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Forces

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2.1 Forces, Equilibrium and Newton's First Law

Using Newton's laws of motion, describe static and dynamic interactions between two or more objects and the changes that result from a contact force – a force mediated by fields.

Types of forces

Contact forces

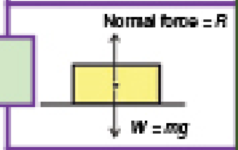
- **Applied forces**

Hitting a ball, punching a bag, kicking a ball, pushing a swing, opening a door, cutting bread, hammering a nail.

- **Frictional forces**

Between tyres and the road, slowing you down on a slide, makes hands warm when you rub them together.

- **Normal forces**



Upward force of floor on you as you stand, of chair on you as you sit, on book resting on table, also called reaction forces.

- **Drag forces**

Air resistance, slowing swimmers down, why objects fall slower through oil than through water, why there is terminal velocity.

- **Tension forces**

Bending a ruler, stretching a rubber band, pulling a bridge cable tight, twisting a bar, forces in ropes, cables, strings and wires.

- **Spring forces**

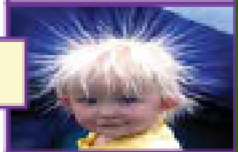
In springs that are compressed or stretched, act in opposite direction to the applied forces, compression or tension forces.

Forces acting at a distance

- **Magnetic forces**

Magnetic field surrounds magnets and electric currents, put magnetic forces on charges. Like magnetic poles repel, unlike poles attract.

- **Electrical forces**



Electric fields surround charges and apply forces to other charges. Like charges repel, unlike charges attract.

- **Gravitational forces**

Force of attraction between all masses in the Universe. Gives masses weight and often called weight force.

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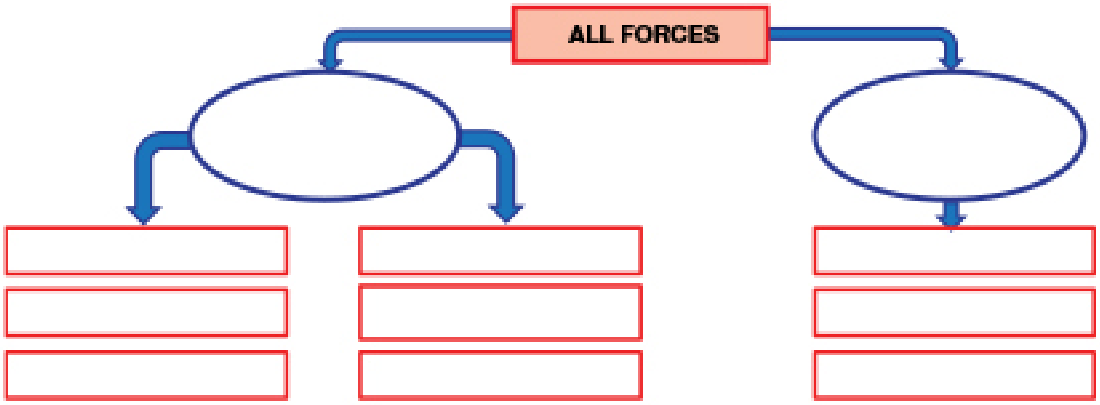
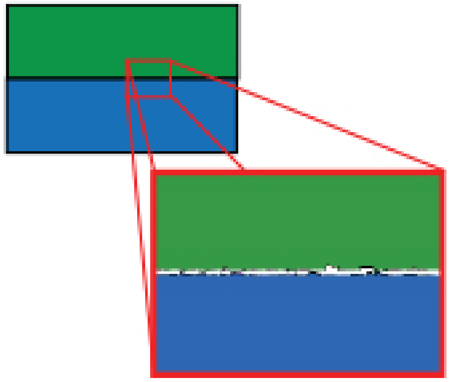
Sample Questions

1. Complete the diagram.



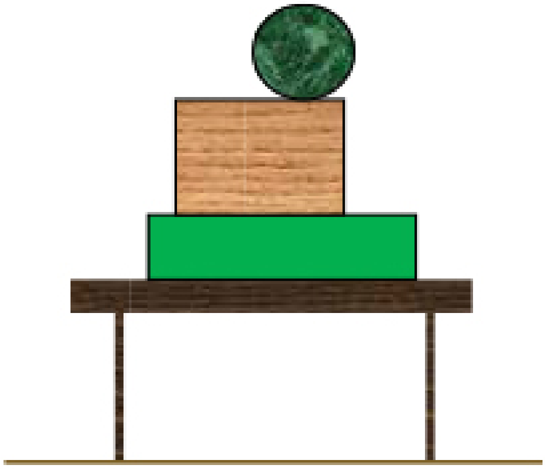
2. Explain, in terms of forces, what the diagram on the right is showing.



