Review of Chapters 1-4

- *Chapter 1 – Measurements in Physics*
- *Chapter 2: Motion in One Dimension*
- *Chapter 3: Motion in Two Dimensions*
- *Chapter 4:Force and Newton's Laws*

Chapter 1 – Measurements in Physics

- *In physics we prefer to use the International System of Units -* **SI** *(Système International). There are 7 base units and 22 derived units. So far, we dealt with 3 base units and one derived unit:* **Distance** *measured in meters* **(m)**, **Time** *measured in seconds* **(s)**, **Mass** *measured in kilograms* **(kg)**, **Force** *measured in Newtons* **(N)**, *where*

$$\frac{1\,\mathrm{kg}\cdot\mathrm{m}}{s^2} = 1\,\mathrm{N}.$$

- *There are many non-SI units that are used in science, and they are accepted for use together with SI ones.*

Quantity	Name of unit	Symbol for unit	Value in SI units
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3600 s
	day	d	1 d = 24 h = 86 400 s
plane angle	degree	°	$1° = (\pi/180)$ rad
	minute	′	$1' = (1/60)° = (\pi/10\,800)$ rad
	second	″	$1'' = (1/60)' = (\pi/648\,000)$ rad
area	hectare	ha	$1\ \mathrm{ha} = 1\ \mathrm{hm}^2 = 10^4\ \mathrm{m}^2$
volume	litre	L, l	$1\ \mathrm{L} = 1\ \mathrm{l} = 1\ \mathrm{dm}^3 = 10^3\ \mathrm{cm}^3 = 10^{-3}\ \mathrm{m}^3$
mass	tonne	t	$1\ \mathrm{t} = 10^3\ \mathrm{kg}$

Chapter 1 – Measurements in Physics

- *Exponential (scientific) notation and suffixes. In science this is the preferred way of writing leading or trailing zeros. If we need to express in meters (SI units) the area of a rectangle with the sides 2.5 mm and 4 mm, we calculate:*

$$2.5\cdot 10^{-3}(m)\times 4\cdot 10^{-3}(m)=9\cdot 10^{-6}(m^2)$$

- *Constants sometimes are used multiples of units, or in the scientific notation. For example, the speed of light in vacuum:*

$$c=299\,792\,458\,\frac{\mathrm{m}}{\mathrm{s}},\ \ 299\,792\,\frac{\mathrm{km}}{\mathrm{s}},\ \text{or}\ 3\cdot 10^{8}\,\frac{\mathrm{m}}{\mathrm{s}}$$

Factor	Name	Symbol	Factor	Name	Symbol
10^{1}	deca	da	10^{-1}	deci	d
10^{2}	hecto	h	10^{-2}	centi	c
10^{3}	kilo	k	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{9}	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a
10^{21}	zetta	Z	10^{-21}	zepto	z
10^{24}	yotta	Y	10^{-24}	yocto	y

Chapter 1 – Measurements in Physics
Units and conversions: distance, time, and mass

- There are many non-SI units that are used in science, and they are accepted for use together with SI ones.
- Pay attention when converting them and using their values in calculations!
- The most common ones that will be used in this course are:

Quantity	Name of unit	Symbol for unit	Value in SI units
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3600 s
	day	d	1 d = 24 h = 86 400 s
plane angle	degree	°	$1° = (\pi/180)$ rad
	minute	′	$1' = (1/60)° = (\pi/10\,800)$ rad
	second	″	$1'' = (1/60)' = (\pi/648\,000)$ rad
area	hectare	ha	$1 \text{ ha} = 1 \text{ hm}^2 = 10^4 \text{ m}^2$
volume	litre	L, l	$1 \text{ L} = 1 \text{ l} = 1 \text{ dm}^3 = 10^3 \text{ cm}^3 = 10^{-3} \text{ m}^3$
mass	tonne	t	$1 \text{ t} = 10^3 \text{ kg}$

Unit Conversions for Physical Quantities

$1 \text{ mi} = 1\,609 \text{ m} = 1.609 \text{ km}$ $\quad$ $1 \text{ ft} = 0.304\,8 \text{ m} = 30.48 \text{ cm}$

$1 \text{ m} = 39.37 \text{ in.} = 3.281 \text{ ft}$ $\quad$ $1 \text{ in.} = 0.025\,4 \text{ m} = 2.54 \text{ cm}$

Convert 15.0 in. to centimeters.

$$1 \text{ in.} = 2.54 \text{ cm} \rightarrow \frac{2.54 \text{ cm}}{1 \text{ in.}}$$

$$15.0 \text{ in.} \times \left(\frac{2.54 \text{ cm}}{1 \text{ in.}} \right) = 38.1 \text{ cm}$$

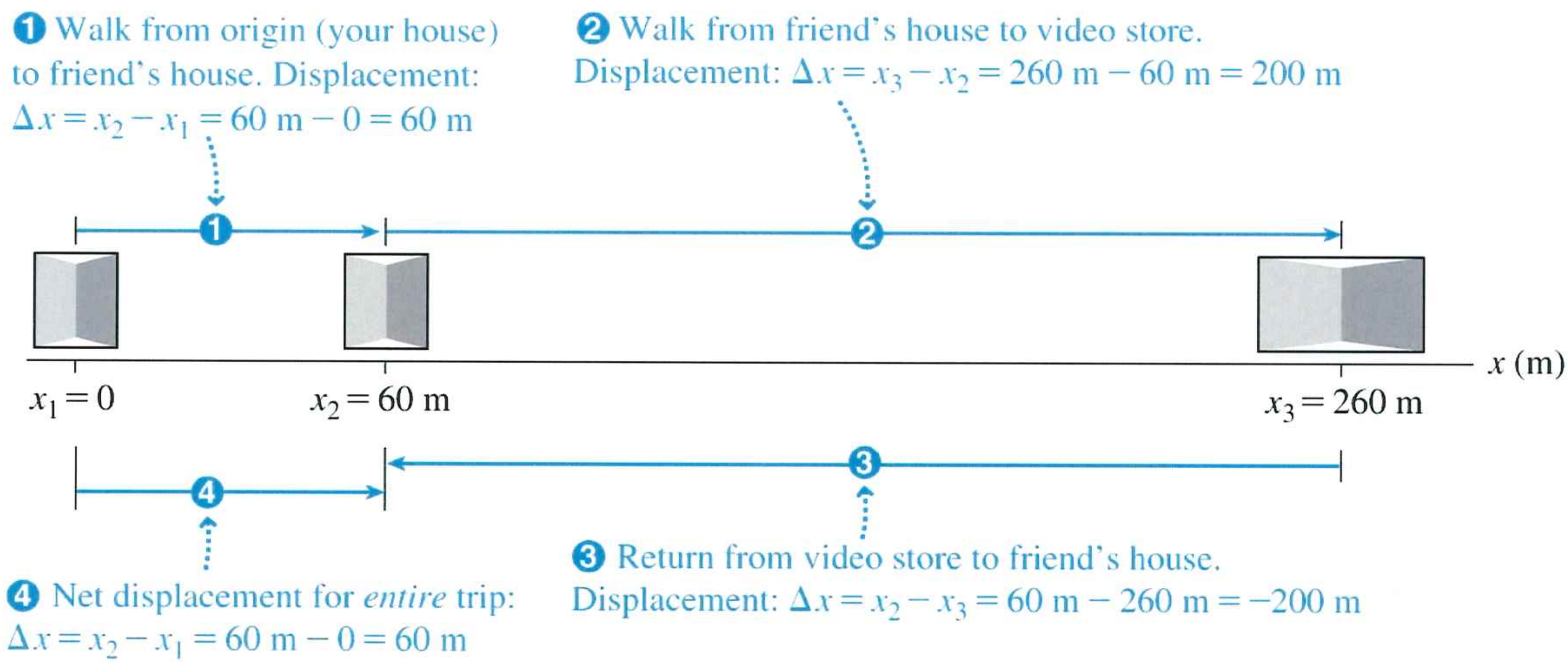
What is (0.888/0.66) to the proper number of significant figures?

Answer = 1.3~~4545~~

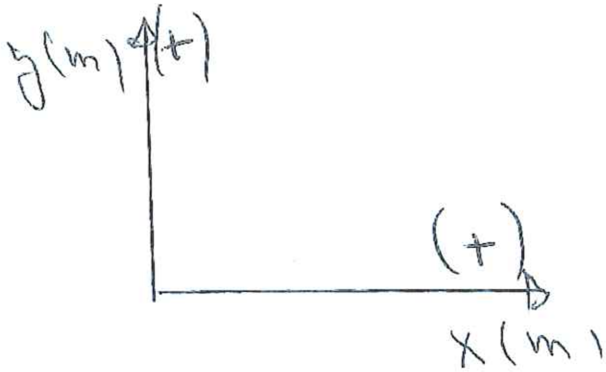
Chapter 2: Motion in One Dimension

- *Displacement = change in position ≠ distance*
  - *In 1-D, moving from x_1 to x_2 produces the displacement:*

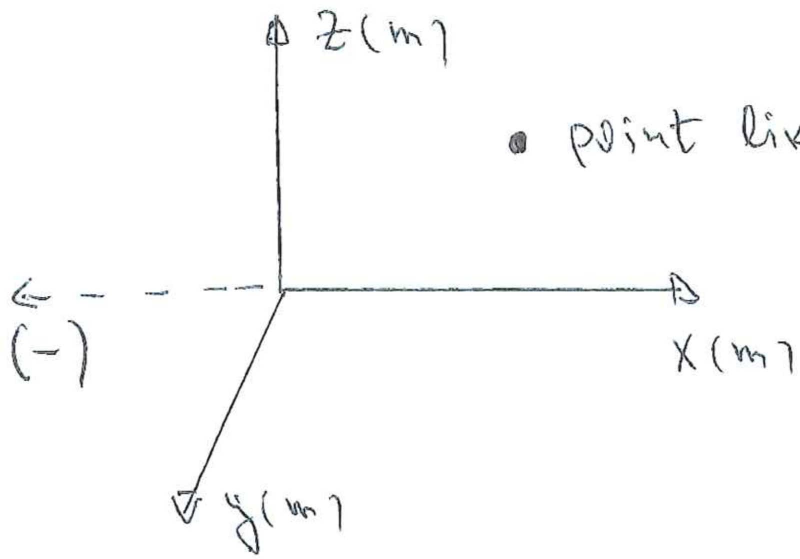
$$\Delta x = x_2 - x_1, \text{ or } x_{\text{final}} - x_{\text{initial}}$$



