ELSEWEDY
UNIVERSITY
OF TECHNOLOGY
- POLYTECHNIC OF EGYPT -

Principles of Physics

Lecture 4: Motion

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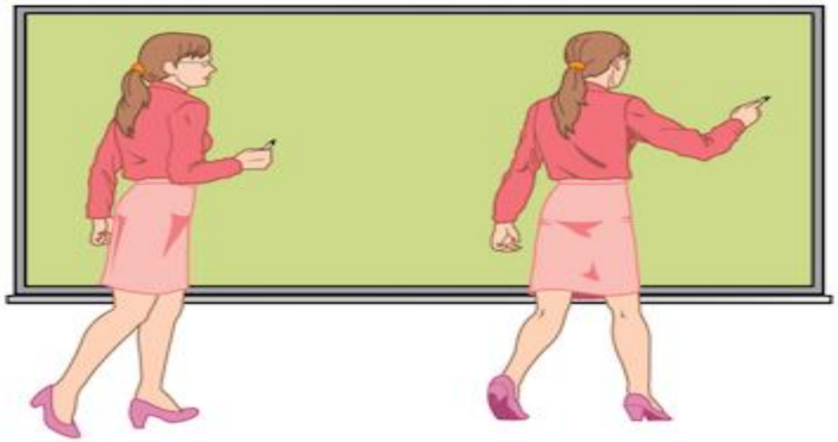
Motion in one dimension

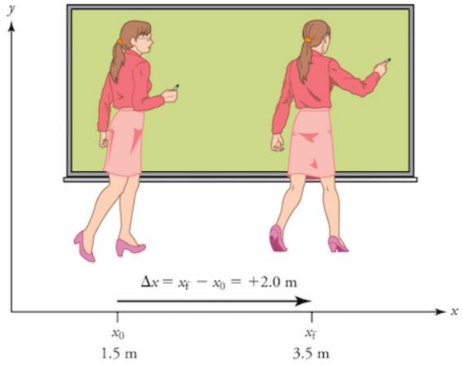
What does position mean?

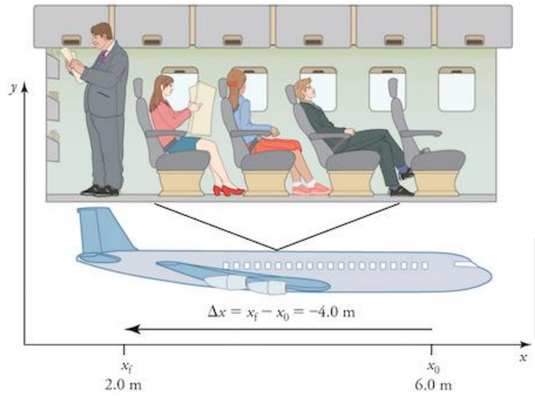
- To describe the position of an object we need to specify its position relative to a convenient reference frame. Earth is often used as a reference frame, and we often describe the position of an object as it relates to stationary objects in that reference frame. For example, a professor's position could be described in terms of where she is in relation to the nearby white board.



What does displacement mean?

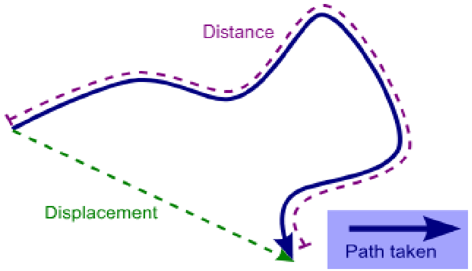
- The professor's initial position is $x_0 = 1.5\ m$ and her final position is $x_f = 3.5\ m$. Thus, her displacement can be found as follows, $\Delta x = x_f - x_0 = 3.5 - 1.5 = +2\ m$. In this coordinate system, motion to the right is positive, whereas motion to the left is negative.
- The airplane passenger's initial position is $x_0 = 6.0\ m$ and his final position is $x_f = 2.0\ m$, so his displacement can be found as follows, $\Delta x = x_f - x_0 = 2.0 - 6.0 = -4\ m$. His displacement is negative because his motion is toward the rear of the plane, or in the negative x direction in our coordinate system.