3. The diagram below shows three objects on top of each other on a table.

(a) On a copy of this diagram label four gravitational forces and four normal forces.

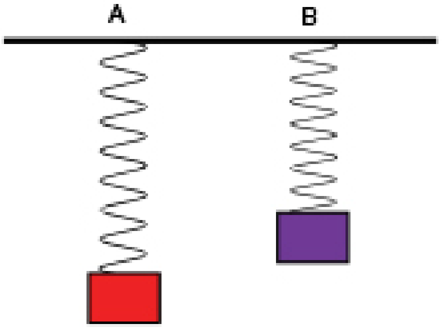
(b) Label each force.



4. The diagram shows the two different masses hanging on the same spring.

(a) Suggest a reason the spring is extended more in A than in B.

(b) Which spring will have the greater tension set up within it? Justify your answer.



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Equilibrium and Newton's first law

- A body is said to be in **equilibrium** if it is at **rest** or if it is **moving with uniform velocity**.
- Note that being in equilibrium does not mean that no forces act.
- When two or more forces act on a body which is in equilibrium, the net force must be zero.
- There will be no acceleration, but the body may still move with constant velocity.

The concept of equilibrium is the focus of **Newton's first law of motion**.

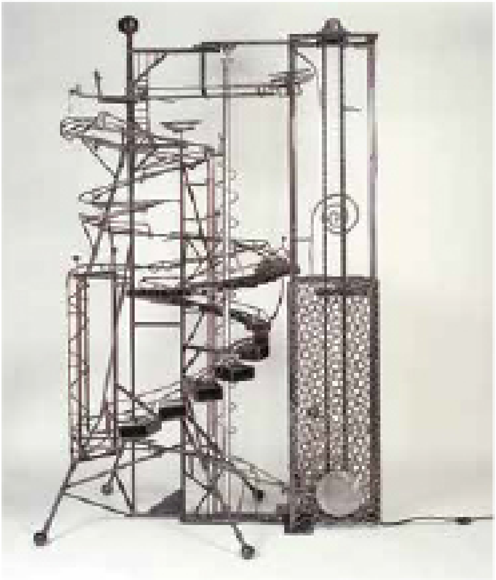
A body at rest, or moving with constant velocity, will remain at rest or moving with constant velocity unless an unbalanced force acts on it.

Types of equilibrium

- **Static equilibrium** exists if all the forces acting on a body add to zero, and the body is at rest.
  - A folder resting on your desk.
  - Your car parked in the school car park.
  - A can of drink sitting on a shelf in the fridge are all in static equilibrium.
- **Dynamic equilibrium** exists if all the forces acting on a body add to zero, and the body is moving at constant velocity.
  - A car moving at constant speed.
  - A parachute jumper falling towards the ground at constant (terminal) velocity.
  - A comet moving through space at constant velocity are all in dynamic equilibrium.

Sample *Questions*

1. State the conditions needed for translational equilibrium.
2. Explain the idea of static equilibrium.
3. Explain the idea of dynamic equilibrium.
4. Identify these as being in static or dynamic equilibrium or as not being in equilibrium.
   (a) Light fitting hanging from the ceiling.
   (b) Ski jumper moving down the slope towards the jumping ramp.
   (c) Plane taking off.
   (d) A computer on your desk.
   (e) Tree branches swaying in the wind.
   (f) Mudslide down the side of a hill.
   (g) Apollo 11 coasting between the Earth and the Moon.
   (h) Arrow poised in bow ready to fire.
   (i) Car travelling at constant speed up hill.
   (j) Car travelling at constant speed on flat road.
   (k) Car travelling at constant speed down hill.



At the moment the ball at the top of this mechanical maze is in static equilibrium – but … touch it and the equilibrium might be lost.

