Physics

Key Stage 4

Your name:

Your tutor's name:

BRILLIANT TUTORING PROGRAMME

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Module 4 - Force

In this module you'll look at diagrams, resolving forces and understanding Hooke's law.

Tutorial	Topic
Tutorial 4.1	Forces
Tutorial 4.2	Resultant forces
Tutorial 4.3	Resolution of forces
Tutorial 4.4	Force and elasticity

Learning objectives

In this module you will look at:

1. Drawing and understanding free body diagrams
2. Resolving forces
3. Understanding Hooke's law

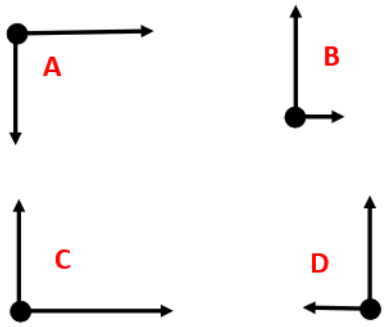
Knowledge Check #1

You will complete this at the start and end of each module. You should complete these using this online form if you can:

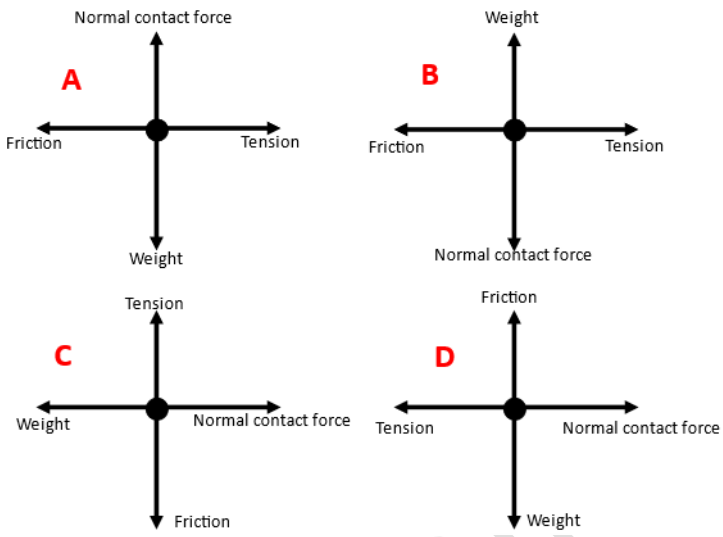
https://forms.office.com/r/WFRipbmwY1

If you can't complete the questions online, you can do it here:

1. Select which diagram below could represent an object experiencing a 2 N vertical force upwards and a 3 N horizontal force towards the right.
   a) A
   b) B
   c) C
   d) D

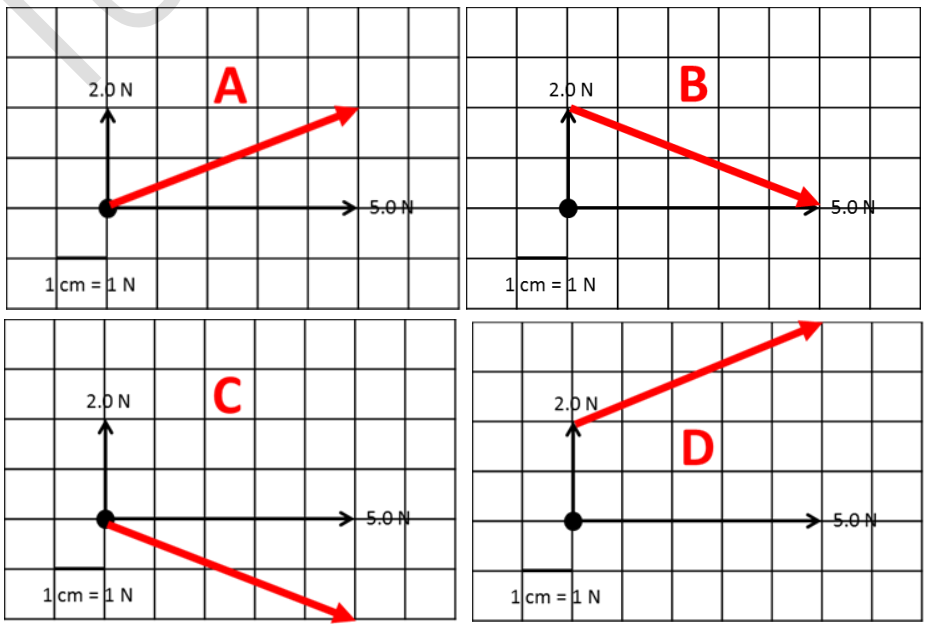


2. A block is pulled by a string towards the right across a surface. The free body diagram shows the forces acting on the block. Which diagram labels the forces correctly?
   a) A
   b) B
   c) C
   d) D

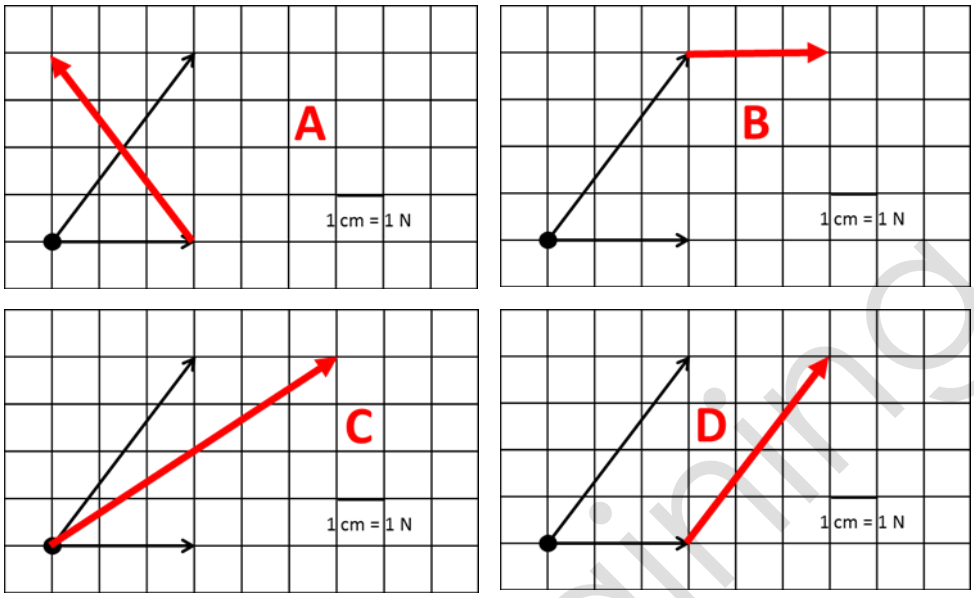


3. Calculate the weight of an object of mass 5 kg on Earth. The gravitational field strength is 10 N/kg
   a) 5 N
   b) 10 N
   c) 15 N
   d) 50 N
4. The free body diagram shown below shows the forces acing on an object. State the magnitude and direction of the resultant force on the body.
   a) 7 N to the left
   b) 3 N to the right
   c) 7 N to the right
   d) 3 N to the left

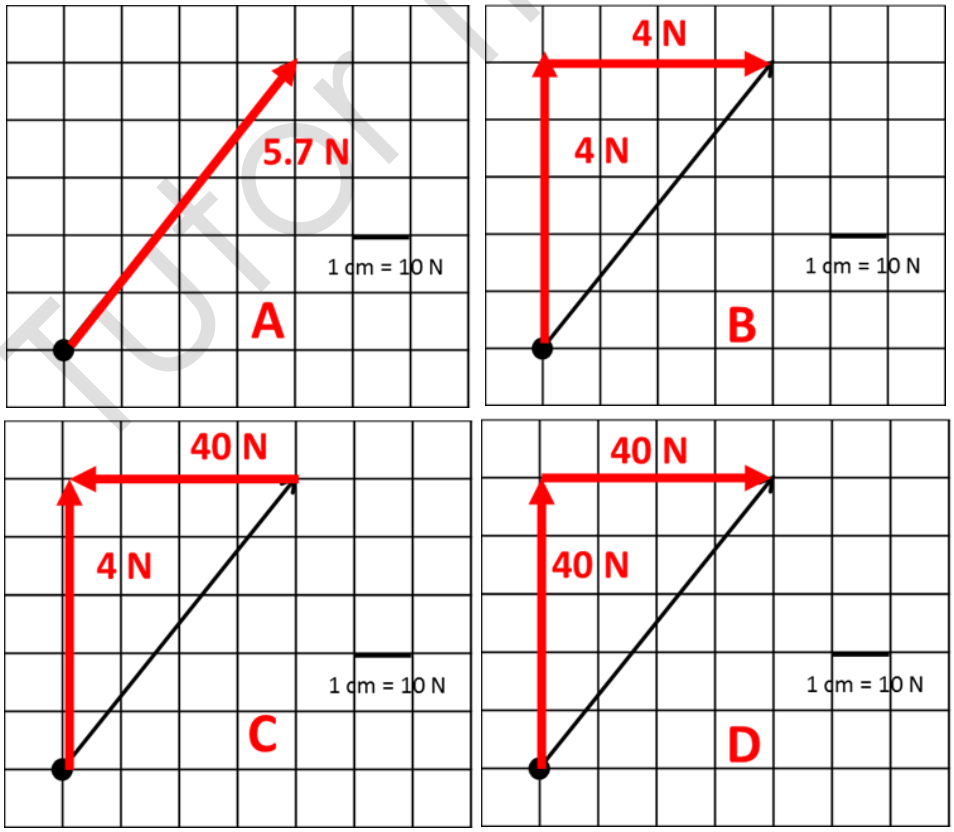
5. These vector diagram below shows the forces acting on an object. Which red arrow correctly shows the resulting forces on the body?
   a) A
   b) B
   c) C
   d) D



