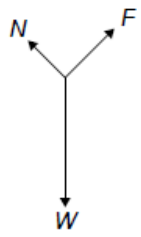
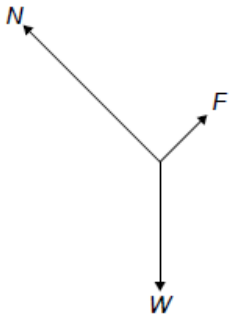
2.2 Friction *[44 marks]*

1. A block of weight W slides down a ramp at constant velocity. A friction force F acts between the bottom of the block and the surface of the ramp. A normal reaction N acts between the ramp and the block. What is the free-body diagram for the forces that act on the block? *[1 mark]*

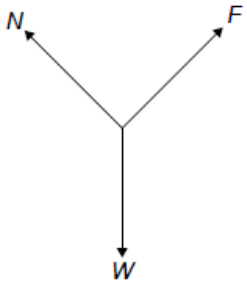
A.



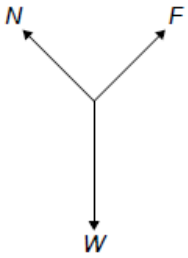
B.



C.



D.



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2. A book is at rest on a table. What is a pair of action–reaction forces for this situation according to Newton's third law of motion? *[1 mark]*

	Force 1	Force 2
A.	the force of the book on the table	the force of the book on the Earth
B.	the force of the table on the Earth	the force of the book on the table
C.	the force of the Earth on the book	the force of the book on the Earth
D.	the force of the Earth on the book	the force of the table on the book

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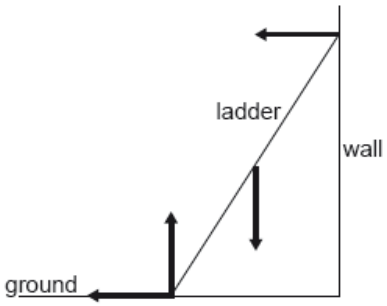
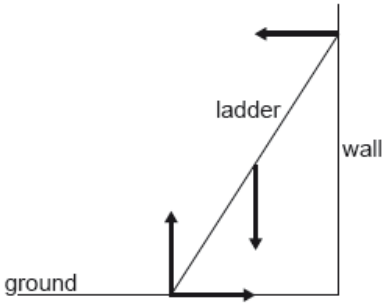
3. A uniform ladder resting in equilibrium on rough ground leans against a smooth wall. Which diagram correctly shows the forces acting on the ladder? *[1 mark]*

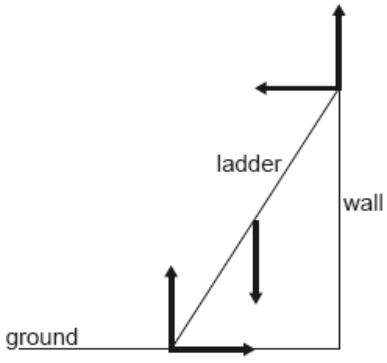
A.



B.



C.



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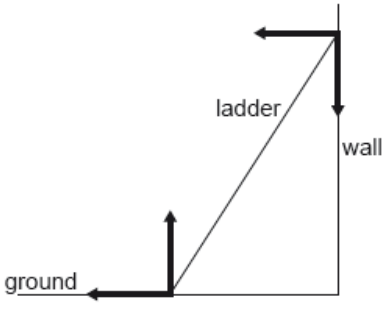
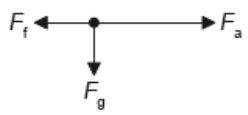
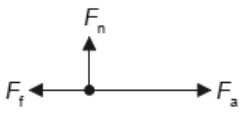


4. A box is accelerated to the right across rough ground by a horizontal force F_a. The force of friction is F_f. The weight of the box is F_g and the normal reaction is F_n. Which is the free-body diagram for this situation? *[1 mark]*

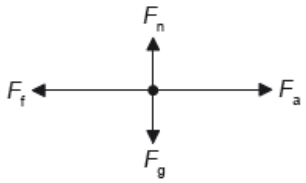
A.



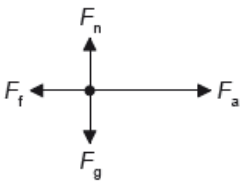
B.



C.

