FREE-BODY DIAGRAMS

Free-body diagrams is a convenient way to keep track of forces acting on a system.

يشكل مخطط الجسم الحر أسلوبا مناسبا للتعامل مع القوى المؤثرة على جسم ما.

A force acts in a specific direction with a magnitude that depends on the strength of the push or pull. Because of these characteristics, forces have both direction and magnitude.
This means that forces follow a different set of mathematical rules than do quantities that do not have direction.

For example, when determining what happens when two forces act on the same object, it is necessary to know both the magnitude and the direction of both forces to determine the resultant force.

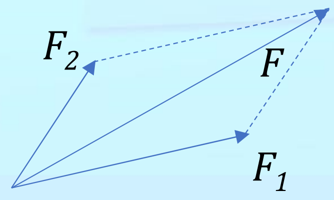
Ideally, these diagrams are drawn with the direction angles and relative magnitudes of the forces listed so that graphical addition can be done to determine the resultant force

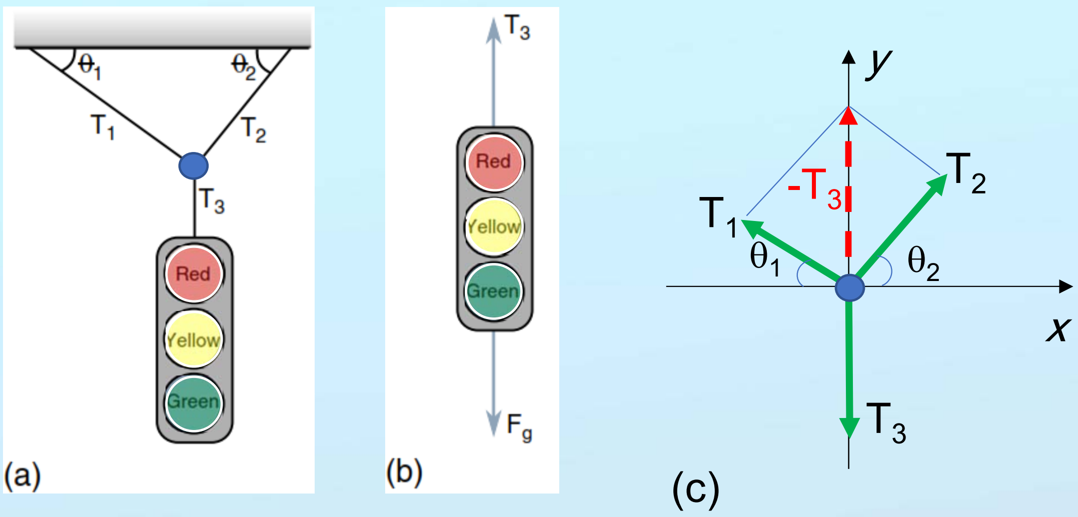
When two forces act on an object, the resultant force can be determined by what is called the ***parallelogram rule of addition***.

The addition of two forces represented by sides of a parallelogram gives a resultant force that is equal in magnitude and direction to the diagonal of the parallelogram.