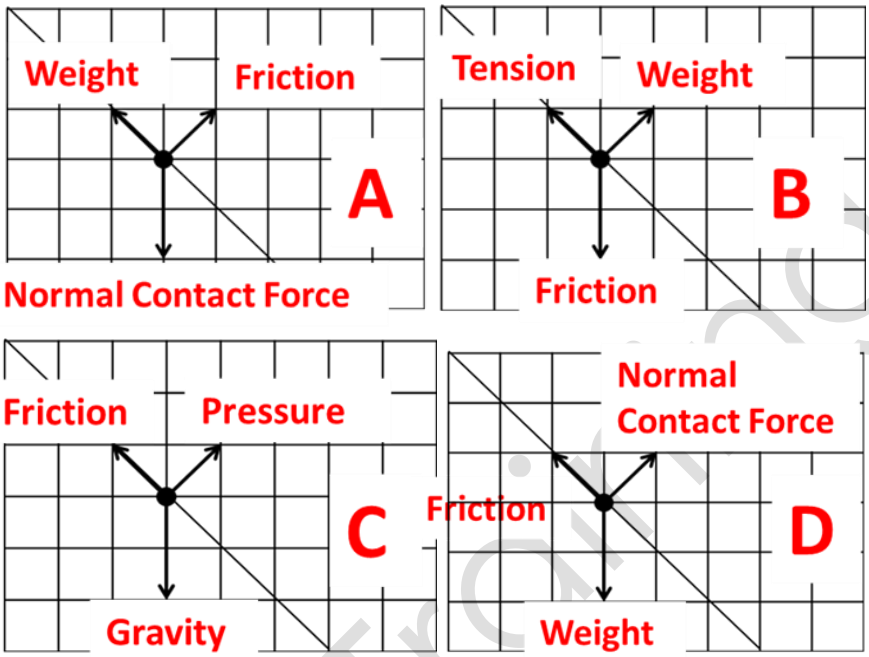
6. The vector diagram below shows the forces acting on an object. Which red arrow correctly shows the resultant force acting on the body.
   a) A
   b) B
   c) C
   d) D



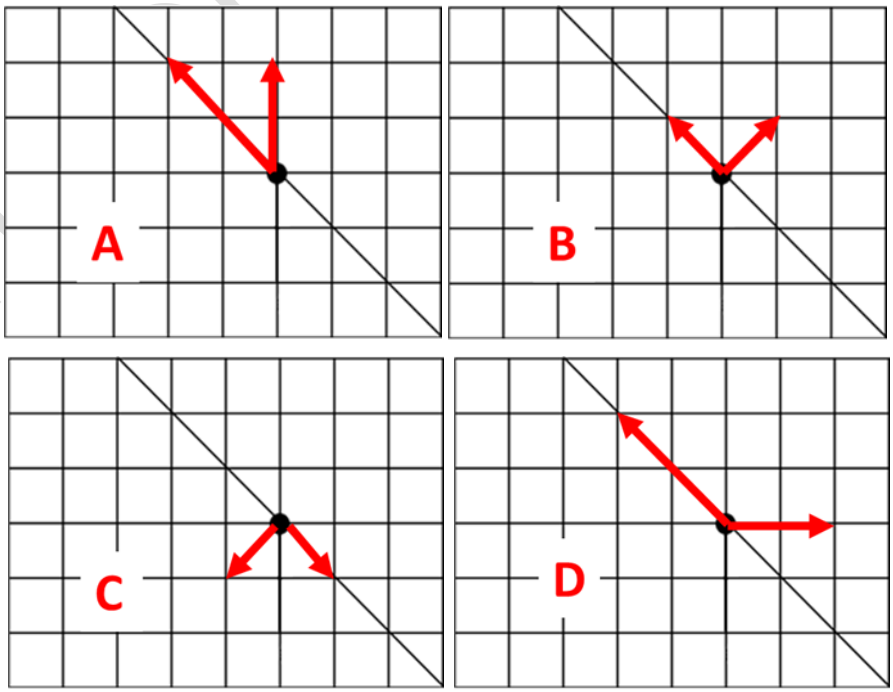
7. The vector diagram below shows a force acting on an object. Resolve the force into its vertical and horizontal components. Select the diagram that correctly shows these components.
   a) A
   b) B
   c) C
   d) D



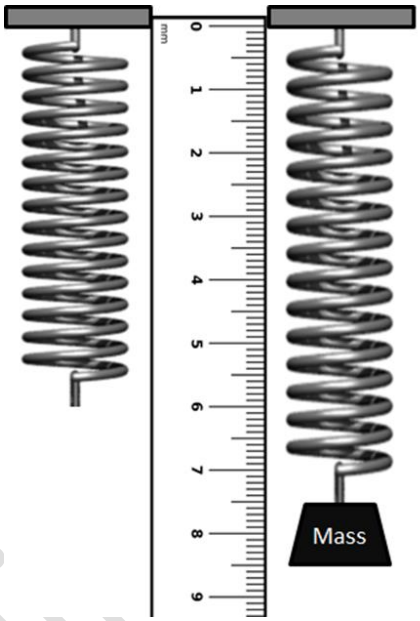
8. The free-body diagram below shows the forces acting on a block sitting at rest on a ramp. Select the diagram with the correctly named forces acting on the block.
   a) A
   b) B
   c) C
   d) D



9. The vector diagram shows the weight of a block on a ramp. Resolve the weight into components that are parallel and perpendicular to the ramp. Select from the diagrams below which shows the resolved components correctly.
   a) A
   b) B
   c) C
   d) D



10. The figure shows a spring before (left) and after (right) it has been extended. Determine the extension of the spring.



    a) 25mm
    b) 15 mm
    c) 25 cm
    d) 15 cm
11. Which statement correctly and fully describes Hooke's Law?
    a) The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.
    b) A spring will stretch if a weight is applied to one end.
    c) A spring will be stretched only if it is held vertically and a large weight in attached to one end.
    d) A heavy weight applied to a spring held vertically does not influence the amount of extension in the spring.
12. A force of 50 N is applied to a spring of stiffness 1000 N/m. Calculate the extension of the spring.
    a) 20 m
    b) 5 cm
    c) 20 cm
    d) 50,000 m

Tutorial 4.1 - Forces

YOU WILL NEED SOME EXTRA PAPER FOR THIS TUTORIAL

In this tutorial you will look at:

1. Free body diagrams
2. Examples of forces
3. Weight

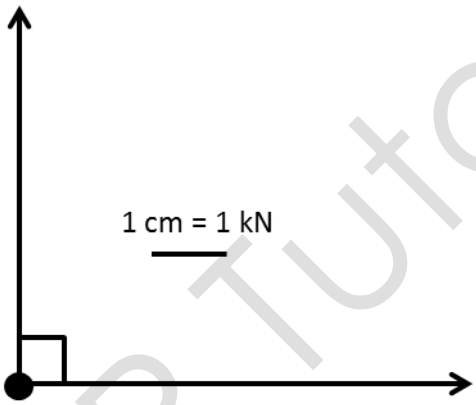
Learning activities

1

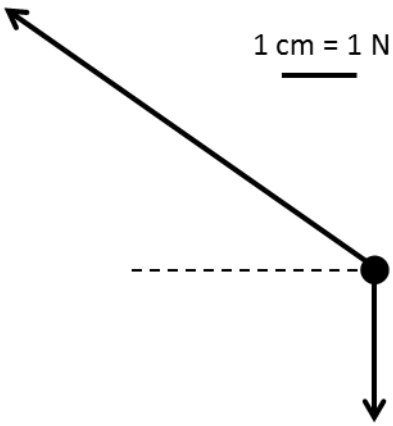
Free body diagrams

Describe the forces acting on the object in each free body diagram.

1 cm = 1 N



1 cm = 1 kN



1 cm = 1 N

On a separate piece of paper, draw a free body diagram to scale for the following situations:

a) A 5 N force acting vertically upward on a body, and a 10 N force acting vertically downward.

b) A 7 kN force acting horizontally to the left on a body, and a 9 kN force acting horizontally to the right.

c) A 6 N force acting leftward on a body at 30 degrees to the horizontal, and a 3 N force acting vertically upward.

