

### 3.3 Basic of Forces and Free Body Diagram

#### LO 3.3 a) Identify the forces acting on a body in different situations

##### a) Type of Forces

- Force is a vector that causes an object to move, stop, change its direction or change its shape.
- The SI unit for all forces is **Newton (N)** or  $\text{kg m s}^{-2}$ .
- There are many forces we will deal with over and over. Table below shows some of them.

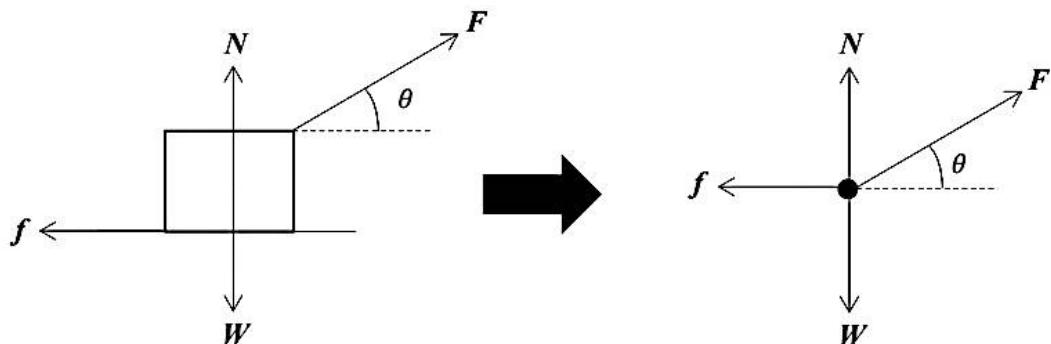
Force	Explanation	Diagram
Weight, $W$	<ul style="list-style-type: none"> <li>• Force exerted on a body under gravitational field on or near the surface of the earth.</li> <li>• Equation:</li> </ul> $\vec{W} = m\vec{g}$ <p><math>W</math>: Weight force ; <math>m</math>: mass  <math>g</math>: gravitational acceleration (<math>9.81 \text{ ms}^{-2}</math>)</p> <ul style="list-style-type: none"> <li>• Direction: points vertically downward and always perpendicular to the ground.</li> </ul>	
Tension, $T$	<ul style="list-style-type: none"> <li>• Tension force exists when there is string/rope/wire/cable/chain etc.</li> <li>• Direction : in the direction of the string and always away from the object that being pulled and along the string.</li> <li>• Same string possessed same tension.</li> </ul>	
Normal, $N$	<ul style="list-style-type: none"> <li>• Reaction force that is exerted by the surface to an object in contact with the surface.</li> <li>• The agent for the normal force is the contact surface.</li> <li>• Direction : always perpendicular to the contact surface and outwards of an object.</li> </ul>	

Force	Explanation	Diagram
Friction, $f$	<ul style="list-style-type: none"> <li>Force that <b>opposes the relative motion</b> of two (<b>rough</b>) surfaces in contact.</li> <li>In our syllabus, the surface is always smooth unless stated <b>rough surface</b>.</li> <li>Friction is directly proportional to the reaction force.  <math display="block">f \propto N</math> </li> <li>Equation :</li> </ul> $\boxed{f = \mu N}$ <p>Where :</p> <p style="text-align: center;"><math>\vec{f}</math> : friction force  <math>\mu</math> : coefficient of friction  <math>\vec{N}</math> : Normal force</p> <ul style="list-style-type: none"> <li><b>Coefficient of friction, <math>\mu</math></b> is defined as the ratio between frictional force to normal force.</li> <li><math>\mu</math> depends on the <b>nature of the surface</b>.</li> <li>There are <b>two types of friction</b> :             <ul style="list-style-type: none"> <li>i) Static friction, <math>\vec{f}_s</math></li> <li>ii) Kinetic friction, <math>\vec{f}_k</math></li> </ul> <math display="block">\mu_s &gt; \mu_k \text{ and } \vec{f}_s &gt; \vec{f}_k</math> </li> <li>The kinetic friction is less than static, because it takes more effort to start sliding something than to keep it sliding.</li> </ul>	<p><b>Static friction, <math>\vec{f}_s</math></b></p> <p>a) Static friction is the force that keeps an object “stuck” on a surface and <b>prevent it from moving</b>.          (frictional force before the object starts moving, <math>v = 0 \text{ ms}^{-1}</math>)</p> <p>b) <b>Direction :</b>          It points <b>opposite the direction of tendency of motion</b>. (it points in the direction to <b>prevent the motion</b>)</p> <p>c) <b>Keywords use in exam :</b></p> <ul style="list-style-type: none"> <li>- When the object is about to move</li> <li>- When the object starts to move</li> <li>- Just before the object begins to move</li> </ul> <p><b>Kinetic friction, <math>\vec{f}_k</math></b></p> <p>a) Kinetic friction appears as an <b>object moves</b> across a surface.</p> <p>b) This is a force that “<b>opposes the motion</b>”.</p> <p>c) <b>Direction :</b>          It points <b>opposite direction</b> to the velocity (“the motion”).</p>

