow



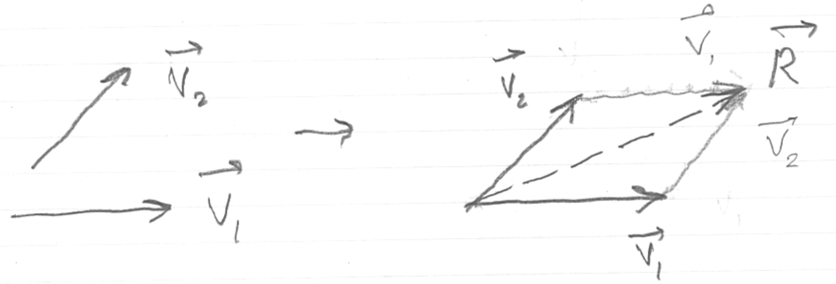
$|\vec{v}| = |-\vec{v}|$


A
F
B

Parallelogram Rule of Vector Addition

All vectors obey the parallelogram rule of combination

$$\vec{R} = \vec{V}_1 + \vec{V}_2$$



* $\vec{R} = \vec{V}_1 + \vec{V}_2 = \vec{V}_2 + \vec{V}_1$ (Commutes)

* $\vec{R}$ is the resultant of the vector (force system)

$\Longrightarrow$ $\vec{R}$ has the same affect as $\vec{V}_1$ and $\vec{V}_2$ combined

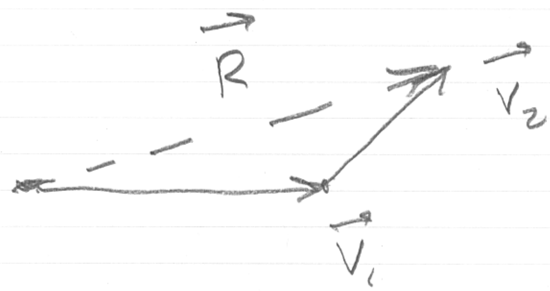
Vector Sum

$$\boxed{\vec{R} = \vec{V}_1 + \vec{V}_2 = \vec{V}_2 + \vec{V}_1 \quad R \neq V_1 + V_2}$$

Triangle Rule of Vector Addition

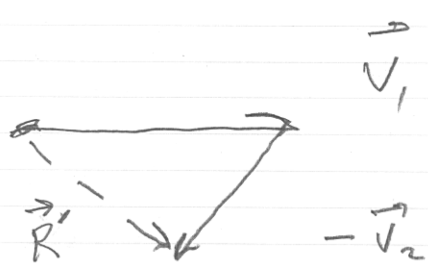
The either the bottom or top of the parallelogram alone

⟶ Head - to Tail



Vector Subtraction

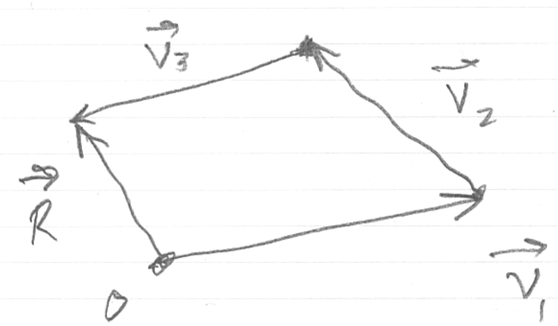
$$\vec{R}' = \vec{V_1} - \vec{V_2} = \vec{V_1} + (-\vec{V_2})$$



Addition/Subtraction of Multiple Vectors

* Head-to-Tail

$$\vec{R} = \vec{V}_1 + \vec{V}_2 + \vec{V}_3$$



From Graphical Representation to Equation

→ In the direction of the vector ⇒ (+)

→ Oppose the direction of vector ⇒ (−)

Using figure above:

Clockwise (CW) from O:

$$\vec{R} - \vec{V}_3 - \vec{V}_2 - \vec{V}_1 = \vec{0}$$

or $$\vec{R} = \vec{V}_1 + \vec{V}_2 + \vec{V}_3$$

Zero Vector: → Include vector sign

→ Very important

→ Whenever a vector triangle closes on itself the sum around the loop is zero

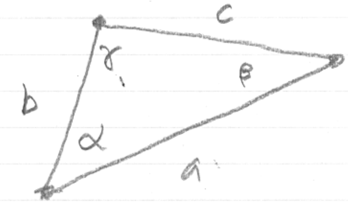
Counter Clockwise (CCW):

$$\vec{V}_1 + \vec{V}_2 + \vec{V}_3 - \vec{R} = \vec{0}$$

$$\underline{\vec{R} = \vec{V}_1 + \vec{V}_2 + \vec{V}_3}$$

Useful Expressions

Law of Sines:



$$\boxed{\cancel{\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma}}}$$

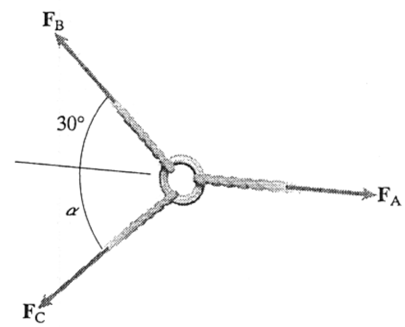
$$\boxed{\frac{a}{\sin\gamma} = \frac{b}{\sin\beta} = \frac{c}{\sin\alpha}}$$

