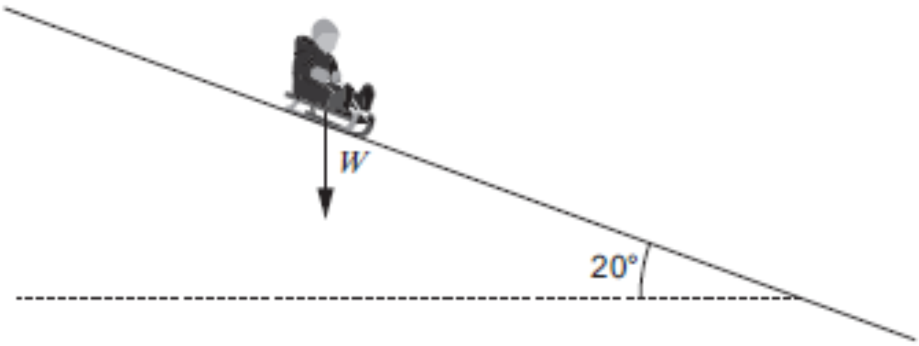
1.

1. Matthew is sliding down a snow-covered slope on a sledge. The total mass of Matthew and the sledge is 62 kg.



(a) On the diagram the arrow represents the total weight, W, of Matthew and the sledge. **Add two more arrows** to show the normal contact force on the sledge and the frictional force on the sledge. [1]

(b) (i) Show that the component of W parallel to the slope is approximately 200 N. [2]

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(ii) Calculate the magnitude of the normal contact force. [2]

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(c) The sledge's acceleration just after it has started moving is measured to be $2.5\,\mathrm{m\,s^{-2}}$. Matthew believes that, starting from rest, it will take him less than 9.0 s to slide 100 m down the slope. Evaluate whether or not he is correct, commenting on whether or not your calculation is conclusive. [3]

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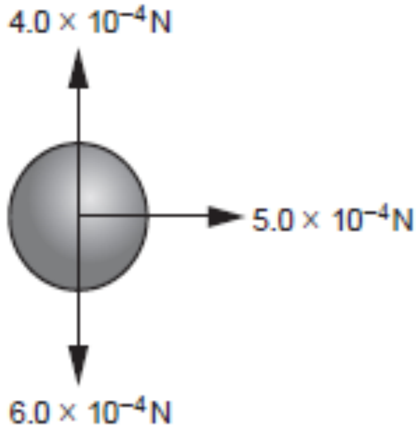
2.

2. *(a)* The forces acting on a hailstone falling in a horizontal cross-wind can be represented as in the diagram.



(i) Calculate the magnitude and direction of the resultant force acting on the hailstone. [3]

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(ii) At a later time, the wind has stopped blowing and the hailstone falls at terminal velocity. In terms of forces, explain why the hailstone is at terminal velocity. [1]

