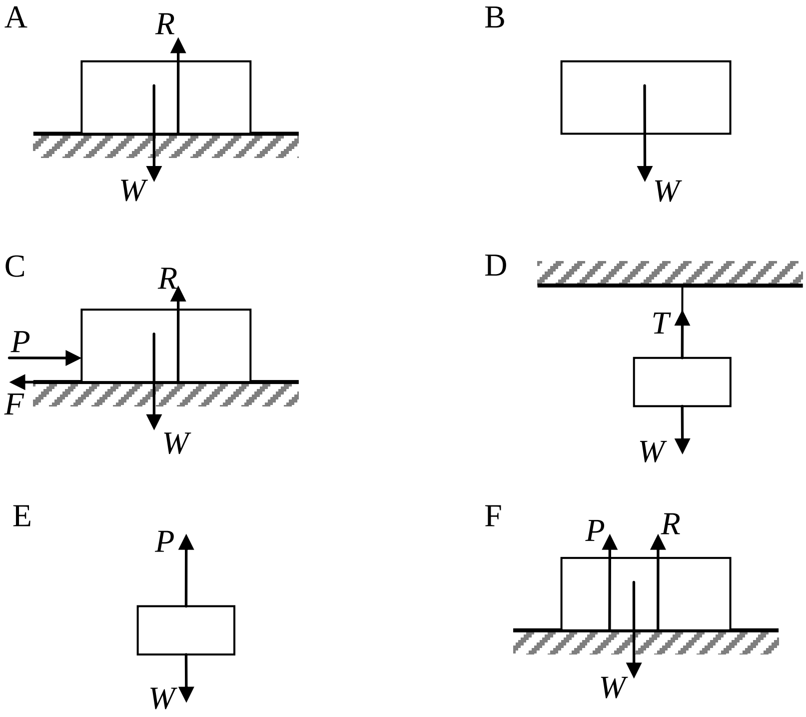
Section 1: Force diagrams and equilibrium

Section test

1. In the diagrams below, R stands for Reaction, W stands for Weight, T stands for Tension, P is an additional force and F stands for Friction.



Which of the force diagrams could represent a ball in flight, if there is no air resistance?

Which two force diagrams could represent a suitcase standing at rest on a smooth floor?

Which force diagram could represent a suitcase being pushed across a rough floor?

Which force diagram could represent a glider flying at constant velocity, assuming negligible air resistance?

Which force diagram could represent a rocket, just after the engines have ignited, but before it begins to leave the ground?

Which force diagram could represent a spider hanging by a thread?

Which force diagram could represent a puck sliding across perfectly smooth ice, assuming no air resistance?

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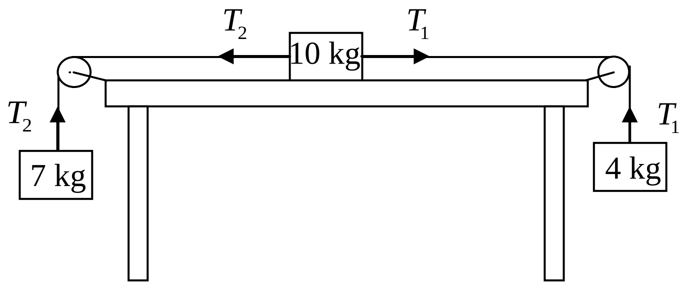
2. In the diagram below, the pulleys are assumed frictionless. The acceleration due to gravity is g.



If the system is in equilibrium, what is the size of the tension T_2?

If the system is in equilibrium, there must also be a friction force acting between the 10 kg block and the table. What is this friction force?

If the maximum frictional force is F and it is not sufficient for the system to remain in equilibrium, what is the resultant force on the 10 kg mass?

(a) $T_2 + T_1$ (b) $T_2 - T_1 + F$

(c) $T_1 - T_2$ (d) $T_2 - T_1 - F$

3. A particle P of weight 20 N is suspended by two strings AP and BP. The tension in string AP is $\begin{pmatrix} a \\ 8 \end{pmatrix}$ and the tension in string BP is $\begin{pmatrix} 6 \\ b \end{pmatrix}$.

Find the values of a and b.

Find the magnitude of the tension in string AP.

Find the angle that the string BP makes with the vertical.

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Solutions to section test

1) If there is no air resistance, the only force acting on a ball in flight is its weight. This is shown in diagram B.

   If a suitcase is at rest, it must be in equilibrium. There must be a reaction force from the floor to balance its weight (diagrams A, C and F). Since the floor is smooth, there can be no frictional force, so diagram C is not possible. The two diagrams are therefore A and F. (The additional force in diagram F must not be so large that it causes the suitcase to move upwards).

   There must be a reaction force from the floor to balance the weight and, as the floor is rough, there will be a friction force in the opposite direction to the pushing force. This is diagram C.

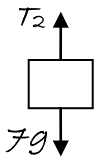
   If the glider is flying at constant velocity, it must be in equilibrium. If there is no air resistance, there cannot be a force pushing it along, otherwise its speed would increase. If it is at constant velocity, its altitude must be constant. Therefore there must be a lift force to balance its weight. This is diagram E.

   The rocket is not moving, so there will be no air resistance, but it is about to lift off, so there must be an additional upwards force, as well as the reaction force. This is diagram F.

   The tension in the thread will pull upward on the spider. The spider's weight will pull downwards. This is diagram D.

   If the ice is perfectly smooth, there will be no friction. If there is also no air resistance, the only forces on the puck will be its weight and the reaction force from the ice. This is diagram A.

2) If the system is in equilibrium, the forces on the 7 kg mass must balance.



$T_2 - 7g = 0$

$T_2 = 7g$

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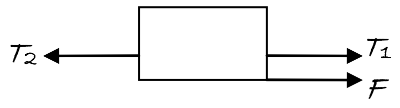


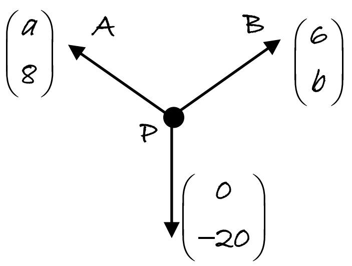
If the system is in equilibrium, $T_1 = 4g$ and $T_2 = 7g$.
As the 10 kg block does not move, $T_1 + F = T_2$

$$4g + F = 7g$$
$$F = 3g$$

So the frictional force is $3g$ N to the right.

If the frictional force is not sufficient for the system to remain in equilibrium, the 10 kg mass will move to the left due to a resultant force acting to the left. From the diagram in question 9, this resultant force is $T_2 - T_1 - F$

3)



Since the particle is in equilibrium, $\begin{pmatrix} a \\ 8 \end{pmatrix} + \begin{pmatrix} 6 \\ b \end{pmatrix} + \begin{pmatrix} 0 \\ -20 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}$

$a + 6 = 0 \quad \Rightarrow a = -6$

$8 + b - 20 = 0 \quad \Rightarrow b = 12$

Magnitude of $\begin{pmatrix} -6 \\ 8 \end{pmatrix}$ is $\sqrt{(-6)^2 + 8^2} = 10$ N

Angle of BP to vertical: $\tan\theta = \dfrac{6}{12}$

$$\theta = 26.6°$$