2

Examples of force

1. Describe situations in which the following forces are present:

   a) Friction
   b) Air resistance
   c) Water resistance
   d) Tension
   e) Upthrust
   f) Lift
   g) Normal contact force
   h) Gravitational force (weight)
   i) Electrostatic force
   j) Magnetic force

2. A mass is suspended from a wire. The weight of the mass is 10 N. The tension force exerted on the mass due to the wire is 10 N. Draw a free body diagram to scale representing this situation. Label the forces.

3. A car moves along a road. The weight of the car is 10 kN and the normal contact force on the car due to the road is 10 kN. The forward force on the car is 1 kN and the resistive forces on the car sum to 0.5 kN. Draw a free body diagram to scale representing this situation. Label the forces.

4. A toy boat moves along the surface of a lake. The weight of the boat is 5 N and the upthrust is 5 N. The thrust on the boat 2 N and the drag is 1 N. Draw a free body diagram to scale representing this situation. Label the forces.

3

Weight

1. Complete the table for a 70 kg astronaut on each planet in the Solar System.

Planet	g (N/kg)	Mass (kg)	Weight (N)
Mercury	3.7		
Venus	8.8		
Earth	9.8		
Mars	3.7		
Jupiter	24.7		
Saturn	10.5		
Uranus	9.0		
Neptune	11.7		

2. Calculate the weight of the following objects on Earth:

   a) A particle of baking powder of mass 2 μg

   b) An ant of mass 3 mg

   c) An apple of mass 100 g

   d) A box of mass 5 kg

   e) A car of mass 1 x 103 kg

3. Calculate the mass of the following objects:

   a) A person on Earth that weighs 100 N

   b) A boulder on Mars that weighs 2000 N

   c) A lorry on Earth that weighs 5000 N

   d) A boulder on Venus that weighs 1000 N

Tutorial 4.2 – Resultant forces

In this tutorial you will look at:

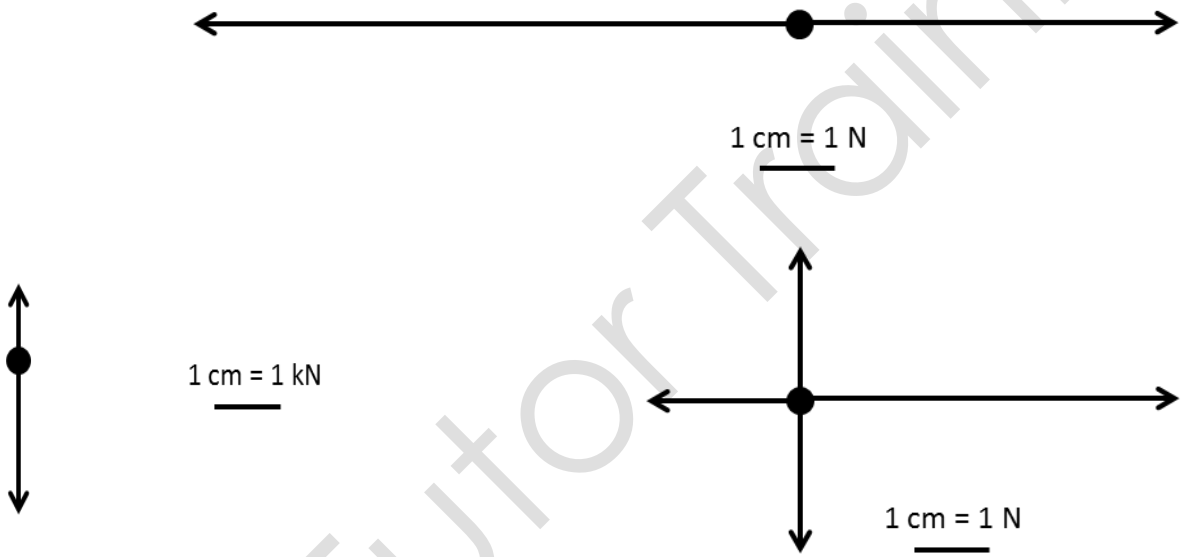
1. Finding resultant force for forces acting along a line
2. Finding resultant force for forces acting at right angles
3. Finding resultant force for forces at an angle to each other

Learning Activities

1

Finding resultant force for forces acting along a line

1. Determine the resultant force in each case:



2. A sky diver jumps out of a plane. The weight of the skydiver is 700 N. The air resistance acting on the skydiver is 200 N.

   a) Draw a free body diagram for the skydiver.

   b) Determine the resultant force on the skydiver.

   c) Draw a free body diagram showing the resultant force on the skydiver.

3. A car is driving along a road. The weight of the car is 2 kN. The normal contact force on the car is 2 kN. The resistive forces acting on the car are 0.1 kN. The forward force on the car is 0.2 kN.

a) Draw a free body diagram for the car.

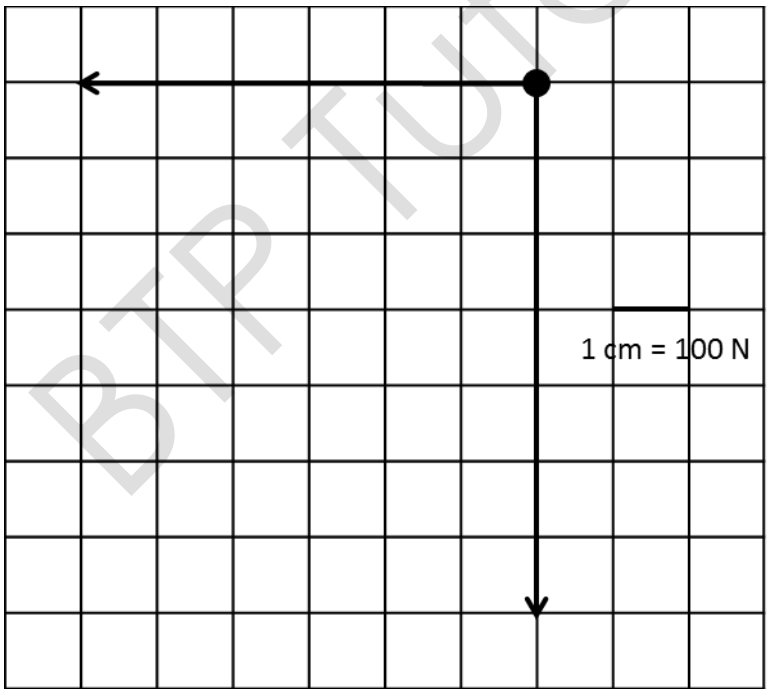
b) Determine the resultant force on the car.

c) Draw a free body diagram showing the resultant force on the car.

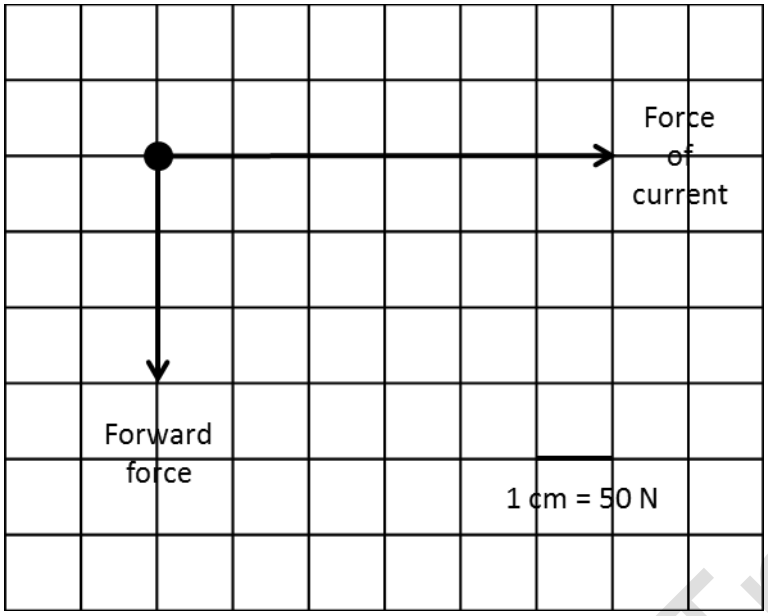
2

Finding resultant force for forces acting at right angles

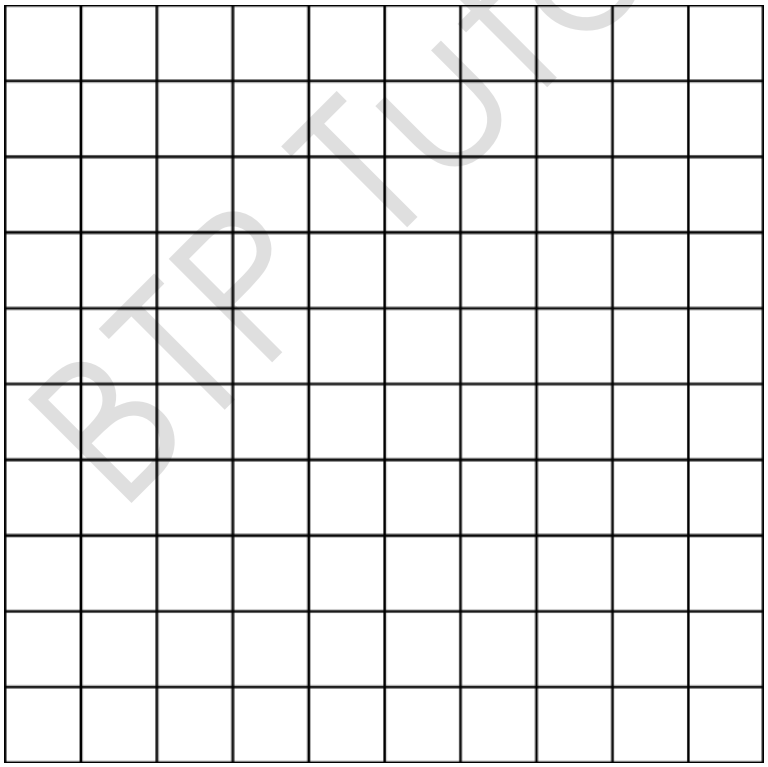
1. A boat is pulled by two tugboats. The forces applied by the tugboats are shown in the vector diagram below. Determine the resultant force on the boat.