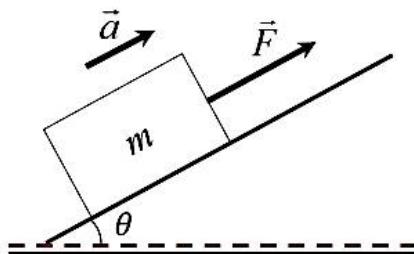
Force	Explanation	Diagram
<b>External Force</b>	<p>External force is a <b>push or a pull</b> on the object.</p> <p><b>Direction :</b> Any direction depends on the situation given in the question.</p>	<p><b>Example :</b> Figure below shows a 500 N force, <math>F</math> act on a stationary box at an angle of <math>\theta</math> :</p>

**LO 3.3 b) Sketch free body diagram**

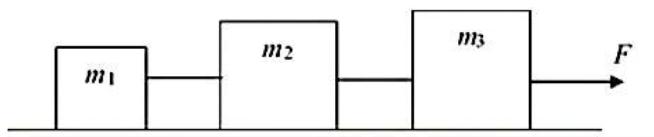
- A **free body diagram** represents an object as a **particle (or dot)** and it shows all the forces acting on the object.
- Example of free body diagram :  
A box of mass  $m$  is pulled along a horizontal surface by a force  $F$ , applied at an angle  $\theta$  above the horizontal. Assume that the surface is **rough**.

**Example 6**

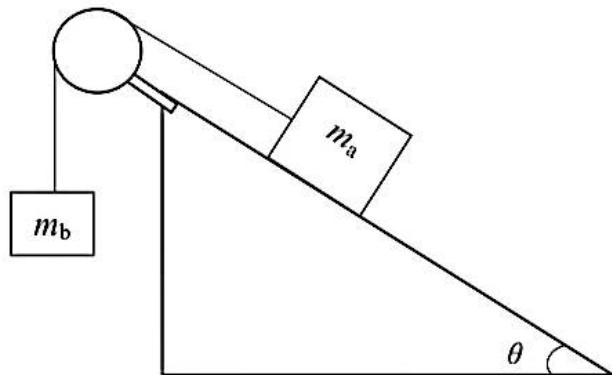
- Identify all forces acting in each of the situation below.
  - A box is pulled up along a rough inclined plane by force,  $F$ .



- Three blocks of masses  $m_1$ ,  $m_2$  and  $m_3$  are connected by strings and pulled by a force  $F$  on a **smooth** horizontal surface.



- b) A box of mass  $m_a$  rest on a rough surface inclined at  $\theta$  to the horizontal. The system is at rest. Assume  $m_b > m_a$ .



### LO 3.3 c) Determine static and kinetic friction

Static Friction, $f_s$	Kinetic Friction, $f_k$
Both forces oppose the relative motion between two rough surfaces which are in contact	
<ul style="list-style-type: none"> <li>exists when object in contact is <b>not moving/ stationary</b>.</li> <li>If the object is not moving, the <b>total (net) force acted on the object is zero</b>.</li> </ul> $\sum F = F_{net} = 0$	<ul style="list-style-type: none"> <li>exists when object in contact is <b>moving</b>.</li> <li>If the object is moving with constant velocity, the <b>total (net) force acted on the object is zero</b>.</li> </ul> $\sum F = F_{net} = 0 \text{ (constant velocity)}$ <ul style="list-style-type: none"> <li>If the object is moving with constant acceleration, the <b>total (net) force acted on the object is :</b></li> </ul> $\sum F = F_{net} = ma \text{ (constant acceleration)}$

### Example 7

A 3.0 kg cube is placed on a rough plane as shown in the figure. The plane is then slowly tilted until the cube starts to move from rest. This occurred when the angle of inclination is  $25^\circ$ . Calculate the **static frictional force** between the cube and the rough plane.

[Answer : 12.44 N]