Reference Frames

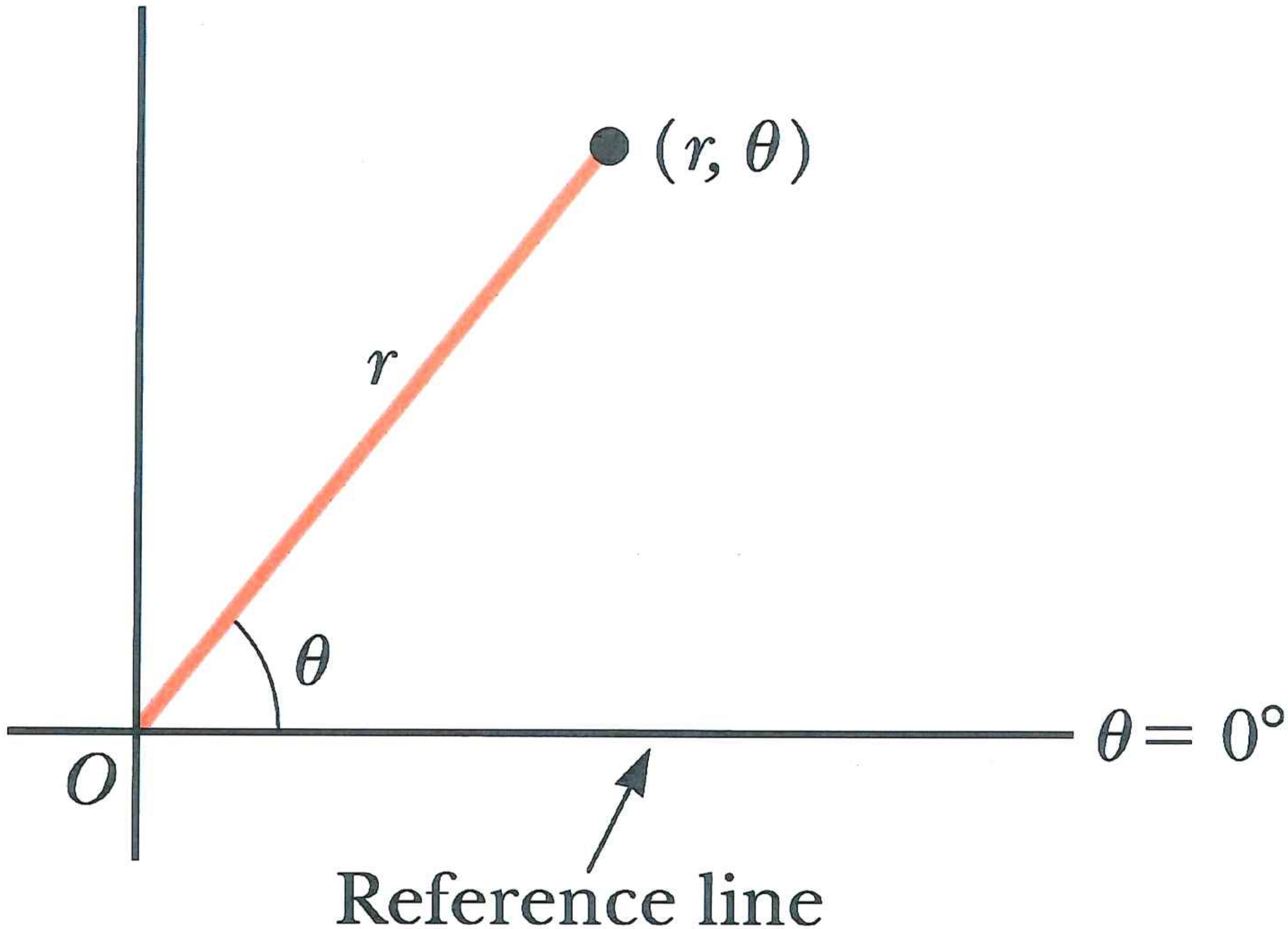


2D

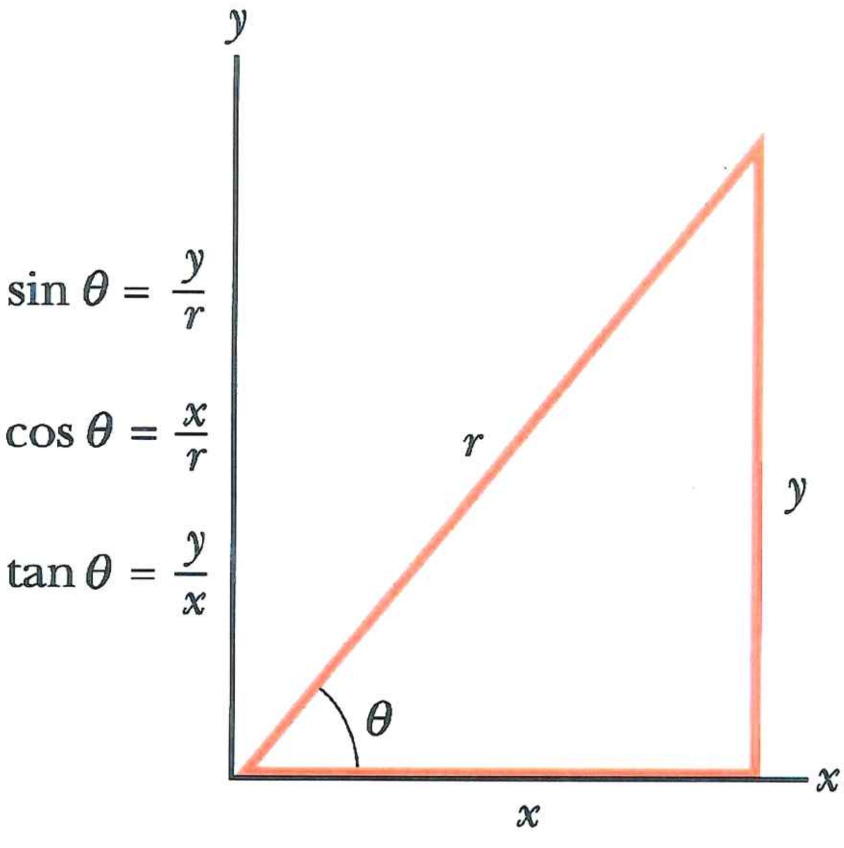


• point like objects

Coordinate Systems



Trigonometry Review



$$\sin\theta = \frac{\text{side opposite } \theta}{\text{hypotenuse}} = \frac{y}{r}$$

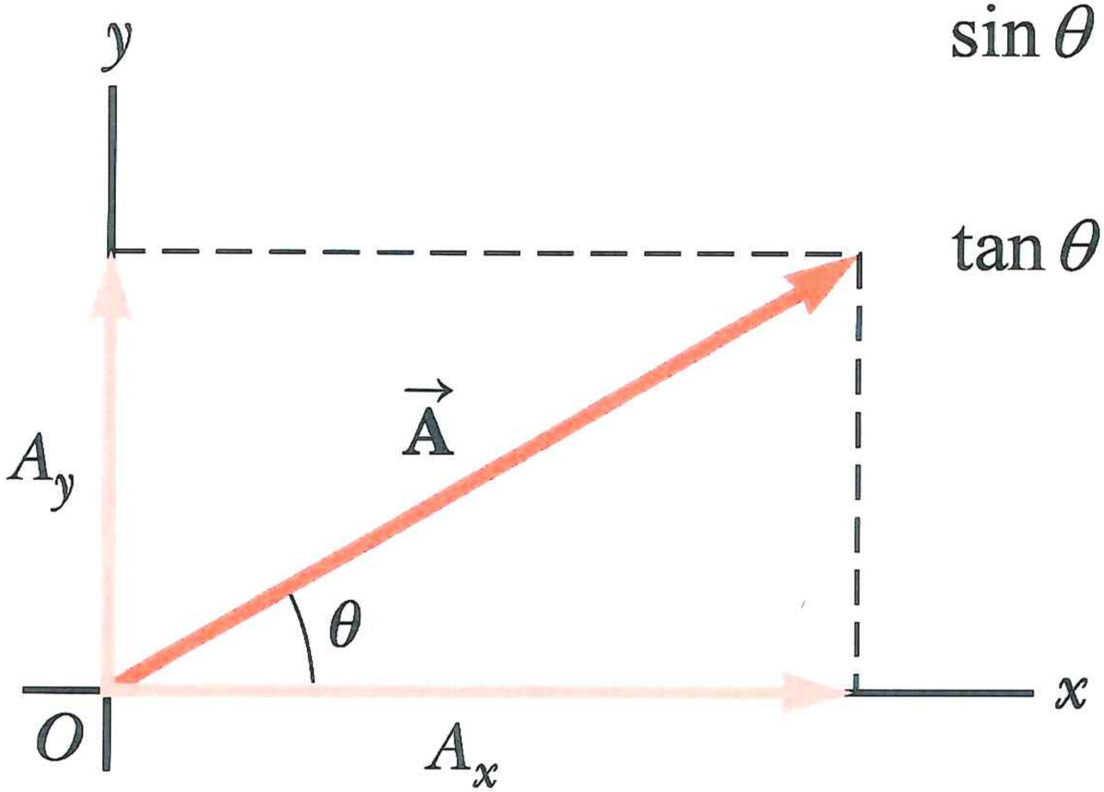
$$\cos\theta = \frac{\text{side adjacent } \theta}{\text{hypotenuse}} = \frac{x}{r}$$

$$\tan\theta = \frac{\text{side opposite } \theta}{\text{side adjacent } \theta} = \frac{y}{x}$$

Pythagorean theorem:

$$x^2 + y^2 = r^2$$

Components of a Vector



$$\cos\theta = \frac{A_x}{A} \rightarrow A\cos\theta = A_x$$

$$\sin\theta = \frac{A_y}{A} \rightarrow A\sin\theta = A_y$$

$$\tan\theta = \frac{A_y}{A_x}$$

$$A_x^{\ 2} + A_y^{\ 2} = A^2$$

$$\rightarrow A = \sqrt{A_x^{\ 2} + A_y^{\ 2}}$$

Chapter 2: Motion in One Dimension

- *Average velocity = ratio of displacement and time:*

$$\bar{v}_x = \frac{\Delta x}{\Delta t} \text{, in SI units is } \frac{m}{s}$$

Displacement

Because velocity is related to displacement, it can be positive, negative, or zero, according to the sign of Δx and Δt can only be positive.
The final time can not be smaller than the initial time.