What was the difference between position, displacement and distance?

- Position: location of an object relative to the origin. We often use the symbol x to refer to position.
- Displacement: change in position of an object. We use the symbol Δx for displacement, where Δ means "change." A vector quantity with units of $distance$.
- Distance: total amount the object has moved. This depends on the whole path traveled, not just the starting and ending points. Distance traveled is always a non-negative number. A scalar quantity with units of $distance$.



What is the meaning of Average, Instantaneous speed and velocity?

- Average speed is the total distance travelled by an object to the total time taken. However, average velocity is the change in position or displacement (Δx) divided by the time intervals (Δt) in which the displacement occurs.

- Instantaneous speed is a measurement of how fast an object is moving at that particular moment. Instantaneous velocity is a vector quantity that includes both the speed and the direction in which the object is moving.

Problems

- **A car travels 70 km in 2 hours. What is the average speed?**

Solution:

$average\ speed\ =\ distance/time$

$Therefore, the\ average\ speed\ of\ the\ car\ =\ 70/2 =\ 35km/hour.$

- **A car moves at a speed of 30 km/hr for 2 hours and then slows down to 20 km/hr for the next 1 hour. Find the average speed of the car.**

Solution:

$Distance\ 1\ =\ 30x\ 2\ =\ 60\ km$

$Distance\ 2\ =\ 20x\ 1\ = 20\ km$

$Distance\ total\ =\ Distance\ 1\ +\ Distance\ 2\ =\ 60\ +\ 20\ =\ 80\ km$

$Total\ distance\ travelled\ /\ Total\ time\ taken\ =\ Average\ speed\ =\ 80/3\ =\ 26.67\ km/hr$

Problems

- **Calculate the average velocity at a particular time of a person if he moves 7 m in 4 s and 18 m in 6 s along the x-axis?**

Solution:

Initial distance travelled by the person, $xi = 7\ m,$

Final distance travelled, $x_f = 18\ m,$

Initial time interval $t_i = 4\ s,$

Final time interval $t_f = 6\ s,$

Average velocity $v = \frac{x_f - x_i}{t_f - t_i} = \frac{18-7}{6-4} = 5.5\ m/s$

Problems

- **Car travels along a straight road to the east for 120 meters in 5 seconds, then goes west for 60 meters in 1 second. Determine average speed and average velocity.**

Solution:

$Distance\ =\ 120\ +\ 60\ =\ 180\,m.$

$Displacement\ =\ 120 - 60\ =\ 60\,m.$

$Total\ time\ =\ 5\ +\ 1\ =\ 6\,s.$

$$Average\ speed\ =\frac{Distance}{total\ time}=\frac{180}{6}=\ 30\,m/s.$$

$$Average\ velocity\ =\frac{Displacement}{total\ time}=\frac{60}{6}=\ 10\,m/s.$$

Problems

- **The position of a particle moving a long the x-axis given by:** $\boldsymbol{x(t) = 5 + t^2 - t^3}$

Where x is in meters and t is in seconds. Find its velocity at t=2 s?

A) -8	B) -2	C) +8	D) -1

Solution:

$$v = \frac{dx}{dt} = 0 + 2t - 3t^2$$

At $t = 2$ s

$v = 2(2) - 3(2)^2$=-8 m/s

Problems

- **The velocity of a particle moving a long the x- axis is given by $V(t) = 4t - 3t^2$ (m/s), where t is in second. Find the acceleration of the particle at ($t = 2$ s)?**

A) 2	B) -8	C) 8	D) -4

$$a = \frac{dv}{dt} = 4 - 6\text{t}$$

At $t = 2$ s

$a = 4 - 6(2) = -8\ m/s^2$

Equations of motion

Equations of one-dimensional motion with uniform acceleration

- $V_2 = V_1 + at$
- $V_2^2 = V_1^2 + 2ax$
- $x = V_1 t + \frac{1}{2} a t^2$
- $x = \frac{1}{2}(V_1 + V_2)t$

At rest	$V_1 = 0$
stopped	$V_2 = 0$
Constant velocity	$a = 0$

Problems

- **A particle starts moving from rest with constant acceleration of (5 m/s^2), what is the velocity of the particle after 3 second?**