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2.2/3 Forces In One and Two Dimensions

Explore the concept of net force and equilibrium in one-dimensional and two-dimensional contexts using algebraic addition, vector addition and vector addition by resolution into components. Apply the following relationships, solve problems or make quantitative predictions about resultant and component forces using $F_x = F\cos\theta$ and $F_y = F\sin\theta$.

Forces in one and two dimensions – vector revision

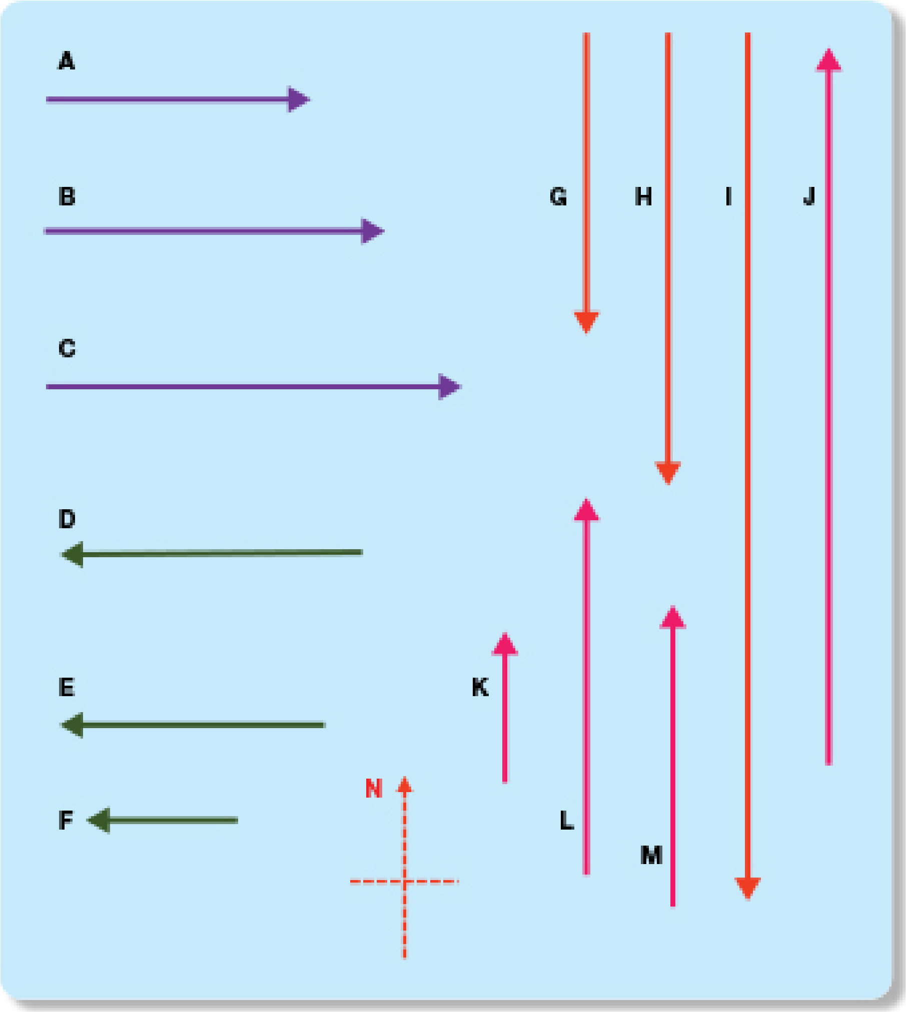
- **Forces are vector quantities** and can therefore be represented by scale diagrams.
- Force is measured in **newtons**, symbol **N.**

Sample *Questions*

Refresh your skills by doing the questions below which refer to the force vectors in the diagram.

The vectors have been drawn using a scale where 1 cm = 10 N. In answering the questions, make all measurements to the nearest 0.5 cm. Give all directions as bearings to the nearest degree.

