Chapter 4:Dynamics: Newton's Laws of Motion

Lecture 2
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Newton's Third Law

Each action has a reaction, equals to it in magnitude and opposite to it in direction.

(action reaction forces are equal and opposite)

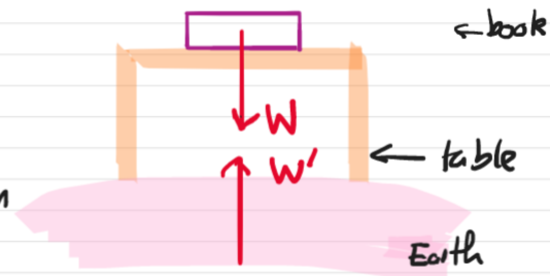
It is very important to identify the correct pair of action-reaction forces.

Exmple A book on a tube which rests on the ground.

Find the pairs of action reaction forces.

weight : $W = mg$

W: force of earth on book, call it action.



W': force of book on earth, call it reaction.

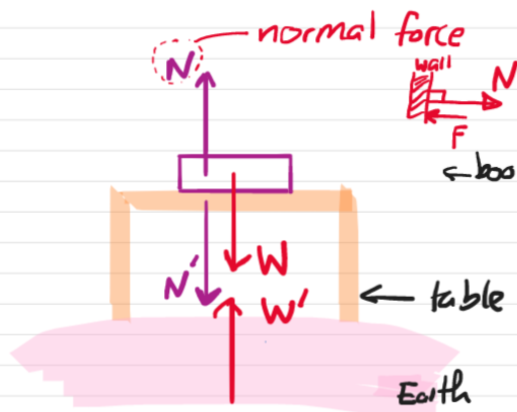
opposite direction

$W = -W'$

i.e equal in magnitude and opposite in direction.

W and W' are called action-reaction pair of forces. one is the action and the other is the reaction.

N : force of table on book. call it action.



N': force of book on table (call it reaction).

$N = -N'$

N and N' are an action-reaction pair.

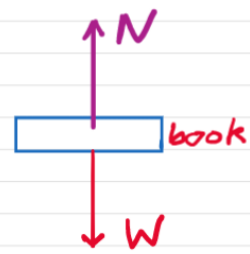
NOTE: Action and reaction forces NEVER act on the same object.

Free-body diagram: (مخطط الجسم الحر)

A diagram that shows all the external forces acting on an object.

Draw the free body diagram for the book.

The book is stationary (at rest)



∴ According to Newton's 2^{nd} law

$$\Sigma F_y = m a_y = m(0) = 0.$$

i.e the book is in static equilibrium. (اتزان سكوني)

equilibrium : $\Sigma F = 0$. (اتزان)

static : at rest. (ساكن)

Since we are dealing with vectors, we must define a positive direction.

Since the book is at rest we can choose any direction (up or down) as positive.

$$\overset{+}{\uparrow} \quad N - W = m a_y = m(0) = 0 .$$

$\Rightarrow$ $N = W$ (as magnitudes; directions are opposite)

NOTE N and W are equal in magnitude and opposite in direction. BUT they are NOT an action-reaction pair. Why?

Answer

① they act on the same object (book)

② N is <u>not</u> alway equal to W. How?

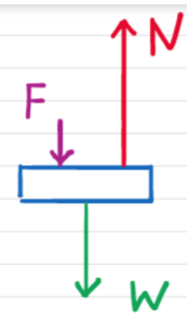
Consider the following situations for a stationary book which is at rest.

F is a force that acts on the book.

$\overset{+}{\uparrow}$ $N - F - W = 0$ $\quad (\Sigma F_y = ma_y = 0)$ — resultant (net) force

$\therefore N = F + W$

i.e $N > W$



$\overset{+}{\uparrow}$ $N + F - W = 0$

$\therefore N = W - F$

$\therefore N < W$

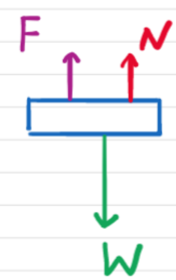
Try $\downarrow +$

$\Sigma F_y = 0$

$W - F - N = 0$

$\therefore W - F = N$

$N = W - F$



Clearly, N can be:

equal, greater or smaller than

$\Rightarrow$ N cannot be a reaction to W.

Solving problems with Newton's laws

1) An object of mass m is at rest and suspended by a string. Find the tension in the string.

Always ignore the mass of the string or rope.

Draw a free-body diagram for the book.

static equilibrium $\Rightarrow \sum F_y = 0$.