Solution:

A) 30	B) 15	C) 1.2	D) Zero

$$V_2 = V_1 + at$$

$$V_2 = 0 + 5(3) = 15\ m/s$$

- **A racing car travelling with constant acceleration increases its speed from (10 m/s) to (50 m/s) over a distance of (60 m), How long does this take?**

Solution:

A) 2	B) 4	C) 5	D) 8

$$x = \frac{1}{2}(V_1 + V_2)t$$

$$60 = \frac{1}{2}(10 + 50)t$$

$$t = 2\ s$$

Problems

- **A car start moving from rest with constant acceleration of (4 m/s^2), what is the distance it traveled after (5 s)?**

Solution:

A) 100	B) 50	C) 30	D) 20

$$x = V_1 t + \frac{1}{2} a t^2$$

$$x = 0 + \frac{1}{2}(4)(5)^2 = 50\text{m}$$

- **A bullet is fired through a board of (14 cm) thick, with its line of perpendicular to the face of the board. If it enters with a speed of (450 m/s) and emerges with a speed of (220 m/s). What is the bullet's acceleration (in unit of km/s^2) as it passes through the board?**

Solution:

A) - 500	B) - 550	C) -360	D) - 520

$$V_2^2 = V_1^2 + 2ax$$

$$(220)^2 = (450)^2 + 2a(0.14)$$

$$a = -550357.1\ m/s^2$$

$$a = -550\ km/s^2$$

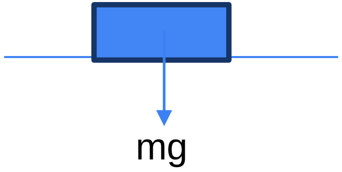
Newton's laws of motion

Type of forces

- Gravitational force & Weight (w)

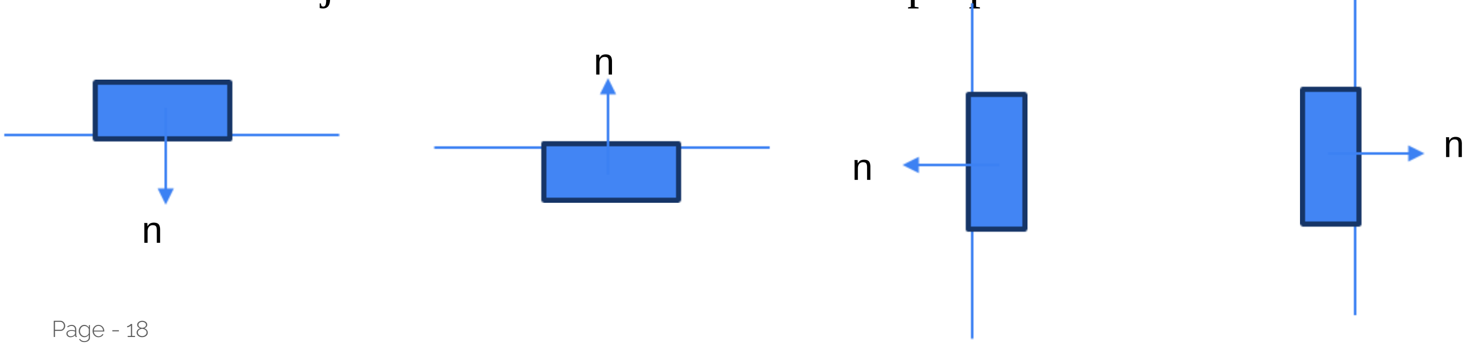
Weight=force of gravity on an object

$w = F_g = mg$



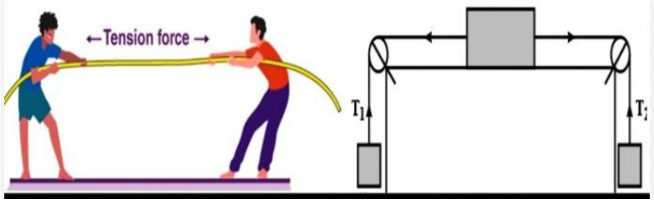
- Normal force (n)