1. A + B
2. C – D
3. E + F
4. G – B
5. D + H
6. E – K
7. A + C + E
8. I + J + K
9. E + F – D
10. M – L – H
11. G + D
12. K – C
13. I + B
14. L – A
15. D + J
16. G + 2J
17. M – C
18. I – A
19. K + B
20. L – E



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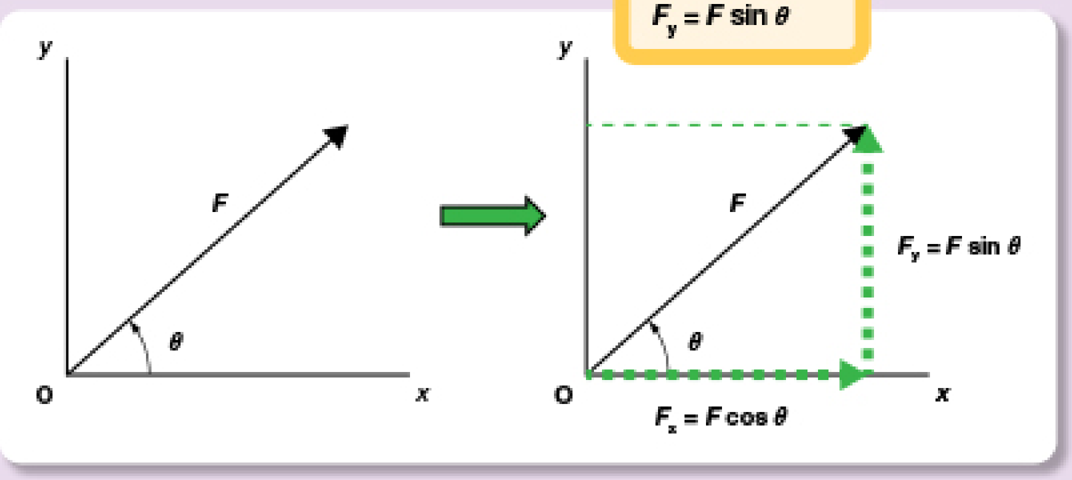
Forces in two dimensions 1

- Like all vector quantities, forces can be resolved into two perpendicular components in the *x* and *y* directions.
- The two force components are given by the equations:

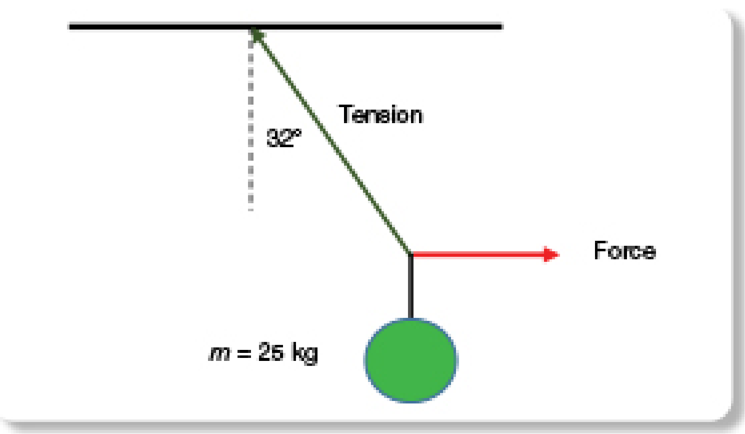
$$F_x = F\cos\theta$$
$$F_y = F\sin\theta$$



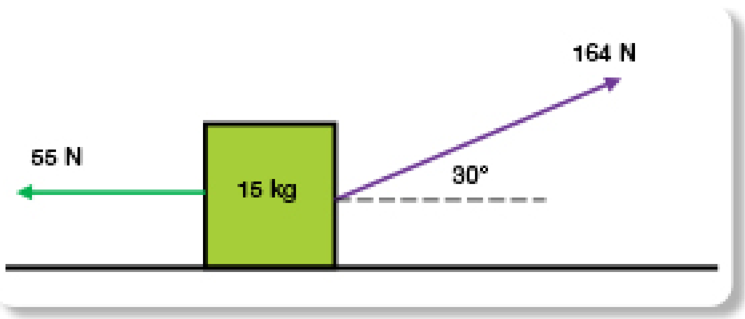
Sample Questions

Each of the following diagrams show masses in static equilibrium. Using your knowledge of components of vectors, analyse each situation to determine the unknown quantities.

1. A mass of 25 kg hangs on a string which is pulled to the side by force *F* until the string makes an angle of 32° to the vertical.
   (a) What is the force pulling the supporting string to the side?
   (b) What is the tension in the rope?



2. The diagram shows the forces acting on a 15 kg mass on a smooth surface.
   (a) Calculate the resultant force on the object.
   (b) What will be its acceleration?
   (c) How fast will it be going after 2.5 s?
   (d) Calculate the normal reaction force of the surface on the mass.



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