2. A swimmer crosses a river. The forward force on the swimmer and the force due to the current is shown in the vector diagram. Determine the resultant force on the swimmer.

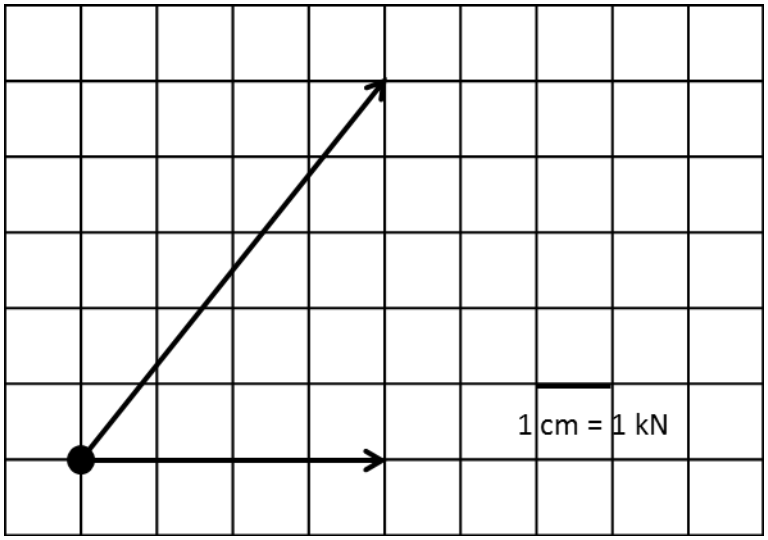


3. An aircraft flies eastward and encounters a northward wind. The forward force on the aircraft is 10 kN. The wind exerts a force of 5 kN on the aircraft. Draw a vector diagram for this situation and determine the resultant force on the aircraft.

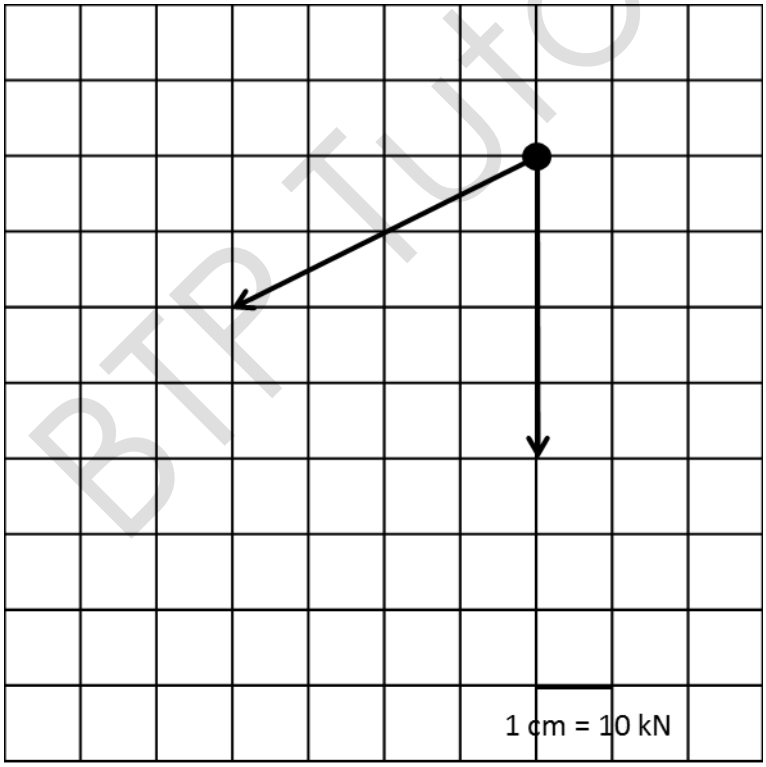


3 Finding resultant force for forces at an angle to each other

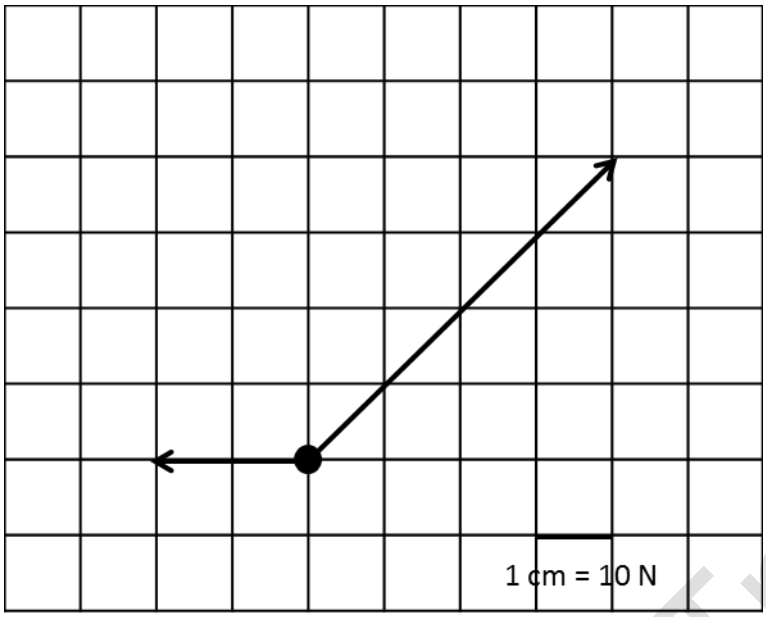
1. A boat is pulled by two tugboats. The forces applied by the tugboats are shown in the vector diagram below. Determine the resultant force on the boat.



2. An aircraft is heading south and experiences a wind toward the southwest. The forces are shown in the vector diagram. Determine the resultant force on the aircraft.



3. A child pulls a toy along the floor by a string. The tension in the string and the friction between the toy and the floor are shown in the vector diagram. Determine the resultant force on the toy.



Tutorial 4.3 – Resolution of forces

In this tutorial you will look at:

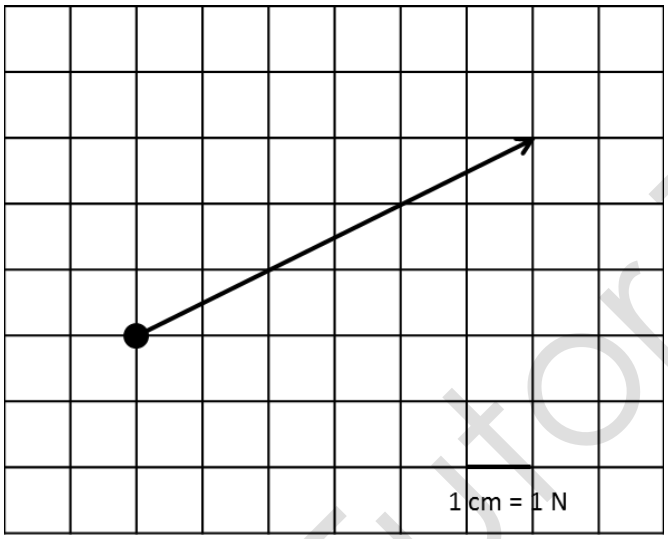
1. Resolving a force into components
2. Forces on an inclined plane
3. Resolution of weight on an inclined plane

Learning activities

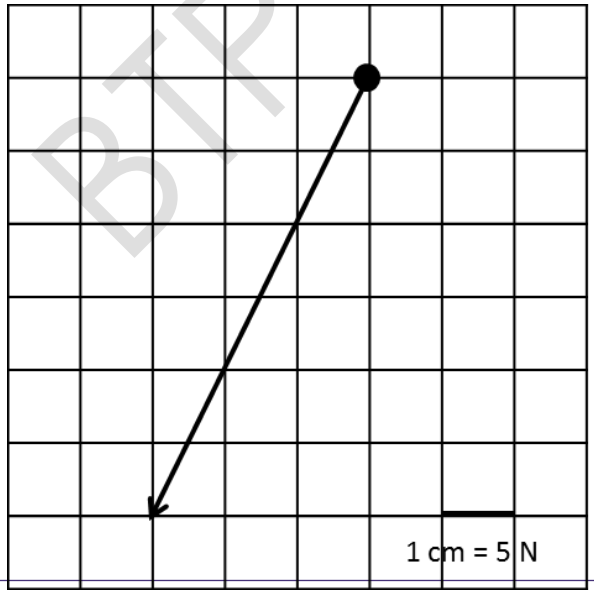
1

Resolving a force into components

1. A child pulls a toy across the floor by a string. The diagram shows the tension force in the string. Resolve the force into its horizontal and vertical components and identify the magnitude of each component.