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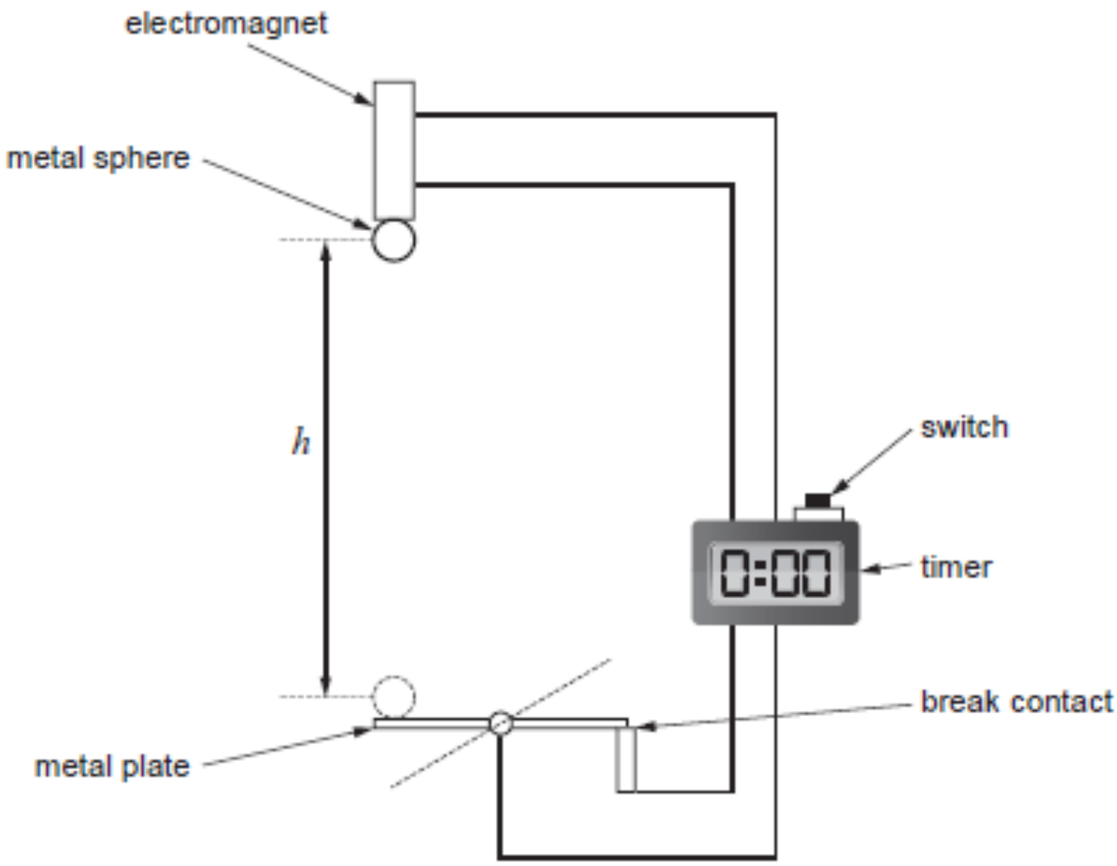
(b) Aled uses the following apparatus to measure the acceleration of free-fall, g.



When the switch is pressed, it starts the timer and disconnects the electromagnet, almost instantly releasing the metal sphere. When the sphere hits the metal plate it breaks the circuit, stopping the timer. The time taken for the metal sphere to fall through a range of different heights, h is measured.

(i) Aled is told that there is a very small time delay between the switch being pressed and the ball being released. This is a systematic error. The manufacturer states that the time delay is 0.05 s. State how Aled should account for the systematic error when taking readings. [1]

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(ii) Aled records his **corrected results (i.e. with the systematic error accounted for)** in the table below. Complete the row for time squared, t^2 giving your answers to an appropriate number of significant figures. [2]

Drop height, h/m	0.40	0.80	1.20	1.60	2.00
Corrected time, t/s	0.27	0.41	0.48	0.58	0.64
Corrected time squared, t^2/s^2					

(iii) The following relationship is used to find a value for g:

$$g = \frac{2h}{t^2}$$

Show how this relationship is obtained from an appropriate equation of accelerated motion. [2]

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(iv) On the grid below, plot a graph of h **(vertical axis)** against t^2 **(horizontal axis)** and draw a line of best fit. [4]

(v) Use your graph to determine a value for g. [3]

(c) Discuss to what extent your graph agrees with the equation in *(b)*(iii). [3]

3.

3. *(a)* State Newton's second law of motion in terms of *momentum*. [2]