- *The average speed = ratio of distance and time:*

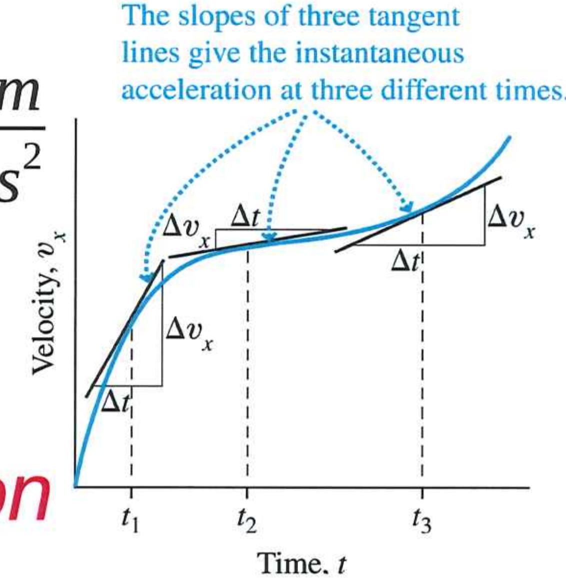
$$\bar{v} = \frac{\text{distance}}{\Delta t} \text{, in SI units is } \frac{m}{s}$$

Chapter 2: Motion in One Dimension

- *Acceleration = a measure for the change in velocity*

Average acceleration: $\bar{a}_x = \frac{\Delta v_x}{\Delta t}$, in SI $\frac{\frac{m}{s}}{s} = \frac{m}{s^2}$

Instant acceleration: $a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t}$



$v_x = v_{x0} + a_x t$ *The first kinematic equation*

$x = v_{x0} t + \frac{1}{2} a_x t^2$ *The second kinematic equation*

$v_x^2 = 2x \cdot a_x + v_{x0}^2$ *The third kinematic equation*

$x = \frac{1}{2}(v_x + v_{x0}) t$ *The extra kinematic equation*

Freely Falling Objects

free-fall acceleration:

$$g = 9.80 \text{ m/s}^2$$

kinematics equations:

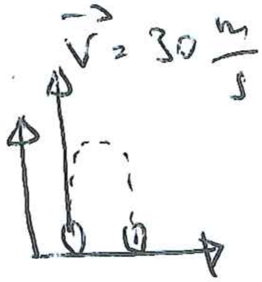
$$v_y = v_{0y} - gt$$

$$\Delta y = v_{0y}t - \frac{1}{2}gt^2$$

$$v_y^{\,2} = v_{0y}^{\,2} - 2g\Delta y$$

A freely falling object is any object moving freely under the influence of gravity alone.

A ball is thrown straight upward with a velocity of 30 m/s. How much time passes before the ball strikes the ground?



$$Y = Y_0 + V_{0y}*t - (1/2)*g*t^2$$

$$0 = Y - Y_0 = V_{0y}*t - (1/2)*g*t^2$$

$$V_{0y}*t = (1/2)*g*t^2$$

$$V_{0y} = (1/2)*g*t$$

$$\boxed{(V_{0y}*2)/g = t}$$

$$(30*2)/9.82 = t$$

$$6.1 \text{ sec} = t$$

Time for $y = y_{max}$

$$t_{y=y_{max}} = \frac{t_{\text{strikes ground}}}{2} = \frac{V_{0y}}{g} = 3.05\,s$$

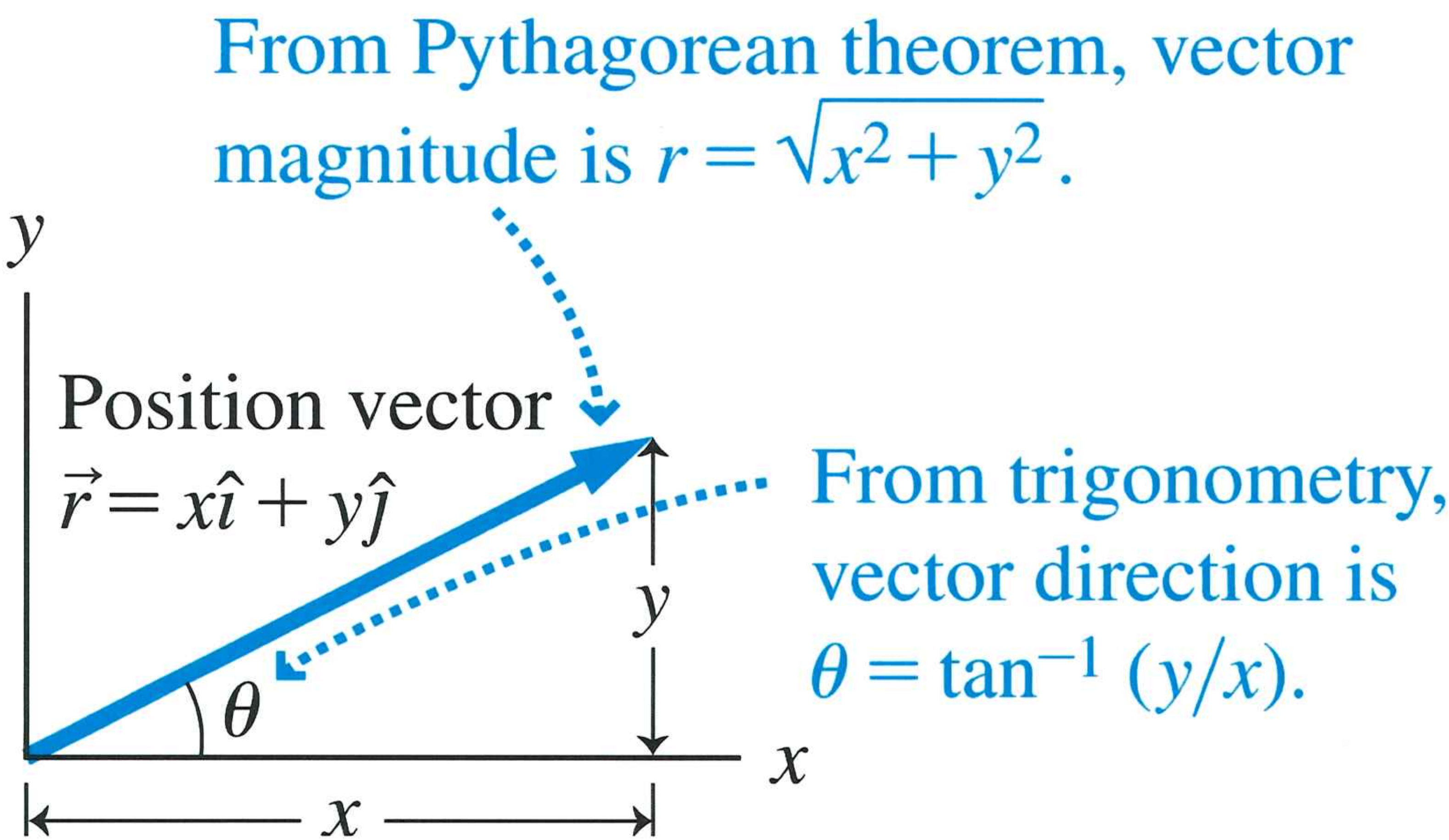
Chapter 3: Motion in Two Dimensions Scalars and Vectors

- *A scalar is a quantity that can be described entirely using a single number. Examples include time (3 hours), volume (123 m^3), mass (3.6 kg), temperature (97 °C), etc.*

- *A vector is a quantity that requires at least two numbers to be described correctly. For example, the GPS position of your travel destination (43.6079113,-84.7117426), a chess piece on a chess board (D8), a pixel on a display (1156, 341), etc.*

Chapter 3: Motion in Two Dimensions
Vector Magnitude and Direction

The vector magnitude is the length of the vector.
The vector direction is given by the direction angle θ.



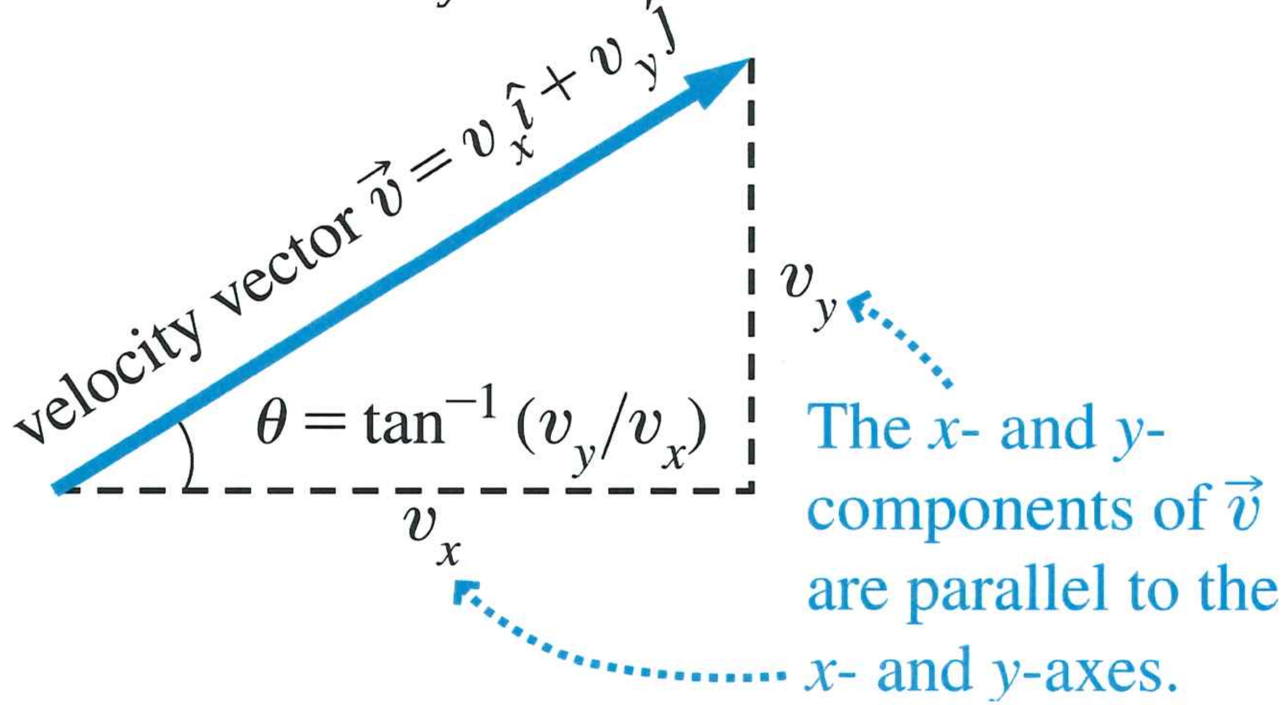
Chapter 3: Motion in Two Dimensions

$$\vec{v} = v_x \hat{i} + v_y \hat{j}$$

The magnitude: $v = \sqrt{v_x^{\,2} + v_y^{\,2}}$, and this can be called Speed

The direction : $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right)$

The components: $v_x = v\cos\theta$, $v_y = v\sin\theta$



$$\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$$
$$\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$$