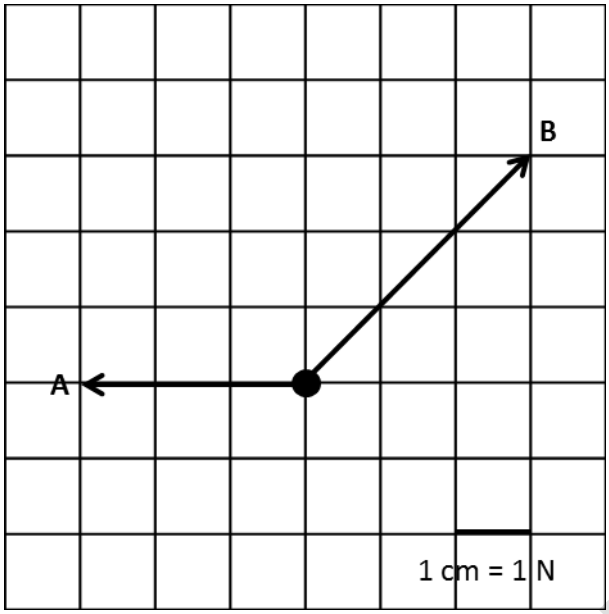


2. A farmer applies a force with his foot to a spade, as represented by the vector diagram below. Resolve the force into horizontal and vertical components and identify the magnitudes of the components.



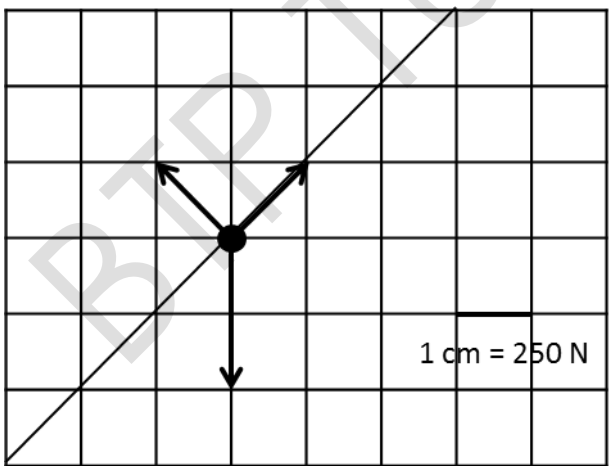
3. Two forces act on a body, as shown in the vector diagram.

   a) Resolve Force B into horizontal and vertical components.
   b) Hence, find the resultant force on the body due to Force A and the components of Force B.
   c) Confirm that the same resultant force is obtained by using the 'parallelogram of forces' approach

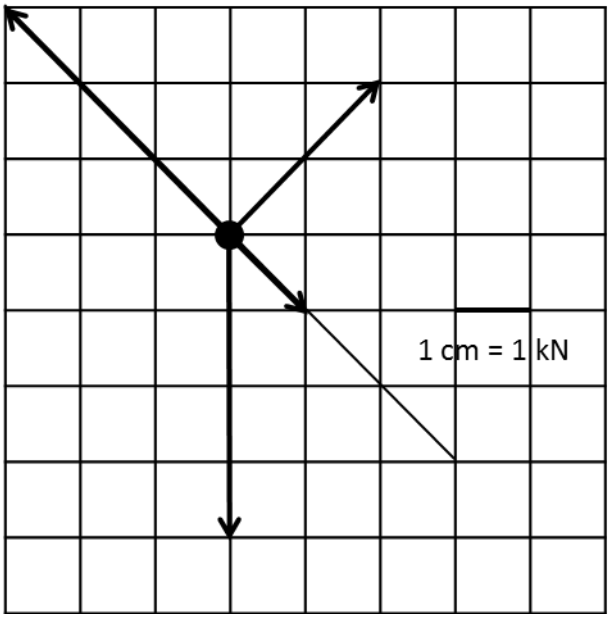


2 Forces on an inclined plane

1. A skier is on a slope. The forces on the skier are shown in the vector diagram. Label the forces and use the scale to determine the magnitude of each.



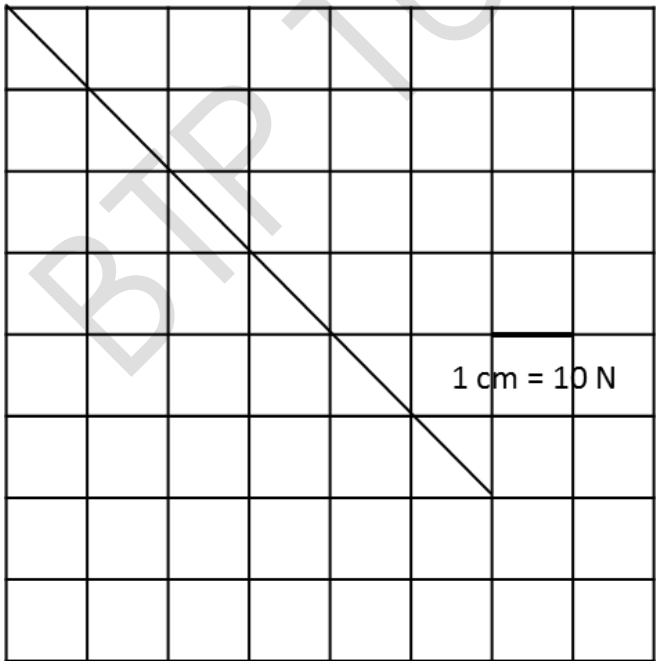
2. A vehicle drives up a ramp. The forces on the vehicle are shown in the vector diagram. Label the forces and determine the magnitude of each.



3. A box slides down a ramp.

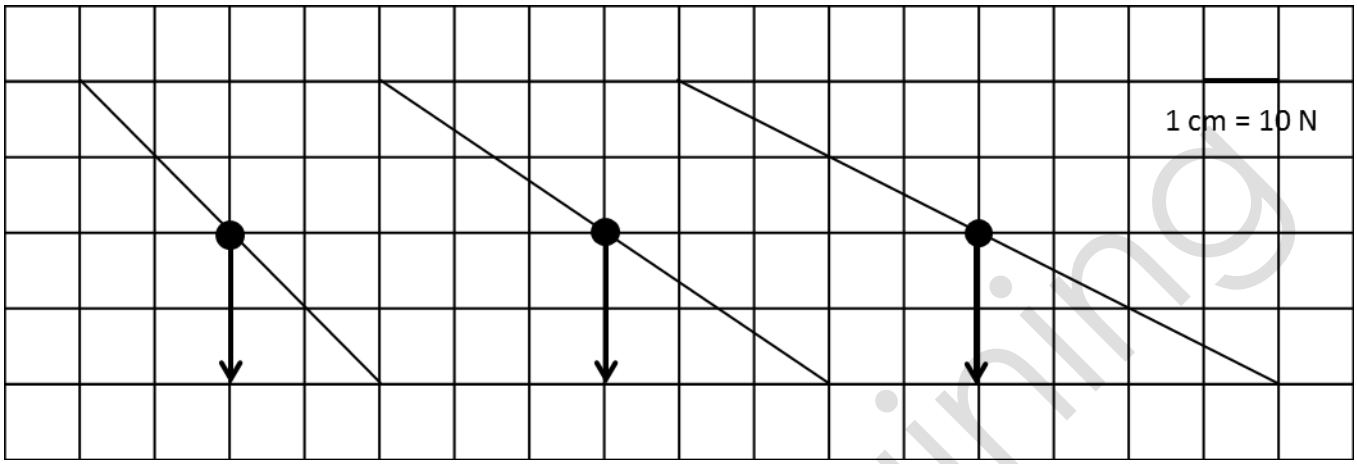
   - The weight of the box is 40 N
   - The normal contact force on the box has a horizontal component of 20 N and a vertical component of 20 N
   - The friction acting on the box has a horizontal component of 10 N and a vertical component of 10 N

   Draw a vector diagram opposite to represent this situation and label the forces.