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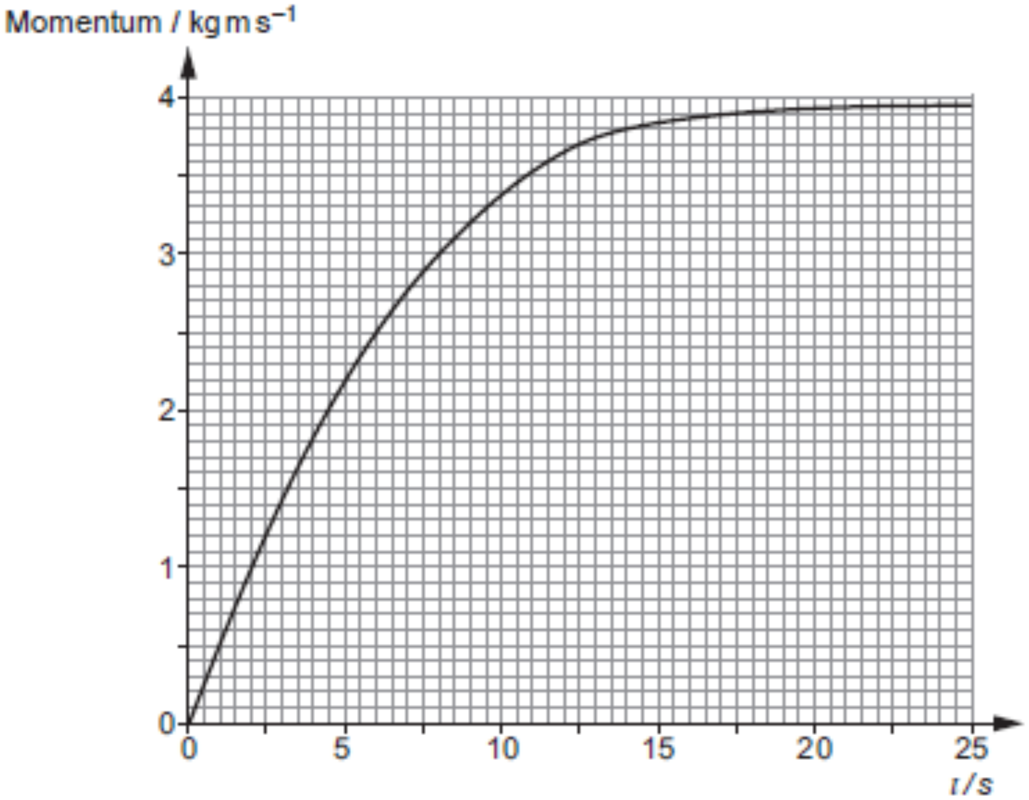
(b) A momentum-time graph is plotted below for an object of mass 0.050 kg dropped (at time $t = 0$) from the top of a high cliff.



(i) Show clearly that the resultant force on the object at t = 10 s is approximately 0.15 N. [3]

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(ii) Deduce the magnitude of the force of air resistance on the object at t = 10 s. [2]

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(iii) State the magnitude of the force of air resistance on the body when it has reached its terminal velocity. [1]

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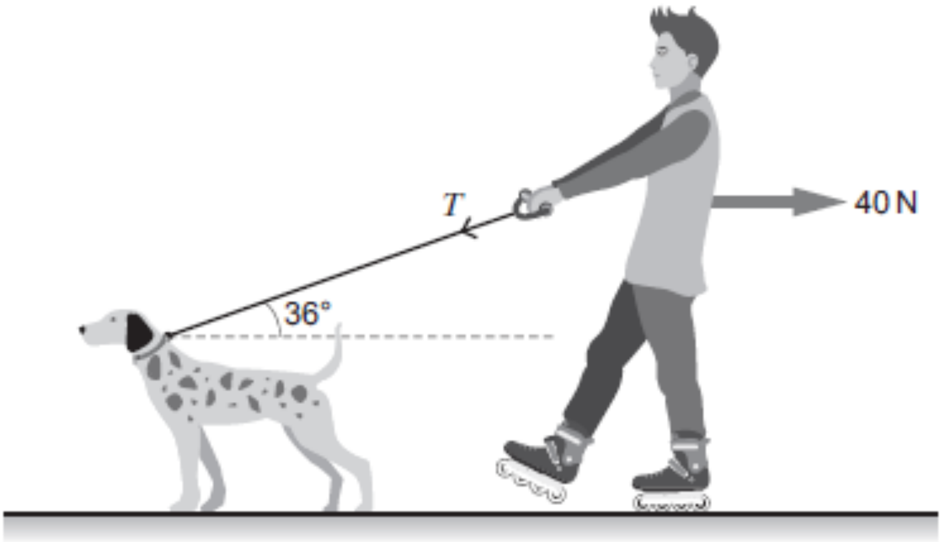
4. **4.** *(a)* The diagram shows a roller-skater being pulled along a horizontal road at **constant velocity**. The total resistive force to the skater's motion is 40 N.