Vector sum

$$\vec{r}_1 + \vec{r}_2 = (x_1 + x_2)\hat{i} + (y_1 + y_2)\hat{j}$$

Vector difference

$$\vec{r}_1 - \vec{r}_2 = (x_1 - x_2)\hat{i} + (y_1 - y_2)\hat{j}$$

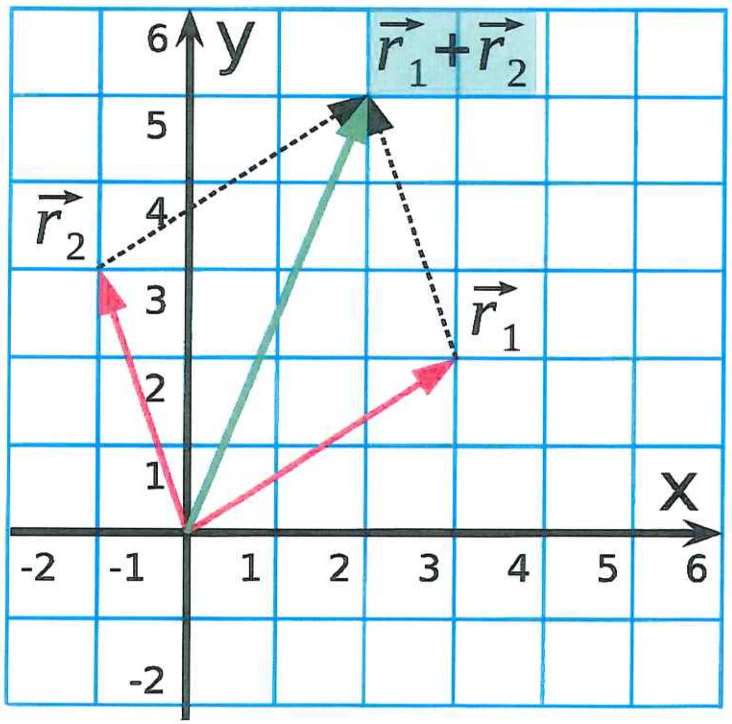
Chapter 3: Motion in Two Dimensions Vector Addition and Subtraction

We simply compute the operation on each component.

$$\vec{r}_1 = x_1 \hat{i} + y_1 \hat{j} \text{ , and } \vec{r}_2 = x_2 \hat{i} + y_2 \hat{j}$$

$$\vec{r}_1 + \vec{r}_2 = (x_1 + x_2)\hat{i} + (y_1 + y_2)\hat{j}$$

$$\vec{r}_1 - \vec{r}_2 = (x_1 - x_2)\hat{i} + (y_1 - y_2)\hat{j}$$

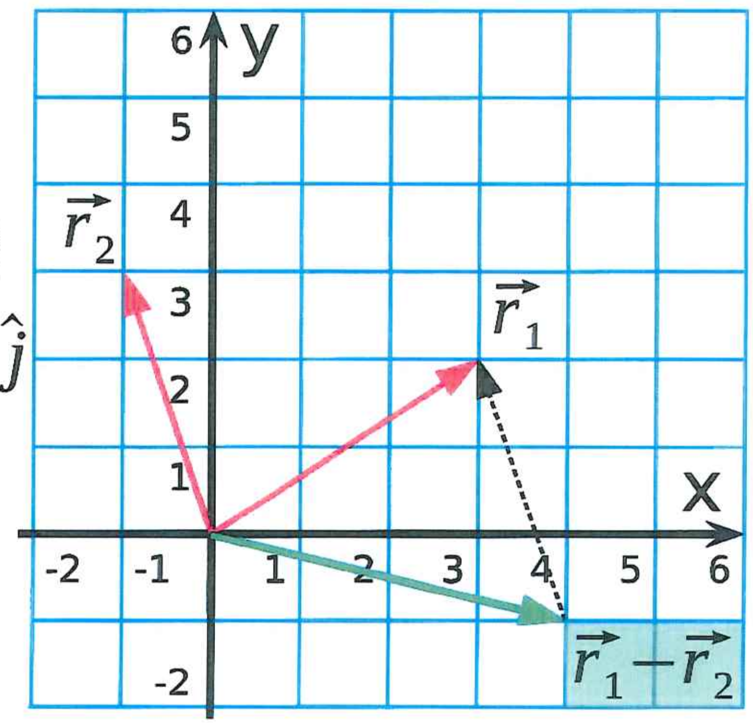


$$\vec{r}_1 = 3\hat{i} + 2\hat{j}$$

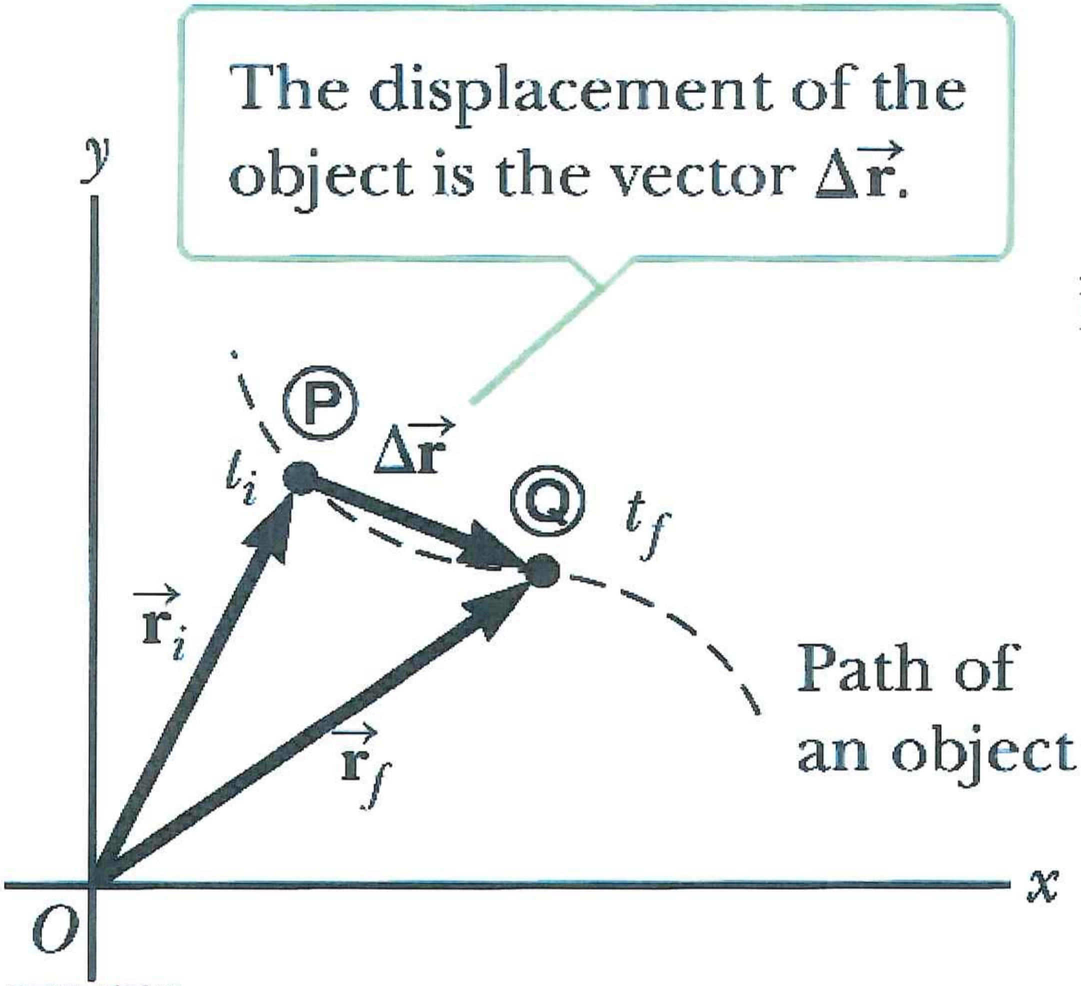
$$\vec{r}_2 = -1\hat{i} + 3\hat{j}$$

$$\vec{r}_1 + \vec{r}_2 = 2\hat{i} + 5\hat{j}$$

$$\vec{r}_1 - \vec{r}_2 = 4\hat{i} - 1\hat{j}$$



Displacement in Two Dimensions



$$\vec{\mathbf{r}}_f = \vec{\mathbf{r}}_i + \Delta\vec{\mathbf{r}}$$

$$\vec{\mathbf{r}} \equiv \vec{\mathbf{r}}_f - \vec{\mathbf{r}}_i \quad \text{SI unit: m}$$

Velocity in Two Dimensions

$$\vec{\mathbf{v}}_{\text{av}} \equiv \frac{\Delta \vec{\mathbf{r}}}{\Delta t} \quad \text{SI unit: m/s}$$

$$v_{\text{av},\, x} = \frac{\Delta x}{\Delta t} \text{ and } v_{\text{av, y}} = \frac{\Delta y}{\Delta t}$$

$$\vec{\mathbf{v}} \equiv \lim_{\Delta t \to 0} \frac{\Delta \vec{\mathbf{r}}}{\Delta t}$$

Velocity in Two Dimensions

$$\vec{\mathbf{a}}_{\text{av}} \equiv \frac{\Delta \vec{\mathbf{v}}}{\Delta t} \quad \text{SI unit: m/s}^2$$

$$a_{\text{av},\,x} = \frac{\Delta v_x}{\Delta t} \text{ and } a_{\text{av},\,y} = \frac{\Delta v_x}{\Delta t}$$

$$\vec{\mathbf{a}} \equiv \lim_{\Delta t \to 0} \frac{\Delta \vec{\mathbf{v}}}{\Delta t}$$

6. A rabbit is moving in the positive x-direction at 2.00 m/s when it spots a predator and accelerates to a velocity of 12.0 m/s along the negative y-axis, all in 1.50 s. Determine