$\uparrow^{+}$ $T - mg = 0 \Rightarrow T = mg$.

2) The figure shows two masses m_1 and m_2 at rest and suspended by two strings. Find the tensions T_1, T_2 in the two strings.

Treat each mass separately.

Start from m_2 at the bottom.

For m_2:

$$\overset{+}{\uparrow} \quad T_2 - m_2 g = 0 \Rightarrow T_2 = m_2 g \quad \text{—(1)}$$

For m_1:

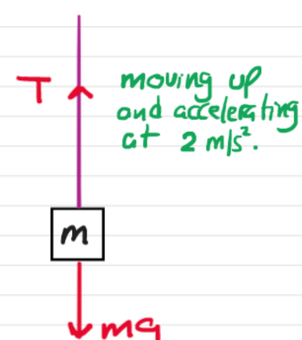
$$\overset{+}{\uparrow} \quad T_1 - T_2 - m_1 g = 0$$

$$\therefore T_1 = T_2 + m_1 g$$

(using eqn (1))

$$\therefore T_1 = m_2 g + m_1 g = (m_1 + m_2) g$$

3] An object of mass m_1 is suspended by a string and accelerated upwards at $2\,m/s^2$. Find the tension in the string.



For a moving object take the direction of motion as positive.

$$\overset{+}{\uparrow} \quad \underbrace{T - mg}_{\Sigma F_y} = m a_y$$

$$\therefore T = m(g + a_y) = m(g + 2)$$

If $a_y = 0$

i.e moving up at constant velocity $\Rightarrow$

$$T = m(g + 0) = mg$$

same as when object was stationary

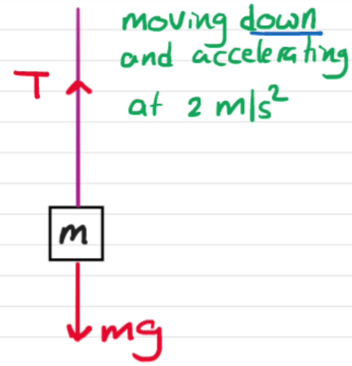
4] Consider the same example in example (3) above but accelerating down at $2\,m/s^2$!

Take direction of motion as positive.

$\downarrow +$ $mg - T = ma$

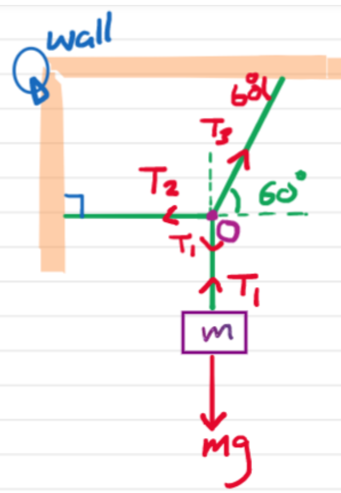
$m(g-a) = T$

$\therefore T = m(g-a) = m(g-2)$



5] Mass m is hung stationary using three strings as shown. Find the tensions in the three strings.

Mass m is at rest. Can take up or down as positive direction.



For mass m:

$\uparrow +$ $T_1 - mg = 0 \Rightarrow T_1 = mg$ — ①

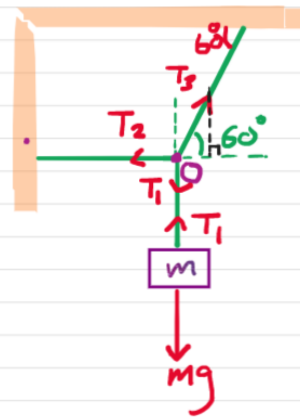
Point O is stationary $\Rightarrow$

net force along x, net force along y

$\Sigma F_x = 0$, $\Sigma F_y = 0$.

$\xrightarrow{+}$ $T_3 \cos 60^\circ - T_2 = 0$

$\therefore \; T_3\left(\frac{1}{2}\right) = T_2 \Rightarrow T_2 = \frac{T_3}{2} \quad - (2)$



$T_1 = mg$ from eq. (1)

$\uparrow^{+}$ $T_3 \sin 60^\circ - T_1 = 0 \Rightarrow T_3\left(\frac{\sqrt{3}}{2}\right) = mg$

$\therefore \; T_3 = \frac{2}{\sqrt{3}} mg \quad - (3)$

Using (2) $\quad T_2 = \frac{1}{2}\underbrace{\left(\frac{2}{\sqrt{3}} mg\right)}_{T_2} = \frac{1}{\sqrt{3}} mg$