Show that the tension, T, in the dog lead is approximately 50 N. [2]

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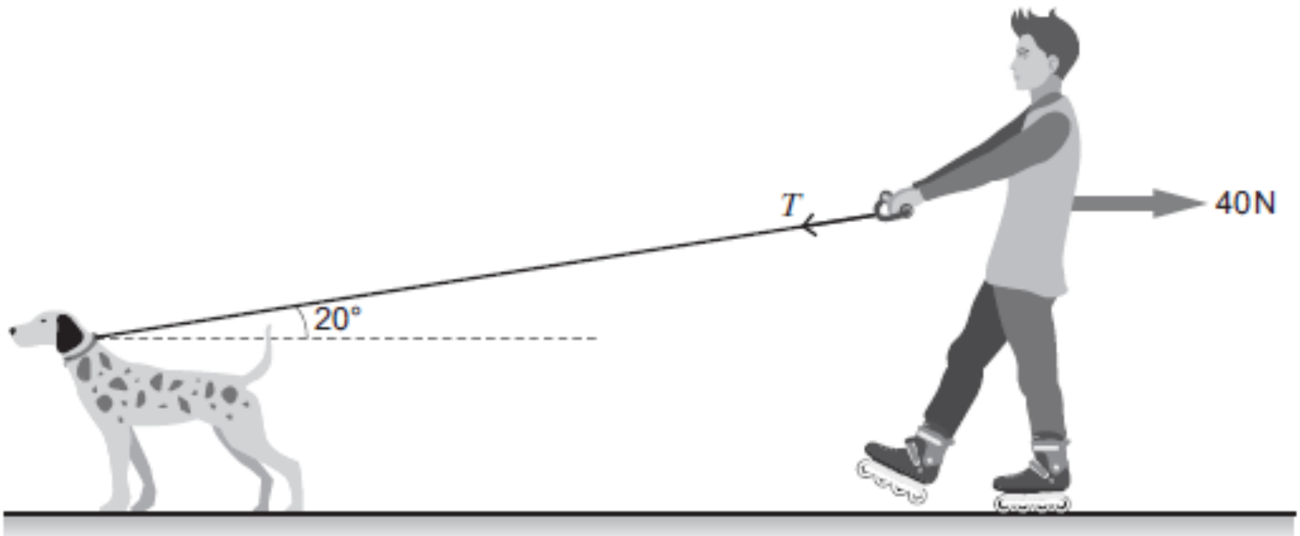
(b) Later, the roller-skater, moving at the same velocity as in part *(a)*, extends the dog lead as shown in the diagram below.



(i) Assuming that the tension, T, is the same as in part *(a)*, explain why the roller-skater initially accelerates. [1]

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(ii) Calculate this initial acceleration, given that the mass of the roller-skater is 35 kg. [3]

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(c) The roller-skater believes that the dog's rate of doing work is the same, regardless of the length of the dog lead. Use information from *(a)* and *(b)* to investigate whether or not this claim is correct. [3]

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5. **5.** *(a)* A law of motion can be expressed as:

$$\text{resultant force} = \frac{\text{change in momentum}}{\text{time}}$$

State the name of the law. [1]