   a. the x-component and

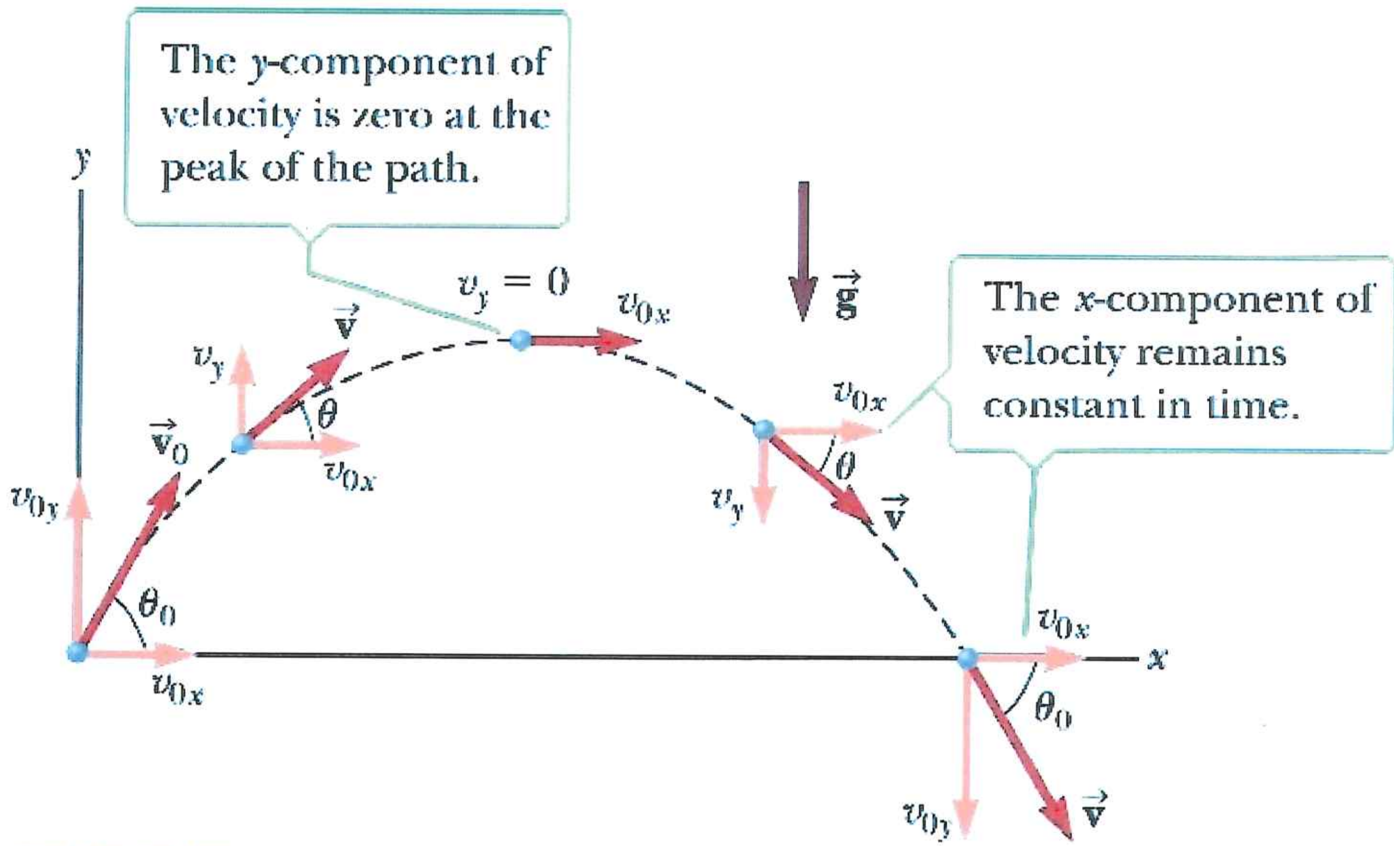
   b. the y-component of the rabbit's acceleration.

3.6 The rabbit's average acceleration has components:

(a) $$a_{av,x} = \frac{v_{x,f} - v_{x,i}}{\Delta t} = \frac{0 - 2.00 \text{ m/s}}{1.50 \text{ s}} = \boxed{-1.33 \text{ m/s}^2}$$

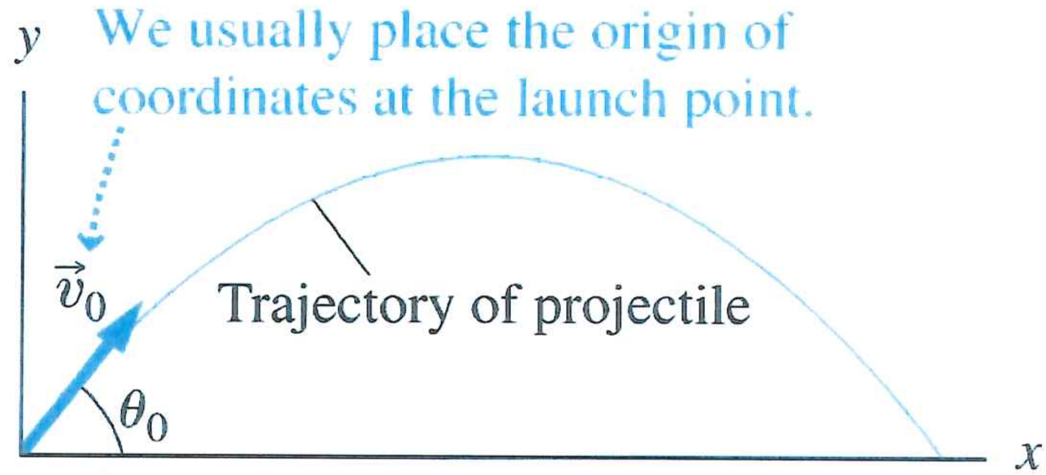
(b) $$a_{av,y} = \frac{v_{y,f} - v_{y,i}}{\Delta t} = \frac{-12.0 \text{ m/s} - 0}{1.50 \text{ s}} = \boxed{-8.00 \text{ m/s}^2}$$

Two-Dimensional Motion



Projectile motion: horizontal and vertical motions are independent

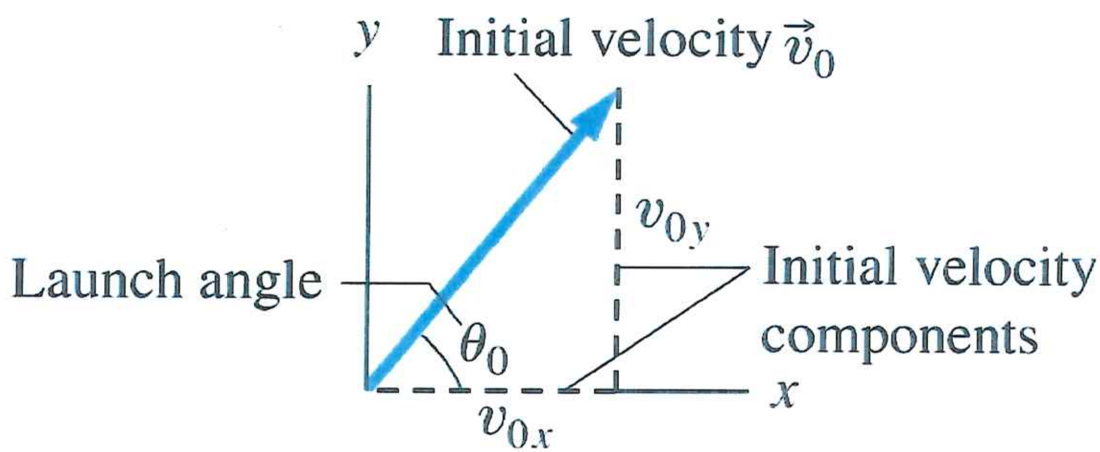
Chapter 3: Motion in Two Dimensions
Projectile motion – Constant Accel.



$$a_x = 0\,\frac{\text{m}}{\text{s}^2}$$

$$a_y = -g = 9.8\,\frac{\text{m}}{\text{s}^2}$$

$$\vec{a} = a_x\,\hat{i} + a_y\,\hat{j} = 0\,\hat{i} - g\,\hat{j} = 0\,\frac{\text{m}}{\text{s}^2}\,\hat{i} - 9.8\,\frac{\text{m}}{\text{s}^2}\,\hat{j}$$



Chapter 3: Motion in Two Dimensions
Projectile motion – Constant Accel.

Kinematic equations for x	For projectile, with $a_x = 0$
$x = v_{0x}t + \frac{1}{2}a_x t^2$	$x = v_{0x}t$
$v_x = v_{0x} + a_x t$	$v_x = v_{0x}$
$v_x^2 = v_{0x}^2 + 2a_x \Delta x$	$v_x = v_{0x}$

Kinematic equations for y	For projectile, with $a_y = -g$
$y = v_{0y}t + \frac{1}{2}a_y t^2$	$y = v_{0y}t - \frac{1}{2}gt^2$
$v_y = v_{0y} + a_y t$	$v_y = v_{0y} - gt$
$v_y^2 = v_{0y}^2 + 2a_y \Delta y$	$v_y^2 = v_{0y}^2 - 2g\Delta y$

17. A projectile is launched with an initial speed of 60.0 m/s at an angle of 30.0° above the horizontal. The projectile lands on a hillside 4.00 s later. Neglect air friction.

a. What is the projectile's velocity at the highest point of its trajectory?

Answer

b. What is the straight-line distance from where the projectile was launched to where it hits its target?

3.17 (a) At the highest point of the trajectory, the projectile is moving horizontally with velocity components of $v_y = 0$ and

$$v_x = v_{0x} = v_0 \cos\theta = (60.0 \text{ m/s})\cos 30.0° = \boxed{52.0 \text{ m/s}}$$

(b) The horizontal displacement is $\Delta x = v_{0x}t = (52.0 \text{ m/s})(4.00 \text{ s}) = 208 \text{ m}$

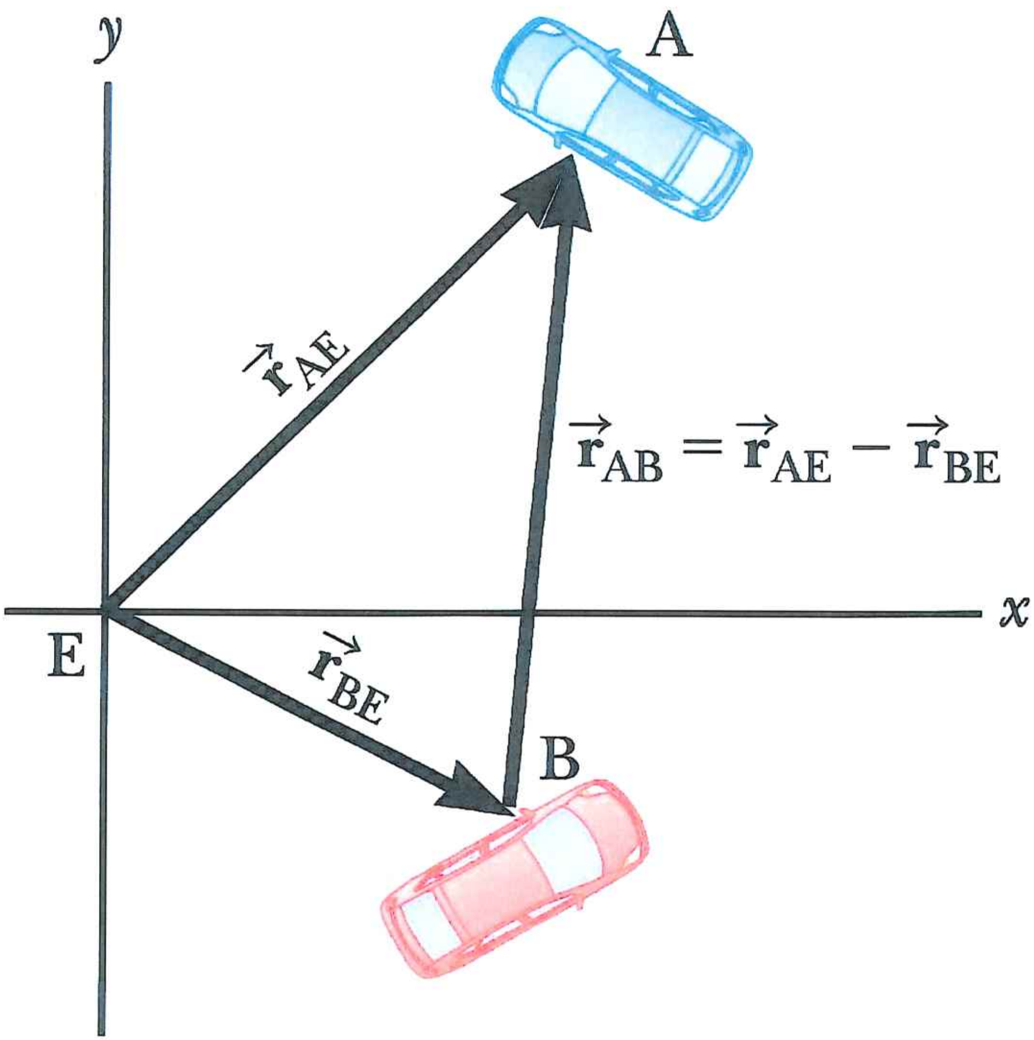
and, from $\Delta y = (v_0 \sin\theta)t + \frac{1}{2}a_y t^2$ the vertical displacement is

$$\Delta y = (60.0 \text{ m/s})(\sin 30.0°)(4.00 \text{ s}) + \frac{1}{2}(-9.80 \text{ m/s}^2)(4.00 \text{ s})^2 = 41.6 \text{ m}$$

