# CHAPTER 5 | Applying Newton's Laws

# CONTENTS

# 1. USING NEWTON'S FIRST LAW: PARTICLES IN EQUILIBRIUM

**Equilibrium:**

$$\sum \vec{F} = 0 \Rightarrow \vec{a} = 0$$

$$\sum F_x = 0 \quad and \quad \sum F_y = 0$$

1. **The object stays at rest, (static equilibrium):**

$$\vec{v} = 0 \Rightarrow \vec{a} = 0$$

2. **The object moves with constant velocity (dynamic equilibrium):**

$$\vec{v} = \text{constant} \Rightarrow \vec{a} = 0$$

# Example 5.1:

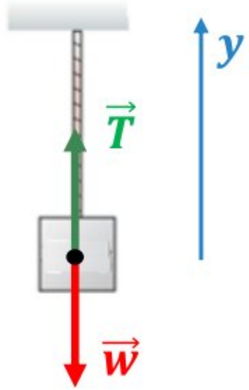
**A 100 Kg block with a weight of 980 N hangs on a rope. Find the tension in the rope if:**

**(a) the block is at rest**

$$\sum F_y = 0$$

$$T - w = 0$$

$$\boxed{T = w = 980\ N}$$

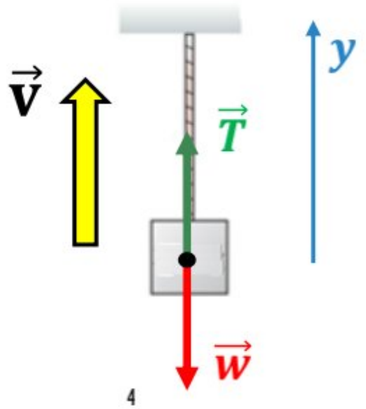



**(b) it's moving upward at a constant speed of $5\ m/s$**

$$\sum F_y = 0$$

$$T - w = 0$$

$$\boxed{T = w = 980\ N}$$



# 2. USING NEWTON'S SECOND LAW: DYNAMICS OF PARTICLES

**The formal statement of Newton's second law is:**

$$\sum \vec{F} = m\,\vec{a}$$

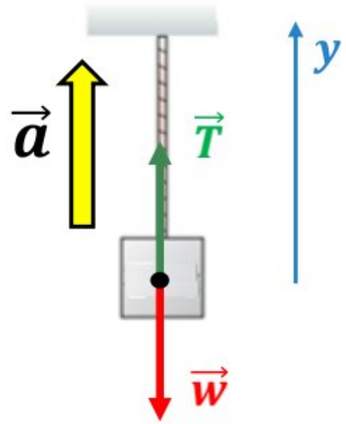
**In component form:**

$$\sum F_x = ma_x \quad and \quad \sum F_y = ma_y$$

**Note that if know the direction of the acceleration, it usually simplifies things to take one positive axis along that direction**

# Example 5.2:

**A $100\ \mathrm{kg}$ block with a weight of $980\ \mathrm{N}$ hangs on a rope. Find the tension in the rope if the block is accelerating upward at $5\ m/s^2$**




$$\sum F_y = ma_y$$

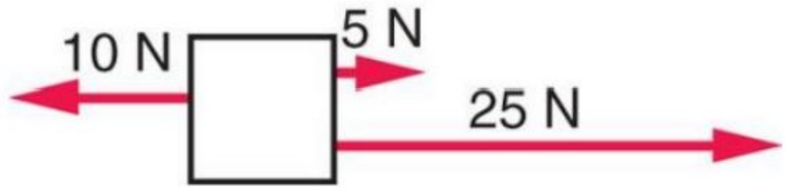
$$T - w = ma_y$$

$$T = ma_y + w$$

$$T = 100 \times 5 + 980 = 1480\ N$$

# Example 5.3

**A 4-kg block is acted on by three horizontal forces.**




**(a) What is the net horizontal force acting on the block?**

**Solution:**

$$\sum F_x = 25 + 5 - 10 = 20\ N$$

**(b) What is the acceleration of the block?**

$$\sum F_x = ma_x$$

$$20 = 4\ a_x$$

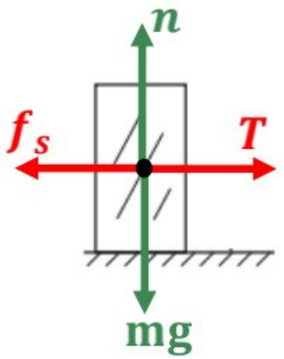
$$a_x = \frac{20}{4} = 5\ \mathrm{m/s^2}$$

# 3. FRICTION FORCES

There are two kinds of friction:

1- static friction ($f_s$): when the object at rest.

$$f_s = \mathrm{T}$$




The maximum friction force is given by:

$$f_{s,max} = \mu_s n$$

If both the surface and the applied force are horizontal, the normal force ($n$) is:

$$n = \mathrm{mg}$$

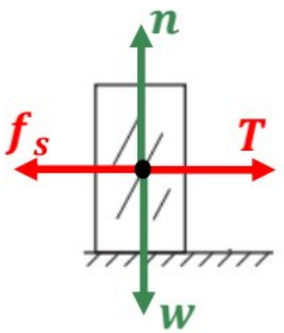
2- kinetic friction ($f_k$): when the object is moving.

$$f_k = \mu_k n$$

Where $\mu_s$ and $\mu_k$ are the coefficients of static and kinetic friction forces, respectively.

## Example 5.4:

A $50\ \mathrm{kg}$ crate is at rest on a rough horizontal floor when it is pulled by a horizontal rope with tension $T = 50N$. What is the friction force?




$$f_s = T = 50N$$

## Example 5.5:

A box of mass $15.5\ \mathrm{kg}$ is at rest on a rough horizontal floor. If the coefficient of static friction between the box and the floor is 0.34, what is the maximum friction force?

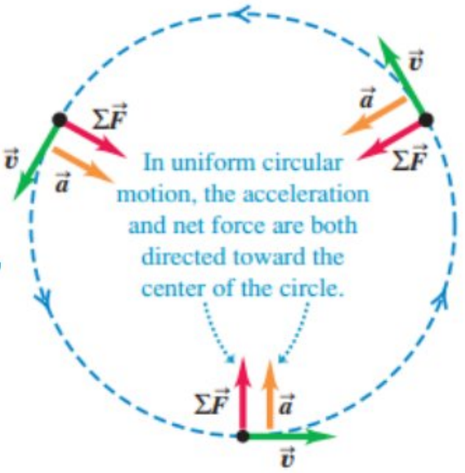
$$n = mg = 15.5 \times 9.8 = 152\ N$$

$$f_{s,max} = \mu_s n = 0.34 \times 152 = 52\ N$$

# 4. DYNAMICS OF CIRCULAR MOTION

The magnitude of the centripetal acceleration $a_c$ is given in terms of the speed $v$ and the radius $R$ of the circle by

$$a_c = \frac{v^2}{R}$$




The centripetal force that experience that acceleration is gi by

$$F_c = ma_c = m\frac{v^2}{R}$$

**Example 5.6:**

A $3\ \text{kg}$ rock swings in a circle of radius $5m$. If its constant speed is $8\ m/s$, find centripetal force acting on the rock ?

$$F_c = m\frac{v^2}{R} = 3 \times \frac{8^2}{5} = 38.4\ N$$