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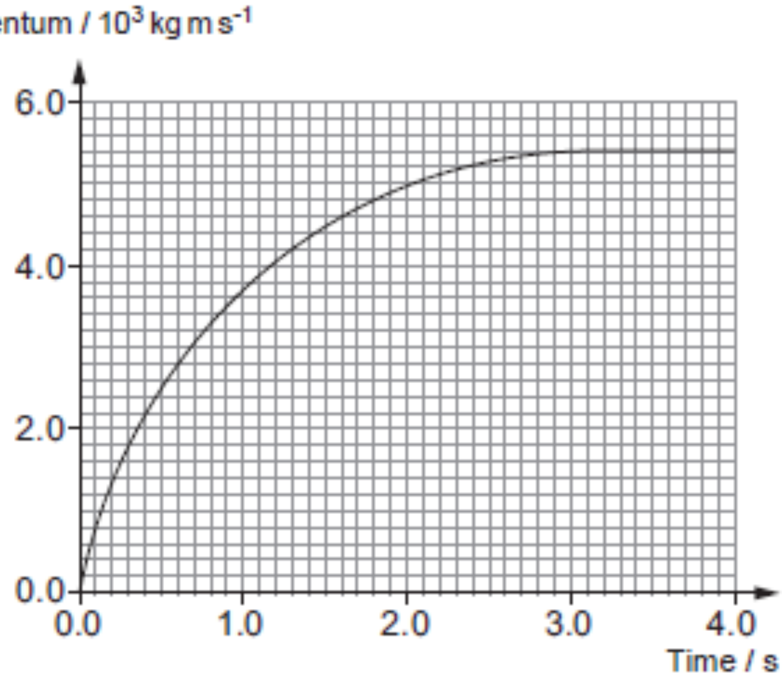
(b) The graph shows how the momentum of a spacecraft varies with time.



(i) By drawing a suitable tangent, show that the resultant force on the spacecraft at t = 1.0 s is approximately 2 kN. [2]

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(ii) Hence show that the mass of the spacecraft is approximately 5000 kg, given that its acceleration at t = 1.0 s is 0.4 m s^{-2}. [1]

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(iii) **Label, with the letter P,** a point on the graph where the resultant force on the spacecraft is zero. [1]

(c) At t = 4.0 s the spacecraft 'docks' (collides) with another stationary spacecraft of mass 7000 kg. They join on impact.

(i) State the principle of conservation of momentum. [2]

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(ii) Calculate the velocity of both spacecraft after colliding. [3]

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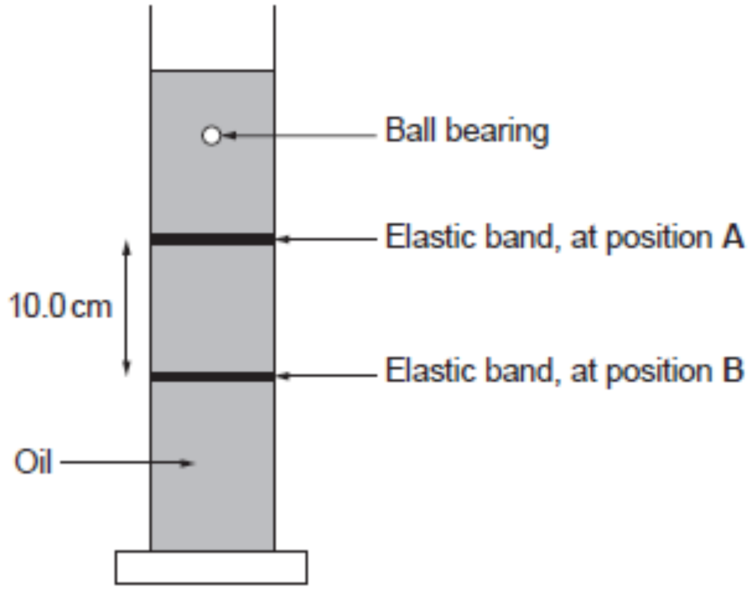
6.

6. Emma investigates the viscosity of oil by measuring the terminal velocities of a number of different sized ball bearings as they move through it. She uses the following apparatus.