The straight line distance is

$$d = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(208 \text{ m})^2 + (41.6 \text{ m})^2} = \boxed{212 \text{ m}}$$

Relative Velocity



$$\vec{\mathbf{r}}_{AB} = \vec{\mathbf{r}}_{AE} - \vec{\mathbf{r}}_{BE}$$

$$\vec{\mathbf{v}}_{AB} = \vec{\mathbf{v}}_{AE} - \vec{\mathbf{v}}_{BE}$$

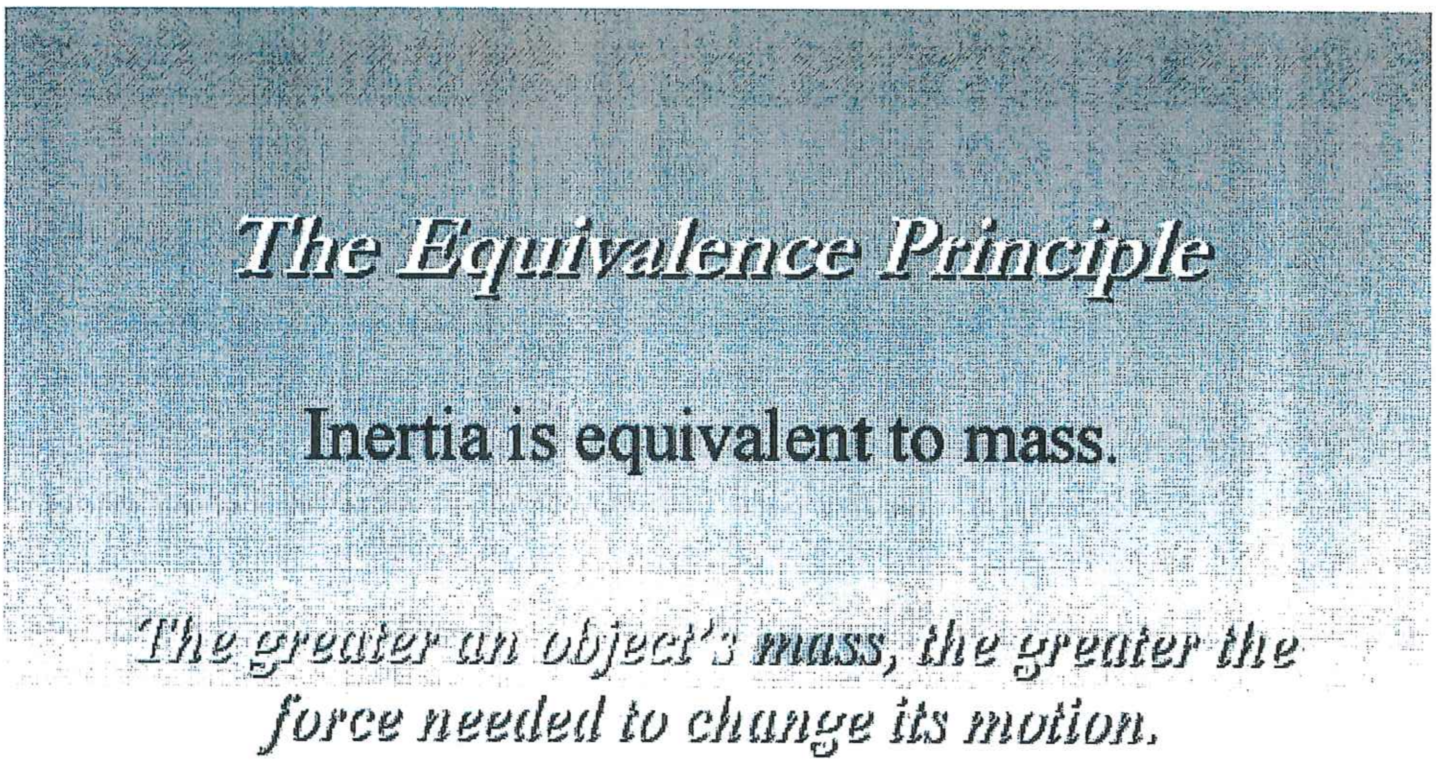
Chapter 4:Force and Newton's Laws

- Force and Mass
- Newton's Laws of Motion

- Applications of Newton's Laws

- Uniform Circular Motion

- Friction and Drag


The Equivalence Principle
Inertia is equivalent to mass.
The greater an object's mass, the greater the force needed to change its motion.

Chapter 4:Force and Newton's Laws
Newton's Second Law

"An object's acceleration and the net force acting on it are directly proportional."

$$\vec{F}_{net} = m \cdot \vec{a}, \text{ in SI: } \frac{\text{kg} \cdot \text{m}}{s^2} = 1\,\text{N}$$

A consequence of the first and second laws is that acceleration (change of velocity in a unit of time) of an object requires a force, is proportional to the force and inversely proportional to the mass of the object.

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

Units of Force and Mass

$$1\ \text{N} \equiv 1\ \text{kg}\cdot\text{m/s}^2$$

$$1\ \text{N} = 0.225\ \text{lb}$$

Table 4.1 Units of Mass, Acceleration, and Force

System	Mass	Acceleration	Force
SI	kg	m/s^2	$\text{N} = \text{kg}\cdot\text{m/s}^2$
U.S. customary	slug	ft/s^2	$\text{lb} = \text{slug}\cdot\text{ft/s}^2$

1kg is accelerated to 2 $\frac{m}{s^2}$ by a force applied at an angle of 20°. Find F_x, F_y and $|F|$.

1. We apply Newton's second law (specifically, Eq. 5-2).

   (a) We find the x component of the force is

   $$F_x = ma_x = ma\cos 20° = (1.00\,\text{kg})(2.00\,\text{m/s}^2)\cos 20° = 1.88\text{ N}\ .$$

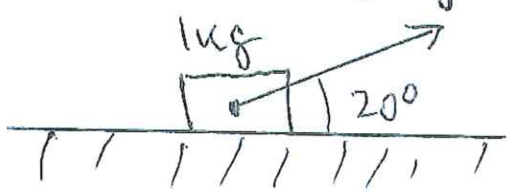
   (b) The y component of the force is

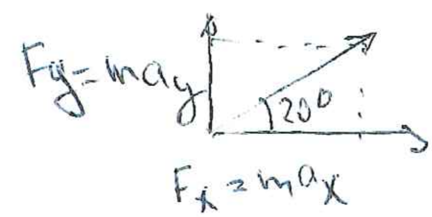
   $$F_y = ma_y = ma\sin 20° = (1.0\,\text{kg})(2.00\,\text{m/s}^2)\sin 20° = 0.684\text{ N}\ .$$

   (c) In unit-vector notation, the force vector (in Newtons) is

   $$\vec{F} = F_x\,\hat{\text{i}} + F_y\,\hat{\text{j}} = 1.88\,\hat{\text{i}} + 0.684\,\hat{\text{j}}\ .$$

$$|\vec{F}| = \sqrt{F_x^2 + F_y^2} = \sqrt{1.88^2 + 0.684^2} \approx 2\,N$$



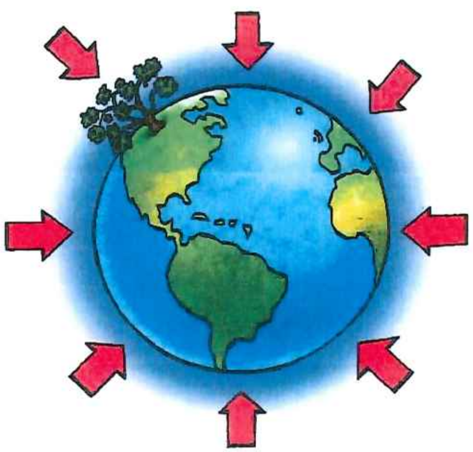


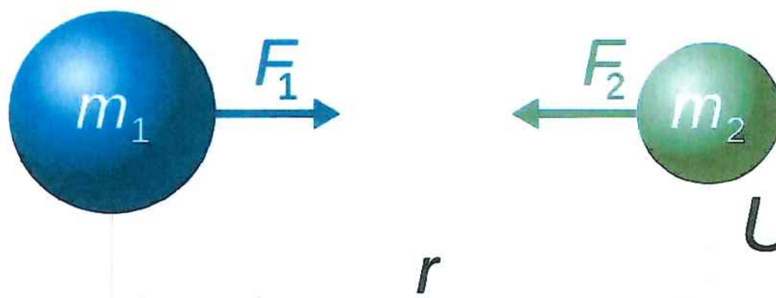
Chapter 4:Force and Newton's Laws
Weight and Gravitational Acceleration

The force of gravity is called **weight***. This is what scales measure.*

$$\vec{w} = m \cdot \vec{g}$$

At Earth's surface, weight is directly proportional to the mass and is pointing towards the Earth.