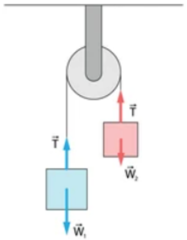
When the object touches the surface and is perpendicular to the surface

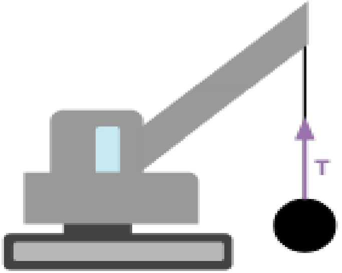


Type of forces

- Tension force (T)

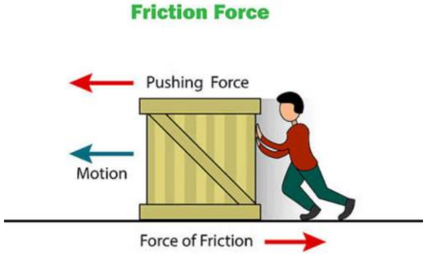


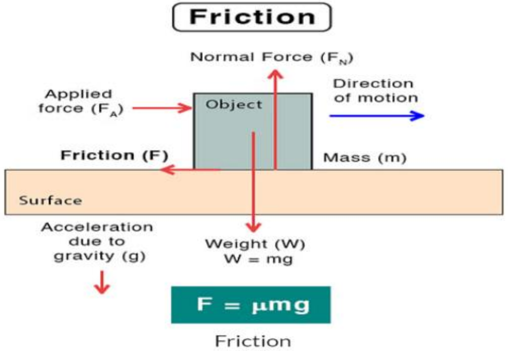




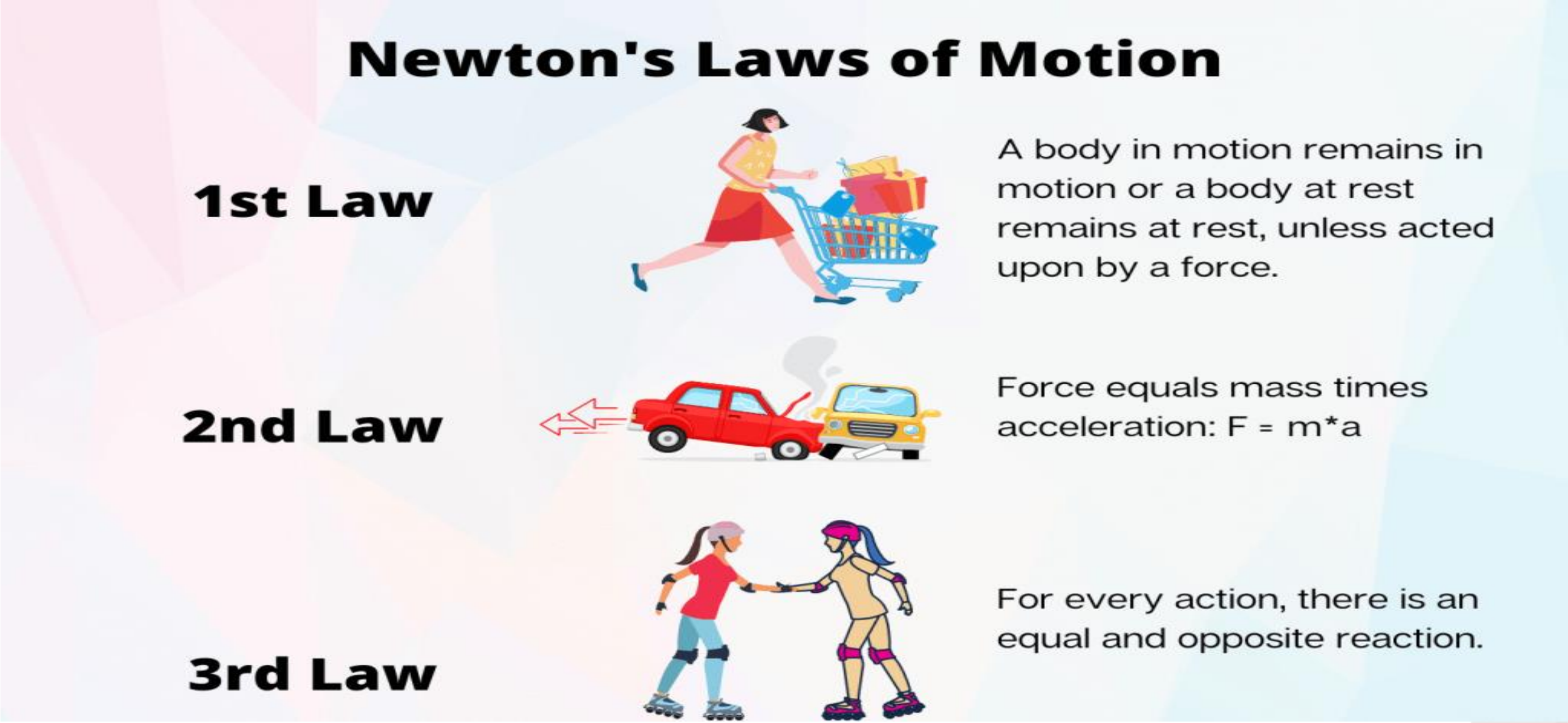
The force exerted by a **rope, cable, chain, etc.** is called the force of tension F_T or T.