Law of Cosines:

$$\boxed{c^2 = a^2 + b^2 - 2ab\cos\alpha}$$

15

Problem 2.8 The sum of the forces $\mathbf{F}_A + \mathbf{F}_B + \mathbf{F}_C = \mathbf{0}$. The magnitude $|\mathbf{F}_A| = 100$ N and the angle $\alpha = 60°$. Determine $|\mathbf{F}_B|$ and $|\mathbf{F}_C|$.



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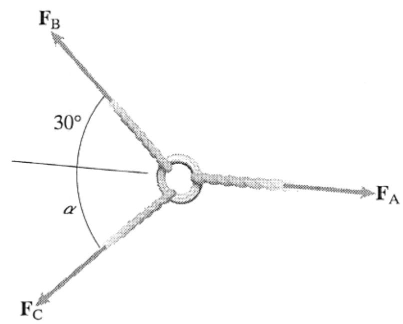
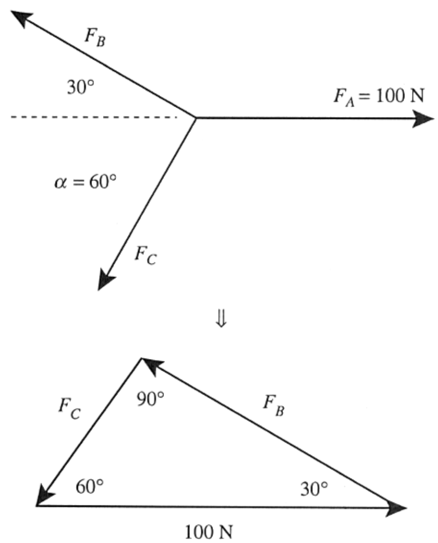
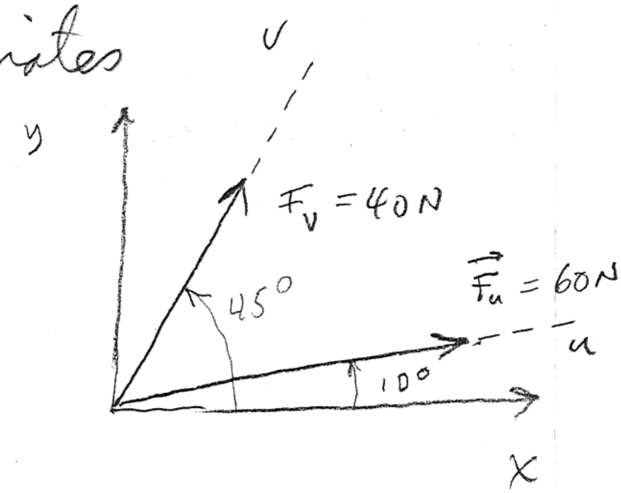


Solution: Using the Law of sines twice we find

$$\boxed{\frac{100\text{ N}}{\sin 90°} = \frac{F_B}{\sin 60°} = \frac{F_C}{\sin 30°} \Rightarrow F_B = 86.6\text{ N}, \quad F_C = 50\text{ N}}$$



Given Forces and coordinates shown

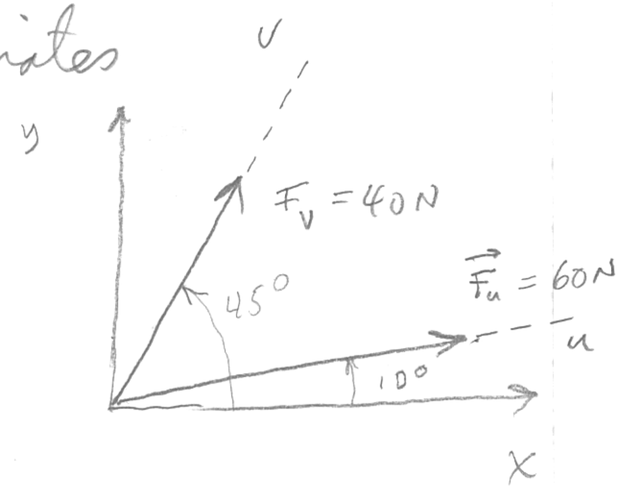


Find The magnitude of the resultant force $|\vec{R}|$

Relationships Law of sines, Law of cosines

Solution

<u>Given</u> Forces and coordinates shown



<u>Find</u> The magnitude of the resultant force $|\vec{R}|$

<u>Relationships</u> Law of sines, Law of cosines

<u>Solution</u>

$$R^2 = F_u^2 + F_v^2 + 2F_uF_v\cos 145$$

$$R = 60^2 + 40^2 + 2(60)(40)\cos 135$$

$$\boxed{R = 73.5\ N}$$

<u>Vector Triangle</u>