Universal gravity

$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2} \qquad G = 6.674 \cdot 10^{-11} \frac{m^3}{kg \cdot s^2}.$$

Weight

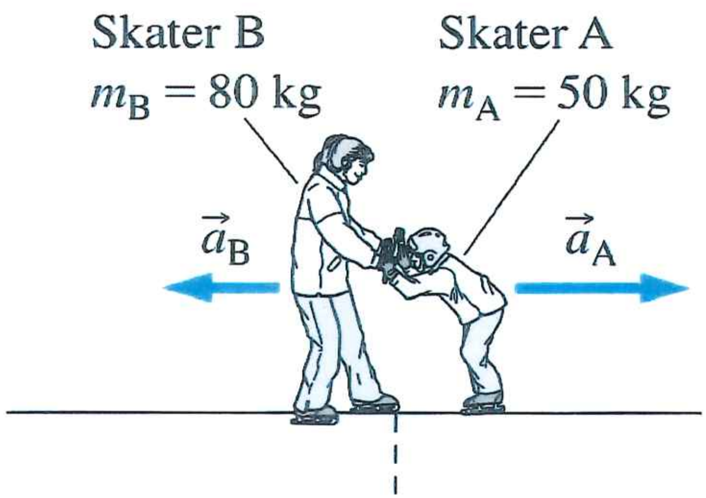
$$w = mg \quad \text{SI unit: N}$$

$$w = G\frac{M_E m}{r^2}$$

$$g = G\frac{M_E}{r^2}$$

Chapter 4:Force and Newton's Laws
Newton's Third Law

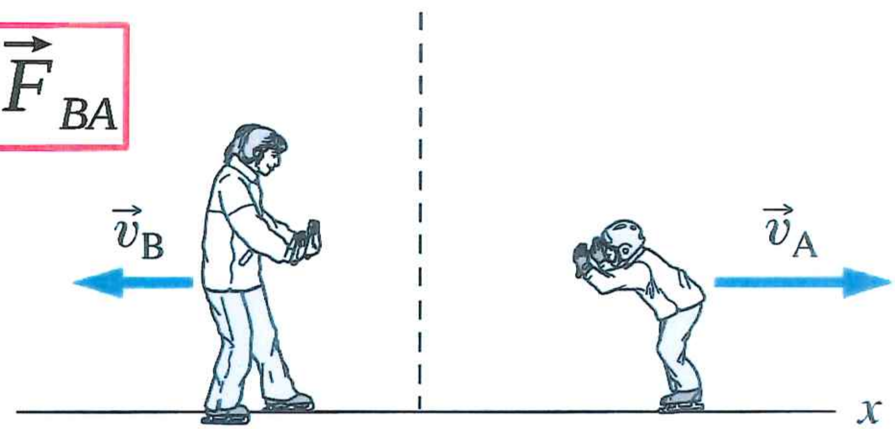
"When two objects (A and B) interact, the force that object A exerts on object B is equal in magnitude and opposite in direction to the force that B exerts on A."



(a) Skaters push off

Skaters accelerate in opposite directions: $m_A < m_B$, so $a_A > a_B$.

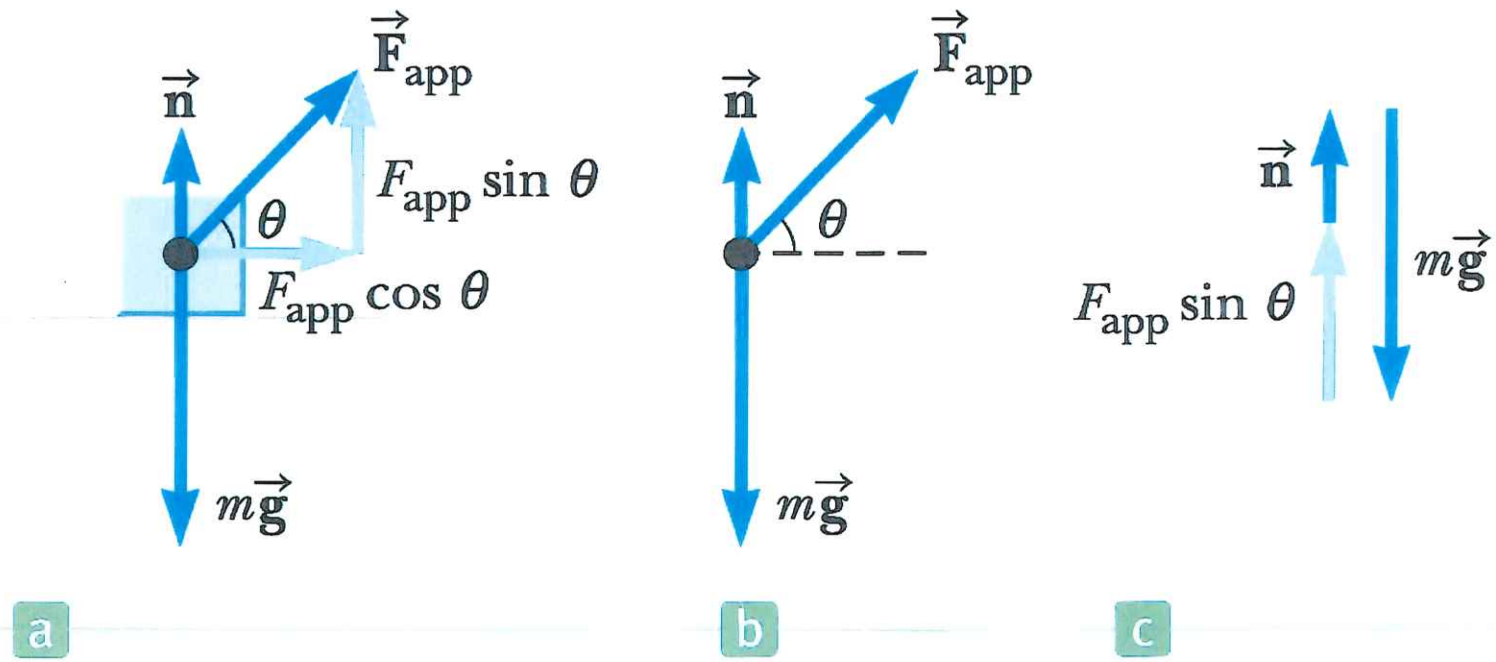
$$\vec{F}_{AB} = -\vec{F}_{BA}$$



(b) Motion after separation

After separation, smaller skater travels faster: $v_A > v_B$.

Case 2: The Normal Force on a Level Surface with an Applied Force

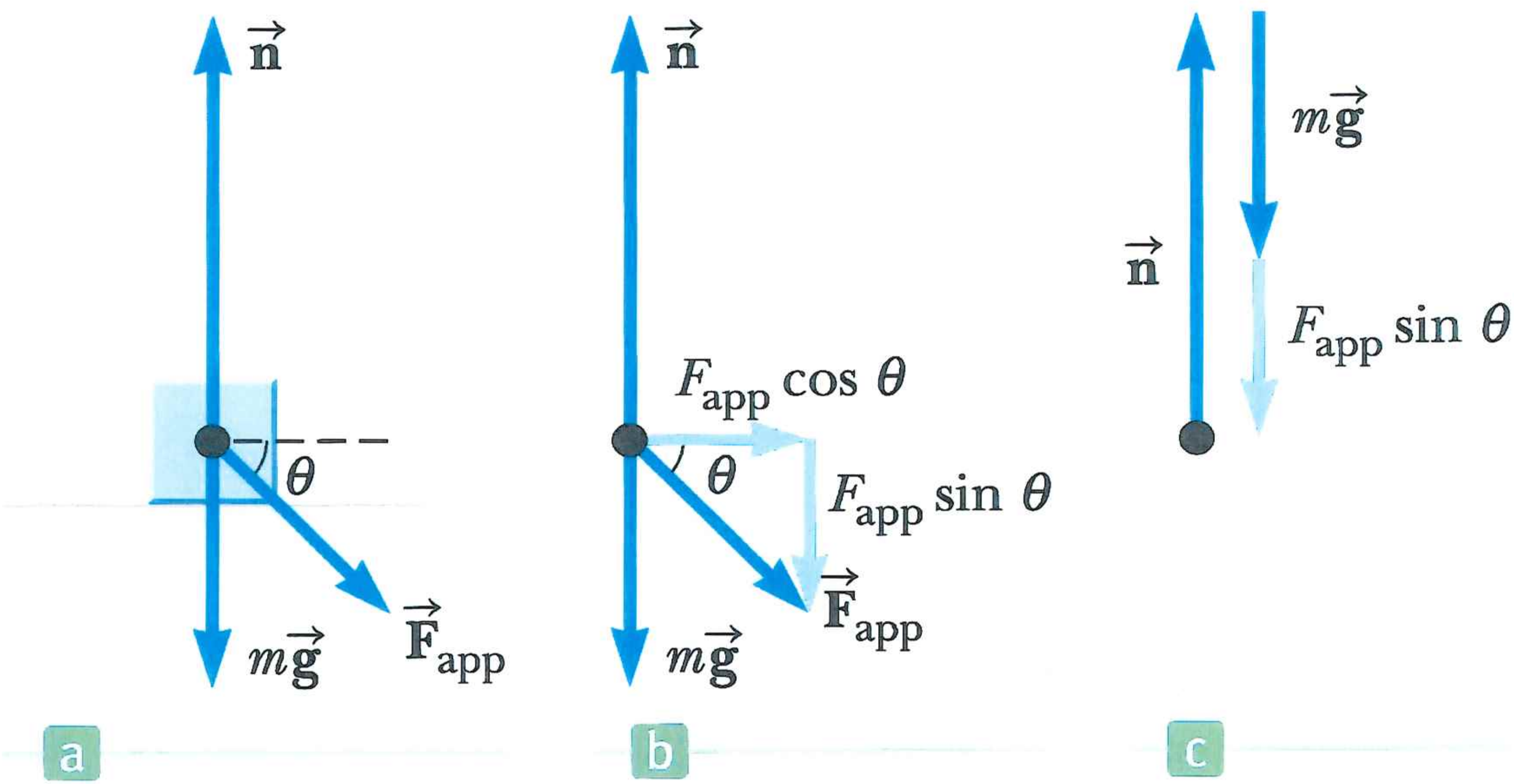


$$\Sigma F_y = ma_y$$

$$n - mg + F_{app} \sin\theta = 0$$

$$n = mg - F_{app} \sin\theta$$

Case 2: The Normal Force on a Level Surface with an Applied Force



25. A rocket takes off from Earth's surface, accelerating straight up at $72.0\ \mathrm{m/s^2}$. Calculate the normal force acting on an astronaut of mass 85.0 kg, including his space suit.