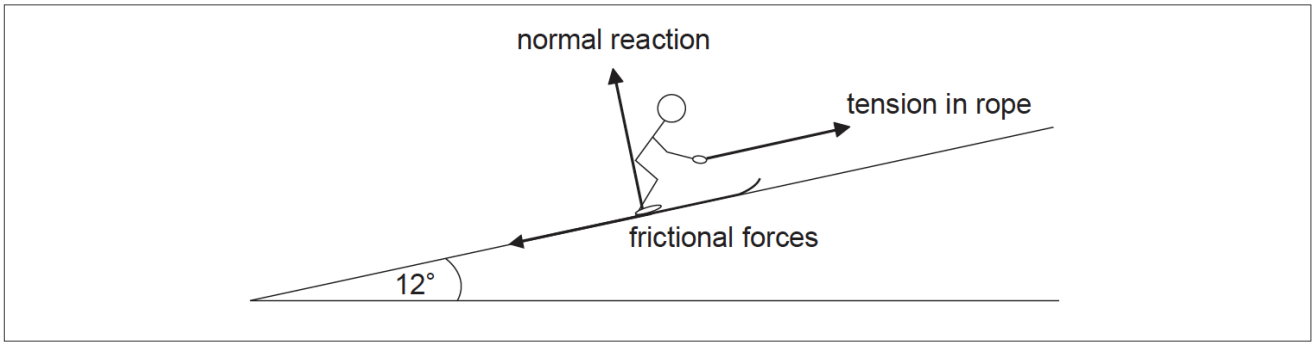


D.



This question is about the forces on a skier.

A skier is pulled up a hill by a rope at a steady velocity. The hill makes an angle of 12° with the horizontal. The mass of the skier and skis is 73 kg. The diagram below shows three of the forces acting on the skier.



5a. On the diagram, draw and label **one** other force acting on the skier. *[1 mark]*

5b. Calculate the magnitude of the normal reaction acting on the skier. *[2 marks]*

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5c. The total frictional force acting is 65 N. Determine the tension in the rope. *[2 marks]*

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5d. Explain, using Newton's first law of motion, why the resultant force on the skier must be zero. *[2 marks]*

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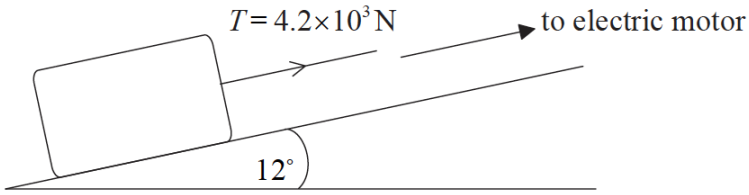
This question is about forces.

A stone block is pulled at constant speed up an incline by a cable attached to an electric motor.



The incline makes an angle of 12° with the horizontal. The weight of the block is 1.5×10^4N and the tension T in the cable is 4.2×10^3N.

6a. On the diagram draw and label arrows that represent the forces acting on the block. *[2 marks]*

6b. Calculate the magnitude of the friction force acting on the block. *[3 marks]*

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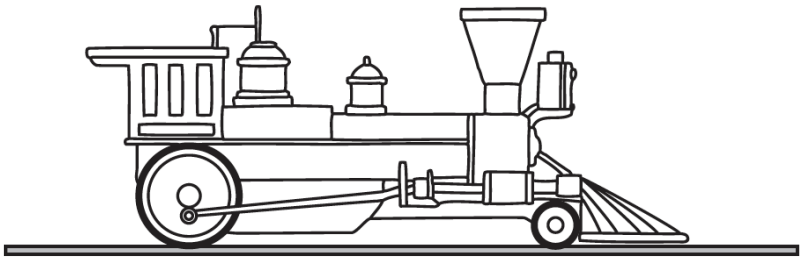
This question is in two parts. **Part 1** is about forces. **Part 2** is about internal energy.

Part 1 Forces

A railway engine is travelling along a horizontal track at a constant velocity.



7a. On the diagram above, draw labelled arrows to represent the vertical forces that act on the railway engine. *[3 marks]*

7b. Explain, with reference to Newton's laws of motion, why the velocity of the railway engine is constant. *[2 marks]*

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7c. The constant horizontal velocity of the railway engine is 16 ms^{-1}. A total horizontal resistive force of 76 kN acts on the railway engine. *[2 marks]*

Calculate the useful power output of the railway engine.

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7d. The power driving the railway engine is switched off. The railway engine stops, from its speed of 16 ms^{-1}, without braking in a distance of 1.1 km. *[2 marks]*
A student hypothesizes that the horizontal resistive force is constant.

Based on this hypothesis, calculate the mass of the railway engine.

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7e. Another hypothesis is that the horizontal force in (c) consists of two components. One component is a constant frictional force of 19 kN. The other component is a resistive force F that varies with speed v where F is proportional to v^3. *[5 marks]*

(i) State the value of the magnitude of F when the railway engine is travelling at 16 ms^{-1}.