(a) (i) Once released, a ball bearing attains terminal velocity before it reaches the elastic band at position **A**. Explain what is meant by terminal velocity. [1]

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(ii) At terminal velocity the two main forces acting on the ball bearing are its weight and the drag of the oil. According to Newton's third law, for each of these forces there is a corresponding equal and opposite force. Identify each of these forces and the body upon which it acts. [2]

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(b) Emma measures the time it takes the ball bearings to fall from the elastic band at position **A** to the elastic band at position **B**. She carries out each measurement twice, and obtains the following results. The distance between the two elastic bands is 10.0 cm. The uncertainty in this distance can be considered negligible when calculating the uncertainty in the terminal velocity.

Ball bearing		Time to fall			Terminal velocity	
Diameter, d / cm	(Diameter)^2, d^2 / cm^2	Reading 1 / s	Reading 2 / s	Mean / s	Velocity, v / cm s^{-1}	Uncertainty, Δv / cm s^{-1}
0.24	0.058	14.0	14.6	14.3		± 0.01
0.32	0.10	8.0	8.6	8.3		± 0.05
0.40	0.16	5.3	5.9		1.8	±
0.48	0.23	3.6	4.1		2.6	±
0.64	0.41	2.2	1.9	2.1	4.8	± 0.3

Complete the table. *Space has been left for any calculations if needed.* [4]

(c) (i) Emma's friend, Fiona, thinks that the terminal velocity, v, is directly proportional to the square of the diameter, d, of the ball bearing,

$$v \propto d^2.$$

Plot a suitable graph to check whether Fiona is correct. [4]

(ii) Evaluate whether or not Fiona is correct. [2]

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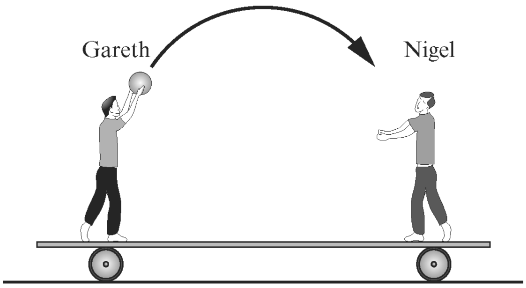
7.

Two boys stand each end of a trolley as shown. The trolley is initially at rest and can move without resistance on a horizontal surface.



(a) (i) Define acceleration. [1]

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(ii) Gareth takes 0.80 s to throw a ball from rest to a speed of $6.0\,\text{m}\,\text{s}^{-1}$. Calculate the acceleration of the ball. [2]

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(b) Describe and explain in terms of forces, the motion of **the trolley** from the instant the ball is released by Gareth until after it is caught by Nigel. [4]

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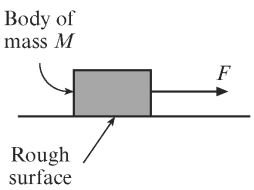
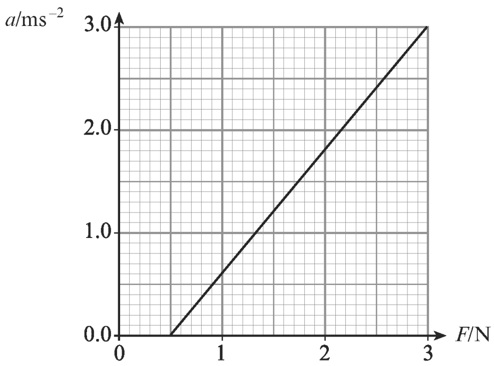
8.

A body of mass M is placed on a rough surface and a horizontal force, F, is applied to it as shown. Data-logging apparatus is used to determine the acceleration of the body for different values of F. The results are shown in the graph.





(a) (i) Explain why the acceleration of the body is 0 when the applied force F is less than 0.5 N. [1]

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(ii) Use your graph to determine the value of M. [3]

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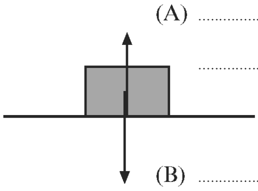
(b) (i) Label forces (A) and (B) also acting on the body. [2]



(A) ....

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(B) ....

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(ii) State the Newton third law reaction to force (B) and the body upon which it acts. [2]

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