- Friction force (F)





Newton's laws of motion



Problems

- **Calculate the net force required to give an automobile of mass 1600 kg an acceleration of 4.5 m/s^2.**

Solution:

We calculate the force using the following formula.

$F = ma$

Substituting the values in the equation, we get

$F = 1600 \times 4.5 = 7200N$

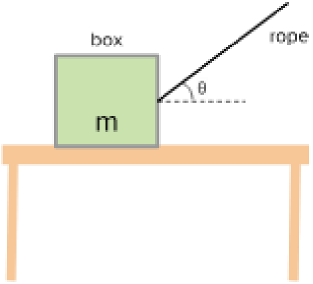
- **A 2kg box of cucumber extract is being pulled across a frictionless table by a rope at an angle $\boldsymbol{\theta = 60°}$ as seen below. The tension in the rope causes the box to slide across the table to the right with an acceleration of 30 $\boldsymbol{m/s^2}$. What is the tension in the rope?**

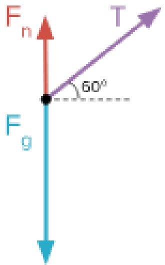
Solution:

$F = ma$

$Tcos(60) = 2 \times 30$

$T = 12\ N$





Problems

- **For the system shown a side, ($m_1 = 3kg$) and ($m_2 = 1kg$). If friction is ignored. What is the magnitude of their acceleration?**

A) 5	B) 1.5	C) 7.5	D) 2.45

Solution:

For $m_1 : T + N + w_1 = m_1 a_1$

For $m_2 : T + w_2 = m_2 a_2$

The tension is the same throughout the string. We see that Mass1 has the vertical forces balanced, so we ignore them and write an equation relating the *x*-components. There are no horizontal forces on Mass2, so only the *y*-equation is written.

When Mass1 moves to the right Mass1 travels an equal distance downward; thus, $a_{1x} = -a_{2y}$. Writing the common acceleration of the masses as $a = a_{1x} = -a_{2y}$, we now have

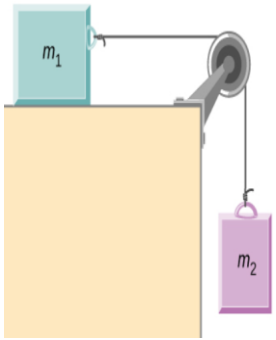
Mass(1)	**Mass(2)**
$\sum F_x = m_1 a_{1x}$	$\sum F_y = -m_2 a_{2y}$
$T_x = m_1 a_{1x}$	$T_y - m_2 g = -m_2\, a_{2y}$