4.25 Two forces act on the astronaut, resulting in an upward acceleration a_y = $+72.0\ \mathrm{m/s^2}$. As in Section 4.3, Case 4, apply the y-component of Newton's second law to find

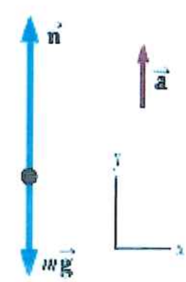
$$\Sigma F_y = ma_y$$

$$n - mg = ma_y$$

$$n = mg + ma_y = m(g + a_y)$$

$$= (85.0\ \mathrm{kg})(9.80\ \mathrm{m/s^2} + 72.0\ \mathrm{m/s^2})$$

$$= \boxed{6.95 \times 10^3\ \mathrm{N}}$$

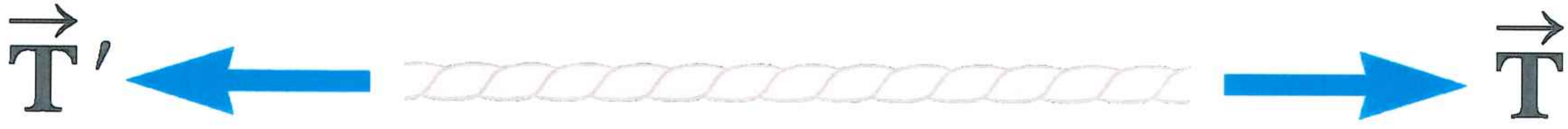


The Force of Kinetic Friction

$$f_k = \mu_k n$$

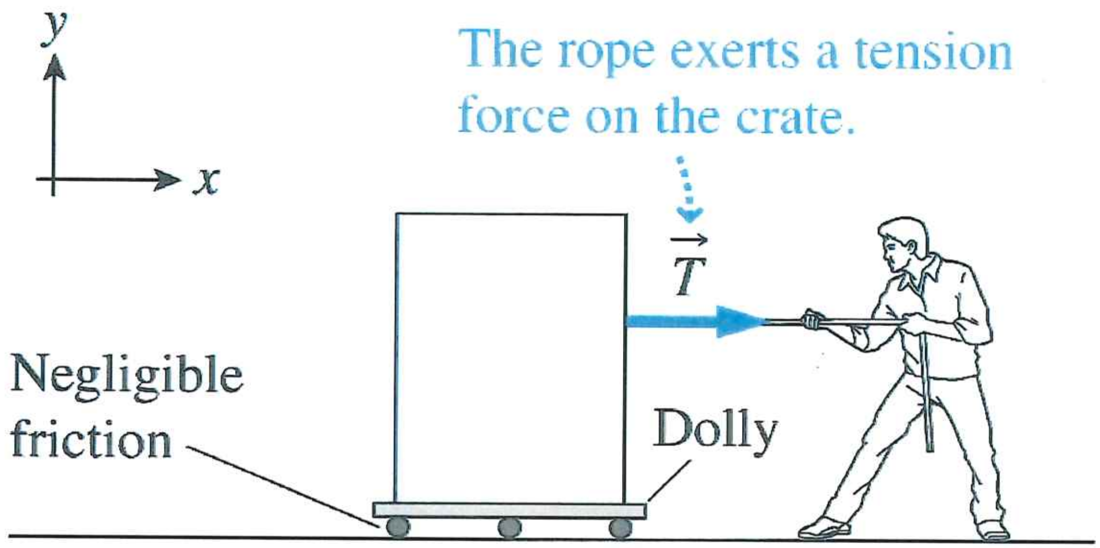
μ_k is coefficient of kinetic friction

Applications of Newton's Laws

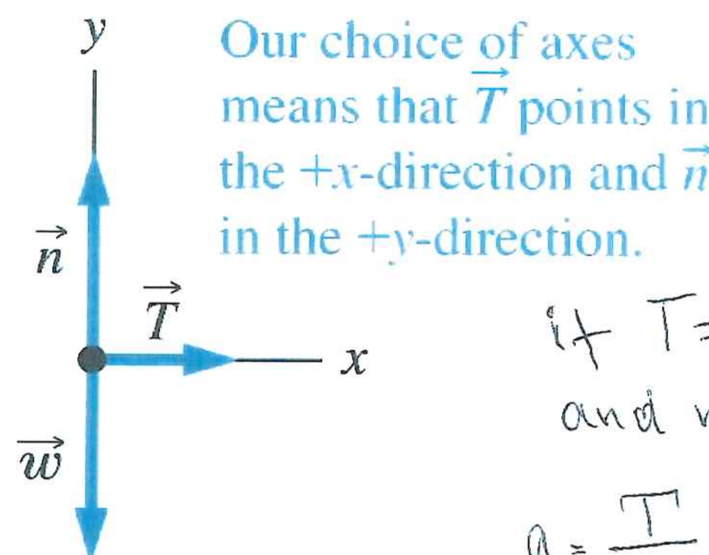


if $m = 0$, then $T = T'$

Figure 4.15



Force diagram for crate



in x direction

if T = 420 N

and m = 120 kg

$$a = \frac{T}{m} = \frac{420\,N}{120\,kg} = 3.5\ \frac{m}{s^2}$$

No motion in y direction

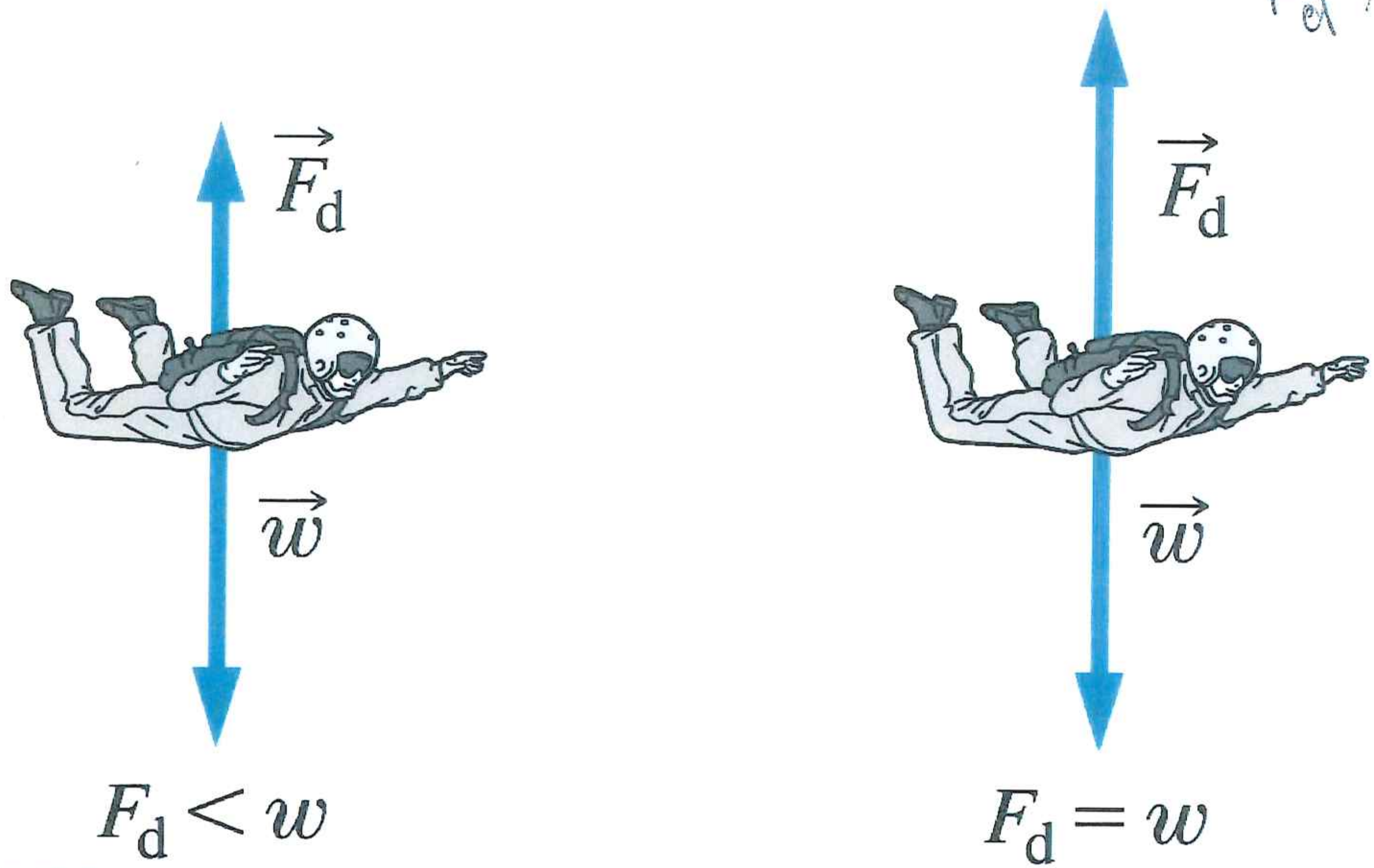
Drag forces

Figure 4.26

Early in fall, upward drag force is less than skydiver's weight, so skydiver accelerates.

Later in fall, drag force equals weight, so skydiver's velocity is constant.

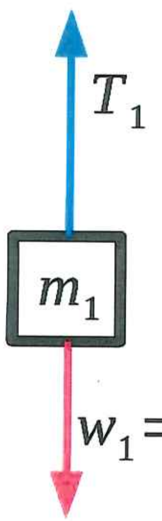
$F_d \sim V_\infty^2 \, \text{Area}$



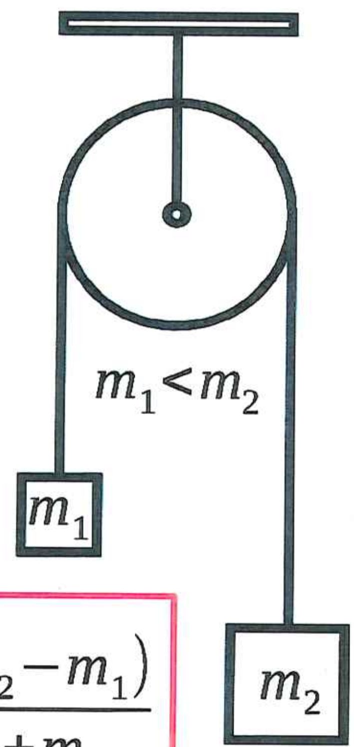
Chapter 4:Force and Newton's Laws

Newton's Second Law – Atwood's Machine

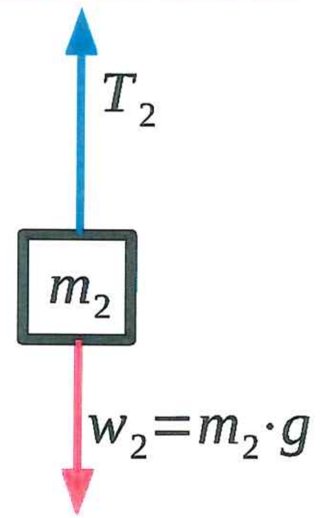
$$\vec{F}_{net}=m\cdot\vec{a}\text{, in SI: }\frac{1\,\text{kg}\cdot 1\,\text{m}}{1\,s^2}=1\,\text{N}$$



$$F_{net,1}=T-w_1$$
$$F_{net,1}=m_1\cdot a$$
$$T=m_1\cdot a+m_1\cdot g$$



$$a=\frac{g(m_2-m_1)}{m_1+m_2}$$



$$F_{net,2}=T-w_2$$
$$F_{net,2}=m_2\cdot a$$
$$T=m_2\cdot g-m_2\cdot a$$