For example, in Fig. the resultant

$$\vec{F} = \vec{F_1} + \vec{F_2}$$



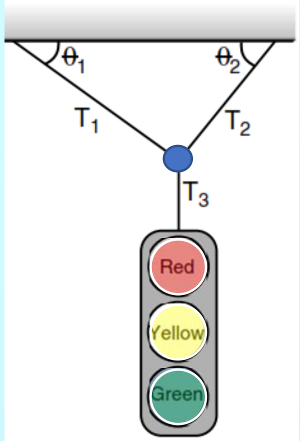


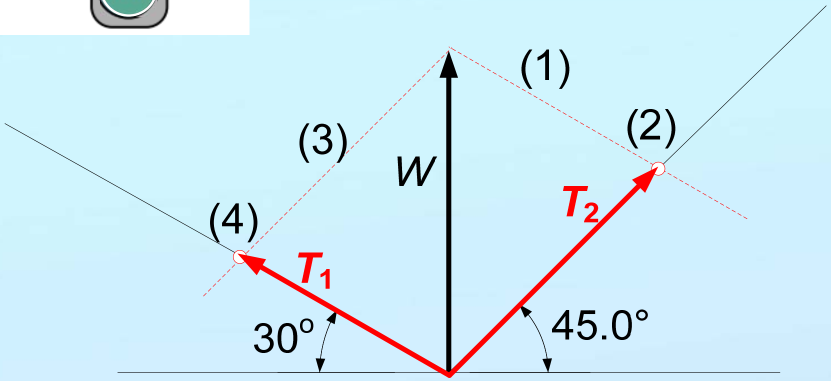
Free- body diagram of a traffic light suspension system;
(a) Geometry of the cables holding the light,
(b) resultant forces on the light, and
(c) force diagram for the forces acting on the ring joining cables

a) جيومتري الإشارة المعلقة والحبال الحاملة.
b) القوى المؤثرة مباشرة على الإشارة الضوئية.
c) القوى المؤثرة على حلقة جمع الحبال.

مثال عن مخطط الجسم الحر لإشارة مرور ضوئية معلقة.

Example 1. If the traffic light weight is W=250 N and θ_1=30°, θ_2=45°, find graphically the magnitudes T_1 and T_2, representing the tensions in the two cables holding the traffic light. Then verify your answers using the sines formula.

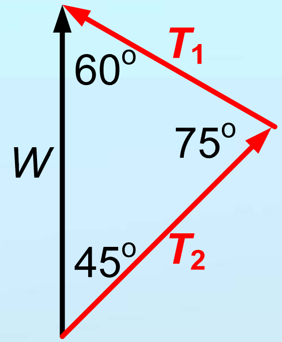




W=250 N [scaled by 5 cm]