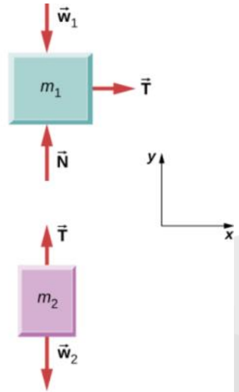
$T = m_1 a$ and $T - m_2 g = -m_2\, a$

$m_1 a - m_2 g = -m_2\, a$

$$a = \frac{m_2}{m_1 + m_2} g$$

$$a = \frac{1}{3+1} 9.8 = 2.45 \text{ m}/s^2$$





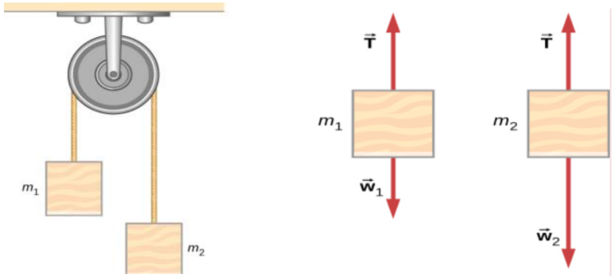
Problems

- **From the figure shown calculate the tension in the string. The pully is massless and frictionless, (m_1 = 20kg) and (m_2 = 30kg).**

A) 500	B) 235	C) 320	D) 410

Solution:

As mass2 accelerates with acceleration a_2 in the downward direction, mass1 accelerates upward with acceleration a_1. Thus, $a = a_1 = -a_2$.



Mass(1)

$$\sum F_y = m_1 a$$

$$T - m_1 g = m_1 a$$

Mass(2)

$$\sum F_y = -m_2 a$$

$$T - m_2 g = -m_2\, a$$

The negative sign in front of $m_2 a$ indicates that m_2 accelerates downward; both blocks accelerate at the same rate, but in opposite directions. Solve the two equations simultaneously (subtract them) and the result is

$$(m_2 - m_1)g = (m_1 + m_2)a$$

$$a = \frac{(m_2 - m_1)}{(m_1 + m_2)} g = \frac{(30-20)}{(20+30)} 9.8 = 1.96\, m/s^2$$

$$T - m_1 g = m_1 a$$

$$T - 20 \times 9.8 = 20 \times 1.96$$

$$T = 235\, N$$

Problems

- **Consider the traffic light (mass of 15.0 kg) suspended from two wires as shown in <u>(Figure)</u>. Find the tension in each wire, neglecting the masses of the wires.**

Solution:

$\mathrm{T_1 sin(30) + T_2 sin(45) - w = 0}$

$\mathrm{T_1 sin(30) + T_2 sin(45) = mg}$

$0.5T_1 + 0.707T_2 = 15 \times 9.8$

$0.5T_1 + 0.707T_2 = 147 \qquad (1)$

$\mathrm{T_1 cos(45) - T_2 cos(30) = 0}$

$0.525\mathrm{T_1} = 0.154\mathrm{T_2}$

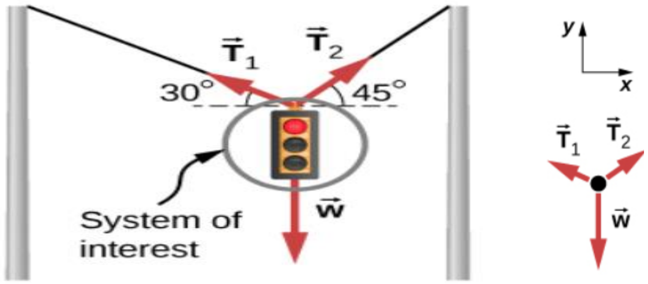
$\mathrm{T_1} = \frac{0.154}{0.525}\mathrm{T_2} = 0.294T_2 \qquad (2)$ *Substitute in Eq(1)*

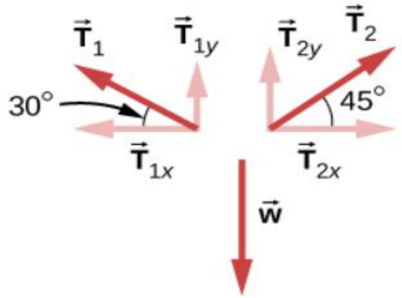
$0.5 \times 0.294T_2 + 0.707T_2 = 147$

$0.147T_2 + 0.707T_2 = 147$

$T_2 = \frac{147}{0.854} = 172\mathrm{N}$ *Substitute in Eq(2)*

$T_1 = 0.294 \times 172 = 50.6N$





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Thank You...