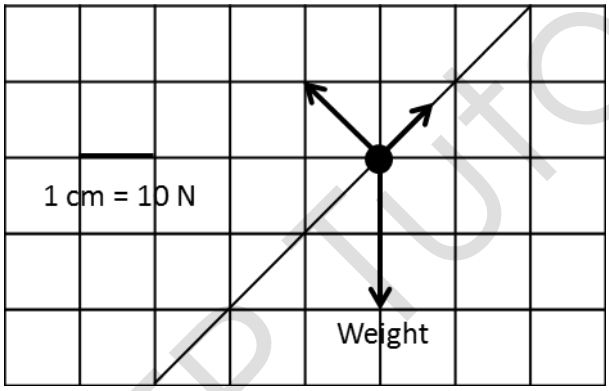


3 Resolution of weight on an inclined plane

1. The diagram shows the weight of three bodies on three different inclined planes. For each body, draw the parallel and perpendicular components of weight, and determine their magnitudes.



2. A box is placed on a ramp. The vector diagram shows the weight of the box, along with the normal contact force and friction experienced by the box. The box will slide down the ramp if the component of its weight parallel to the ramp is greater than the friction between the ramp and the box. Will the box slide down the ramp?



Tutorial 4.4 – Force and elasticity

In this tutorial you will look at:

1. Elasticity
2. Hooke's Law
3. Equation for Hooke's Law

Learning activities

1

Elasticity

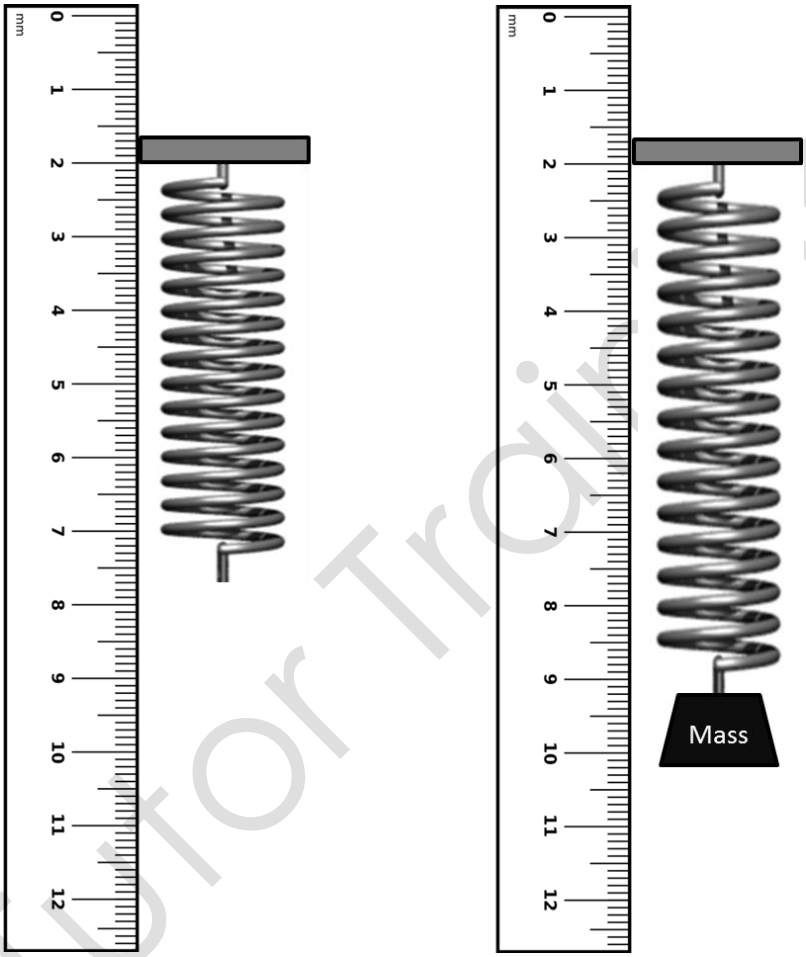
1. Some objects are elastic, and others are inelastic.
   a. Suggest examples of elastic and inelastic objects

   b. Suggest how you can test whether an object is elastic or inelastic

2. In the questions below, assume the gravitational field strength of the Earth is 10 N/kg.
   a. A mass of 500 g is added to a hanging spring, causing the spring to extend. After the system reaches equilibrium, the resultant force on the mass is 0 N. Draw a free body diagram for the mass, to scale, showing the forces acting on the mass.

   b. A mass of 700 g is added to a standing spring, causing the spring to compress. After the system reaches equilibrium, the resultant force on the mass is 0 N. Draw a free body diagram for the mass, to scale, showing the forces acting on the mass.

3. The diagrams show a setup for measuring the extension of a spring[1]. Use the diagram to determine:
    a. The natural length of the spring
    b. The extension of the spring
    c. The new length of the spring after extension



4. A student experiments with different springs by adding the same mass to each and measuring their extension. Complete the table and rank the springs in order of stiffness (from least to most stiff):

Spring	Natural length (m)	Extension (m)	New length (m)
A	0.10	0.01	
B	0.10		0.15
C		0.02	0.12

[1] Image adapted from https://commons.wikimedia.org/wiki/File:Stiffness_of_a_coil_spring.png

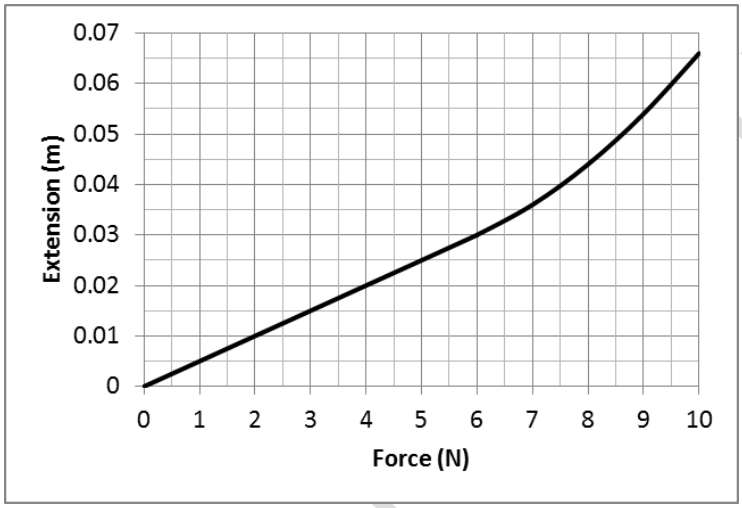
2 Hooke's Law

The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.

1. In the graph of extension versus force below:
   a. Estimate the range of forces for which the extension of the spring is directly proportional to force applied. Explain your answer.

   b. Estimate the extension at which the limit of proportionality is reached. Explain your answer.

   c. Describe the relationship between extension and force applied after the limit of proportionality is exceeded.



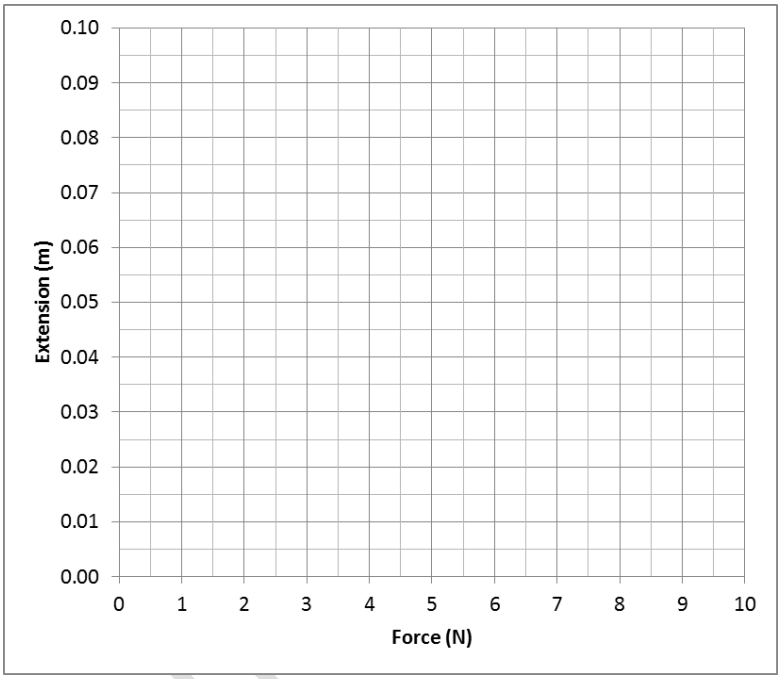
2. In the graph of extension versus force above:
   a. What is the extension of the spring when a force of 3 N is applied?

   b. The natural length of the spring is 15 cm. What is the new length of the spring under a force of 4 N?

   c. What force needs to be applied to make the spring 18 cm long?

3. A student collected data for two springs, as shown in the table below. Plot the data and determine which spring is stiffer.