T_1 [scaled by 4.5 cm]=(250/5)(4.5)=225 N

T_2 [scaled by 3.7 cm]=(250/5)(3.7)=185 N

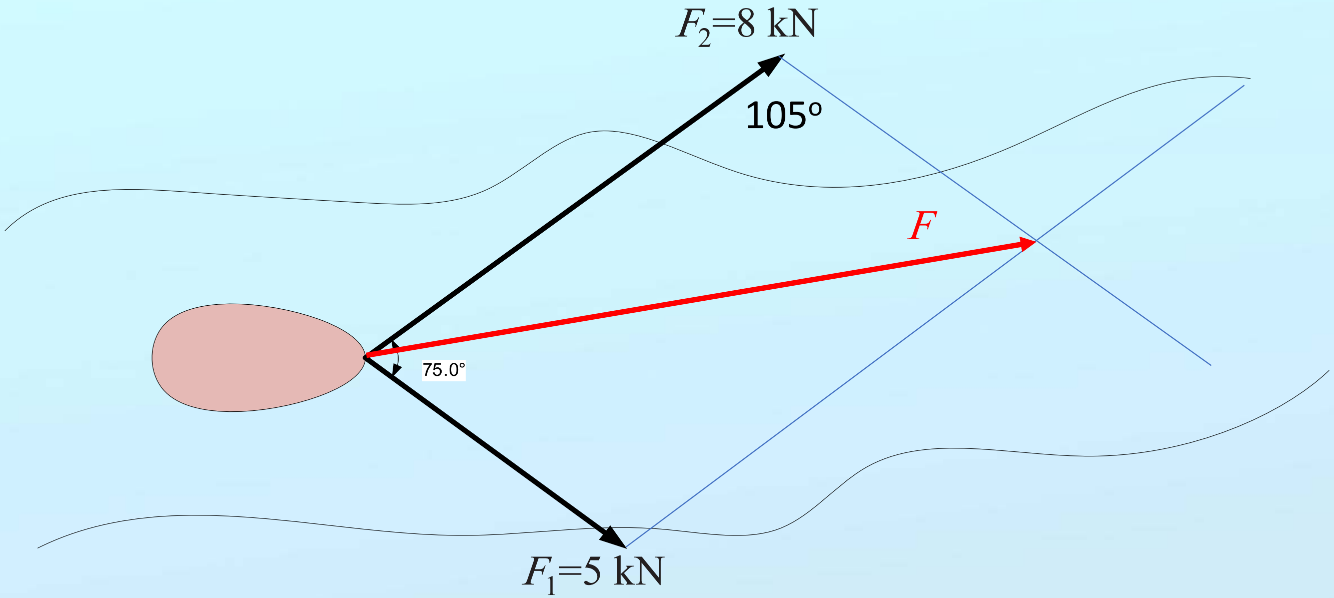


$$\frac{W}{\sin 75^o}=\frac{T_1}{\sin 45^o}=\frac{T_2}{\sin 60^o}$$

$$T_1=\frac{W\sin 45^o}{\sin 75^o}=\frac{250\sin 45^o}{\sin 75^o}=183\text{ N}$$

$$T_2=\frac{W\sin 60^o}{\sin 75^o}=\frac{250\sin 60^o}{\sin 75^o}=224\text{ N}$$

Example 2. A boat is towed by two cables as in the figure if the tension in first cable is F_1=5 kN and in the second cable is F_2=8 kN, if the angle between the cables is θ=75º, find graphically the resultant F of the tensions. Then check your answer using the cosine formula.



F [scaled]=??? N

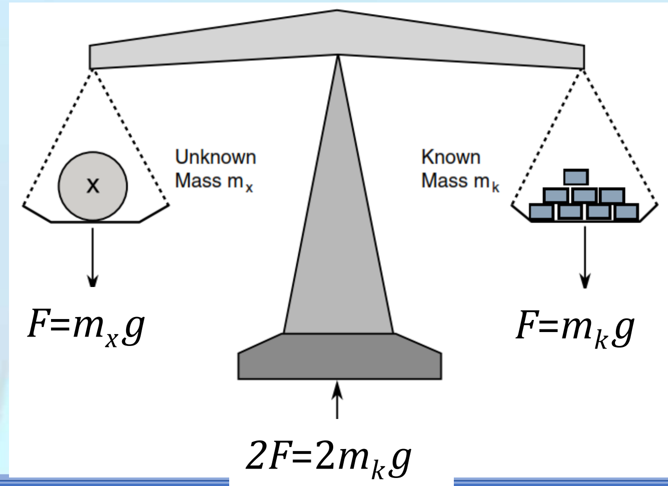
$$F^2 = F_1^2 + F_2^2 - 2F_1F_2 \cos 105^0$$
$$F = \sqrt{F_1^2 + F_2^2 - 2F_1F_2 \cos 105^0} = 10.47 = 10.5\ N$$

STATIC EQUILIBRIUM

The simplest case of static equilibrium occurs when two forces are equal in magnitude but opposite in direction. For example, an object on a level surface is pulled downward by the force of gravity (i.e., its weight). At the same time, the surface under the object resists the object's downward force with an equal upward force. This condition is one of zero net force and no acceleration.

Pushing horizontally on an object on a horizontal surface can result in a situation where the object does not move because the applied force is opposed by a force of static friction between the object and the surface. In this case, the static friction force balances the applied force resulting in no acceleration.

Static equilibrium between two forces is a common way of measuring the force of gravity (i.e., weight). This can be done using balance scales, as shown in Fig.



DYNAMIC EQUILIBRIUM

The definition of *dynamic equilibrium* is when an object moves at a constant speed, and all the forces on the object are balanced. A simple case of dynamic equilibrium occurs when a horizontal force is applied to an object causing it to move with a constant speed across a horizontal surface.

In this case, the applied force is in the direction of motion, while a friction force in the opposite direction balances the applied force, producing no unbalanced force on the object. The object continues to move with a constant speed, as in Fig.