(ii) Determine the **total** horizontal resistive force when the railway engine is travelling at 8.0 ms^{-1}.

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7f. On its journey, the railway engine now travels around a curved track at constant speed. Explain whether or not the railway engine is accelerating. *[3 marks]*

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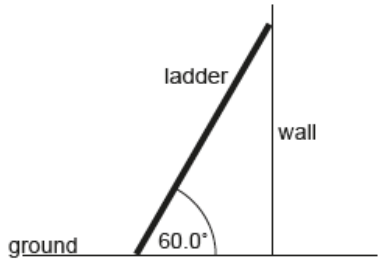
A uniform ladder of weight 50.0 N and length 4.00 m is placed against a frictionless wall making an angle of 60.0° with the ground.



8a. Outline why the normal force acting on the ladder at the point of contact with the wall is equal to the frictional force *F* between the ladder and the ground. *[1 mark]*

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8b. Calculate *F.* *[2 marks]*

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8c. The coefficient of friction between the ladder and the ground is 0.400. *[2 marks]*
Determine whether the ladder will slip.

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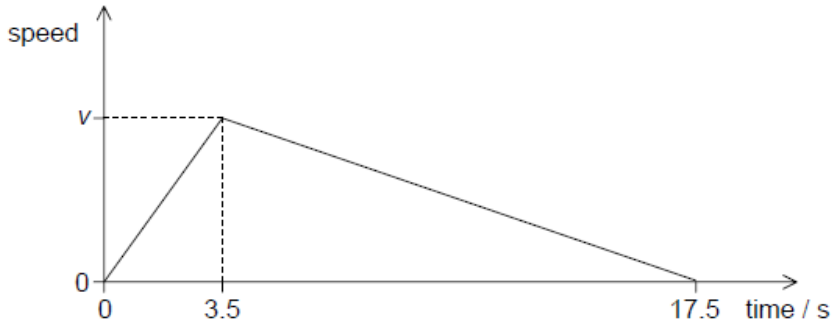
Curling is a game played on a horizontal ice surface. A player pushes a large smooth stone across the ice for several seconds and then releases it. The stone moves until friction brings it to rest. The graph shows the variation of speed of the stone with time.



The total distance travelled by the stone in 17.5 s is 29.8 m.

9a. Determine the coefficient of dynamic friction between the stone and the ice during the last 14.0 s of the stone's motion. *[3 marks]*

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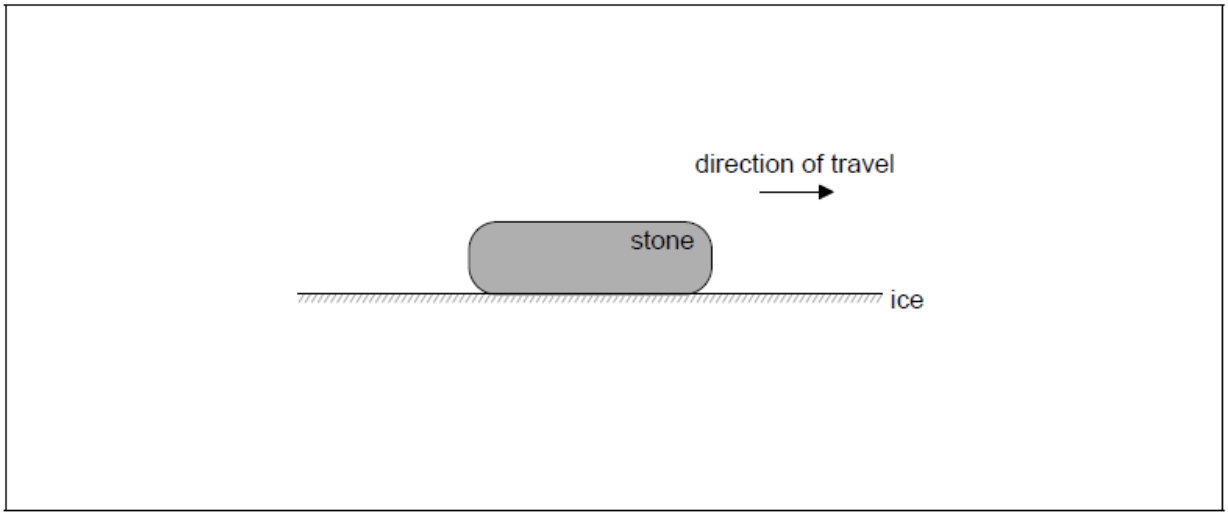
9b. The diagram shows the stone during its motion **after** release. *[3 marks]*



Label the diagram to show the forces acting on the stone. Your answer should include the name, the direction **and** point of application of each force.