	Extension (m)	
Force (m)	Spring A	Spring B
0	0.000	0.000
1	0.010	0.005
2	0.020	0.010
3	0.030	0.015
4	0.040	0.020
5	0.050	0.025
6	0.060	0.030
7	0.070	0.035
8	0.080	0.040
9	0.090	0.045
10	0.100	0.050



3 Equation for Hooke's Law

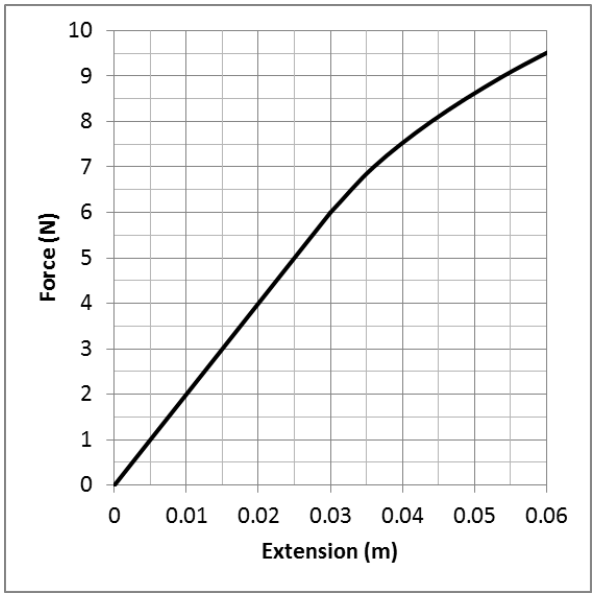
1. A student investigates a spring with spring constant 750 N/m.

a. Calculate the force required to extend the spring by 5 cm.

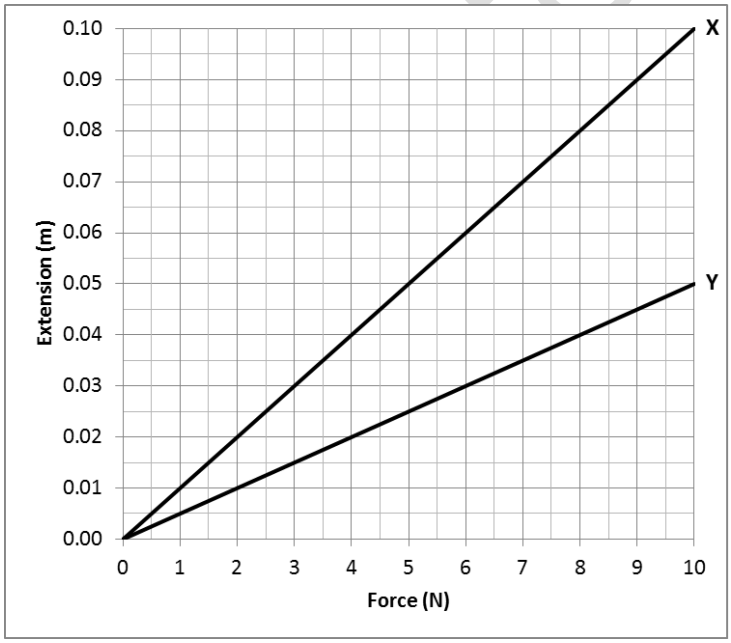
b. Calculate the extension of the spring when the force applied is 50 N.

c. The students applies a force of 10 N to another spring, which causes an extension of 1 cm. Calculate the spring constant for this spring and compare the stiffness of the two springs.

2. A student varies the extension of a spring by pulling on the spring with a newton meter. The student measures the force applied by the spring for each extension. The data collected by the student is shown on the graph below. By measure the gradient at a suitable place on the graph, determine the spring constant of the spring.



3. A student investigated two springs. The data collected by the student is plotted on the graph. Determine the spring constant for each spring. Compare the stiffness of the springs.



Module 4 review

How do you feel now?

This module aimed to help you with:

1. Drawing and understanding free body diagrams
2. Resolving forces
3. Understanding Hooke's law

Reflection is important because it helps you review and improve the way you approach tasks, rather than just carrying on doing things as you have always done them.

Take a few minutes to think about where you think you did well during the last four tutorials, and what you think you could improve on. Write your thoughts in the boxes below.

What I did well…	What I could have improved on…
What I could do differently to make the most of my next tutorials…	

Knowledge Check #2

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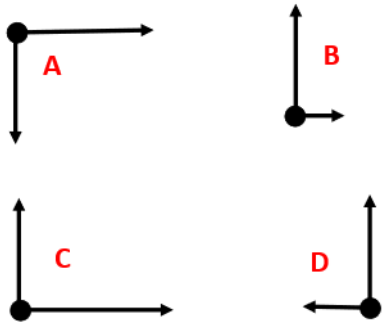
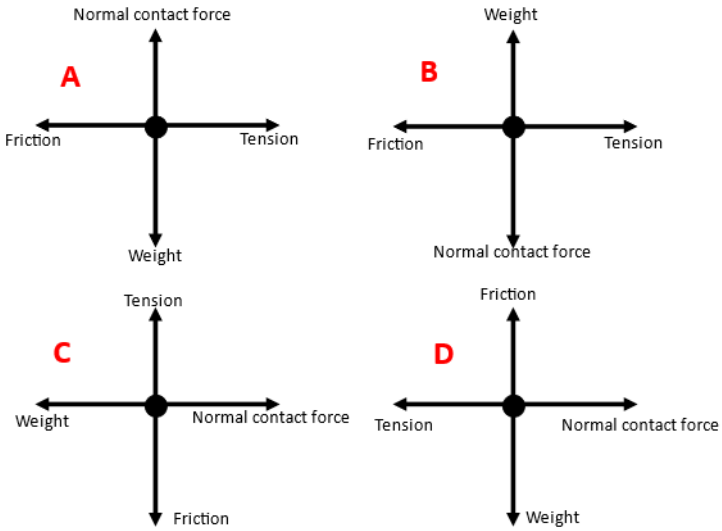
https://forms.office.com/r/WFRipbmwY1

If you can't complete the questions online, you can do it here:

1. Select which diagram below could represent an object experiencing a 2 N vertical force upwards and a 3 N horizontal force towards the right.
   a) A
   b) B
   c) C
   d) D

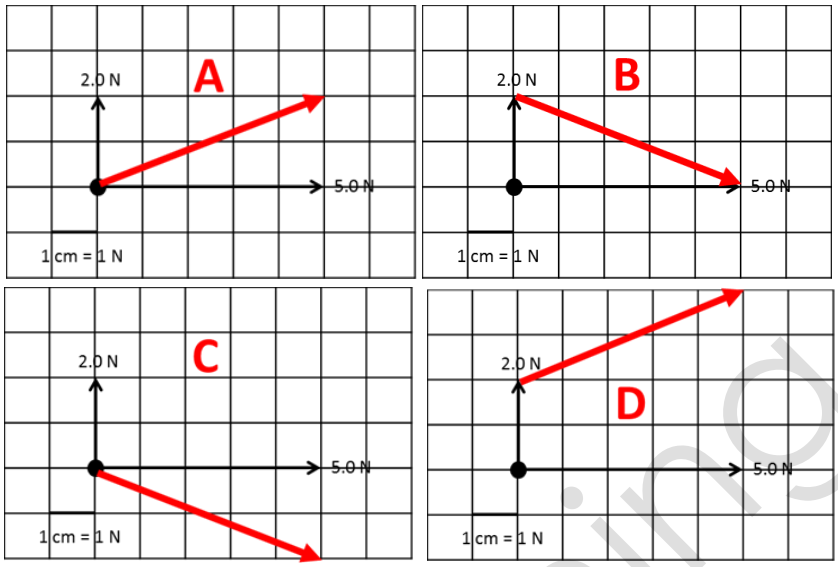


2. A block is pulled by a string towards the right across a surface. The free body diagram shows the forces acting on the block. Which diagram labels the forces correctly?
   a) A
   b) B
   c) C
   d) D

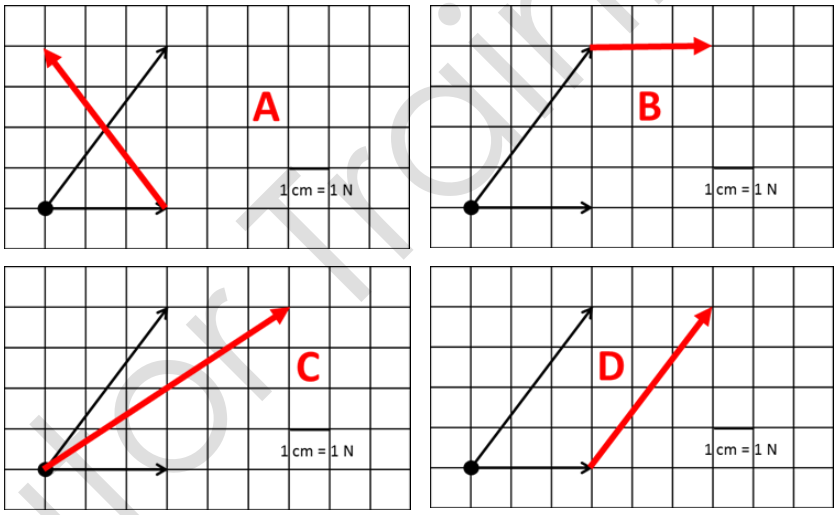


3. Calculate the weight of an object of mass 5 kg on Earth. The gravitational field strength is 10 N/kg
   a) 5 N
   b) 10 N
   c) 15 N
   d) 50 N
4. The free body diagram shown below shows the forces acing on an object. State the magnitude and direction of the resultant force on the body.
   a) 7 N to the left
   b) 3 N to the right
   c) 7 N to the right
   d) 3 N to the left

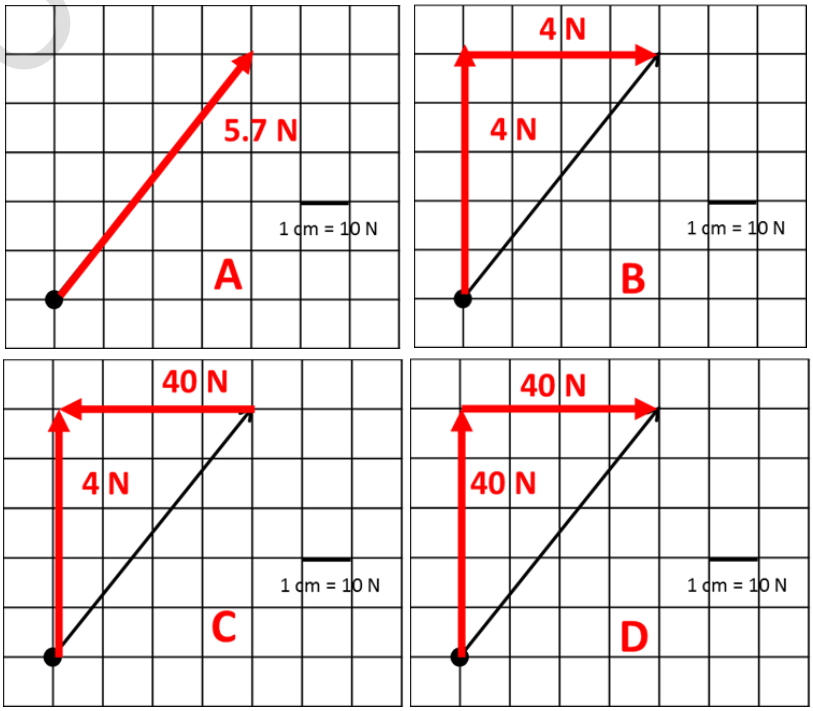
5. These vector diagram below shows the forces acting on an object. Which red arrow correctly shows the resulting forces on the body?
   a) A
   b) B
   c) C
   d) D



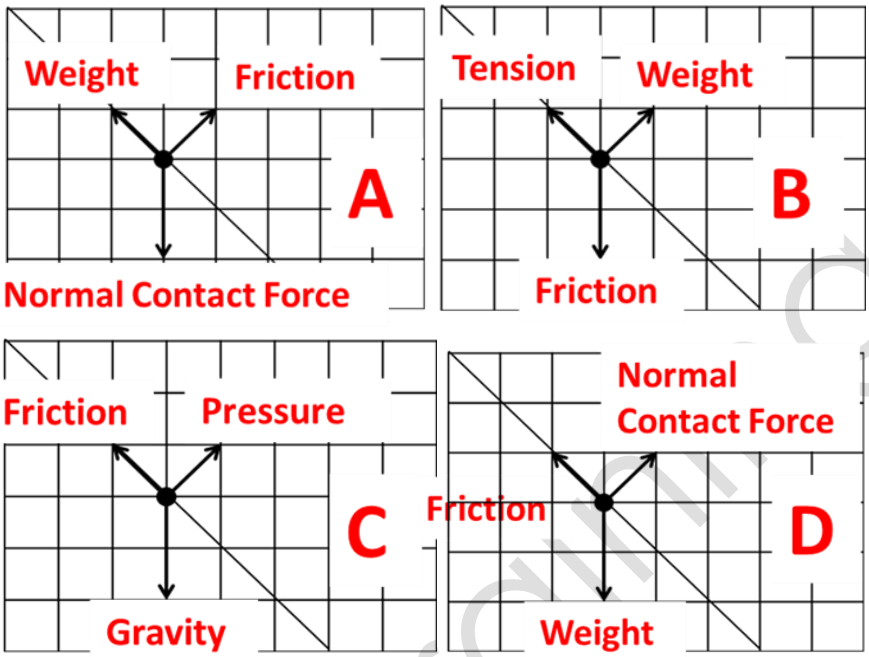
6. The vector diagram below shows the forces acting on an object. Which red arrow correctly shows the resultant force acting on the body.
   a) A
   b) B
   c) C
   d) D



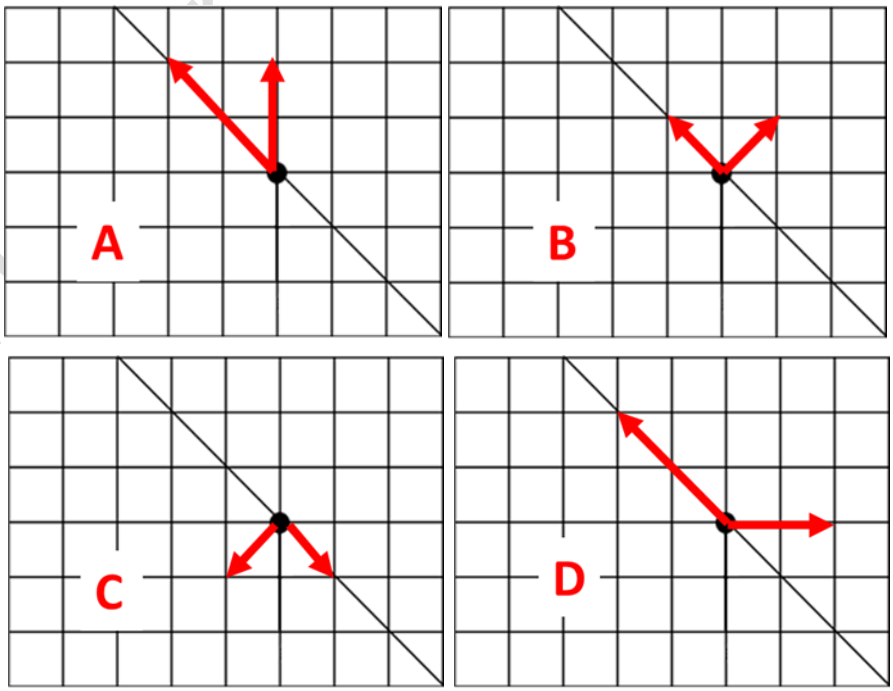
7. The vector diagram below shows a force acting on an object. Resolve the force into its vertical and horizontal components. Select the diagram that correctly shows these components.
   a) A
   b) B
   c) C
   d) D



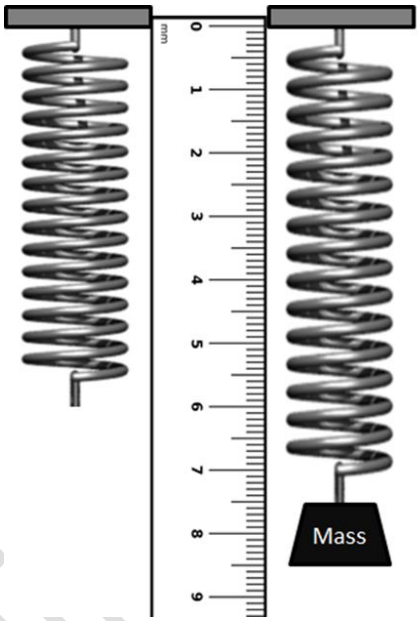
8. The free-body diagram below shows the forces acting on a block sitting at rest on a ramp. Select the diagram with the correctly named forces acting on the block.
   a) A
   b) B
   c) C
   d) D



9. The vector diagram shows the weight of a block on a ramp. Resolve the weight into components that are parallel and perpendicular to the ramp. Select from the diagrams below which shows the resolved components correctly.
   a) A
   b) B
   c) C
   d) D



10. The figure shows a spring before (left) and after (right) it has been extended. Determine the extension of the spring.



    a) 25mm
    b) 15 mm
    c) 25 cm
    d) 15 cm
11. Which statement correctly and fully describes Hooke's Law?
    a) The extension of an elastic object, such as a spring, is directly proportional to the force applied, provided that the limit of proportionality is not exceeded.
    b) A spring will stretch if a weight is applied to one end.
    c) A spring will be stretched only if it is held vertically and a large weight in attached to one end.
    d) A heavy weight applied to a spring held vertically does not influence the amount of extension in the spring.
12. A force of 50 N is applied to a spring of stiffness 1000 N/m. Calculate the extension of the spring.
    a) 20 m
    b) 5 cm
    c) 20 cm
    d) 50,000 m

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