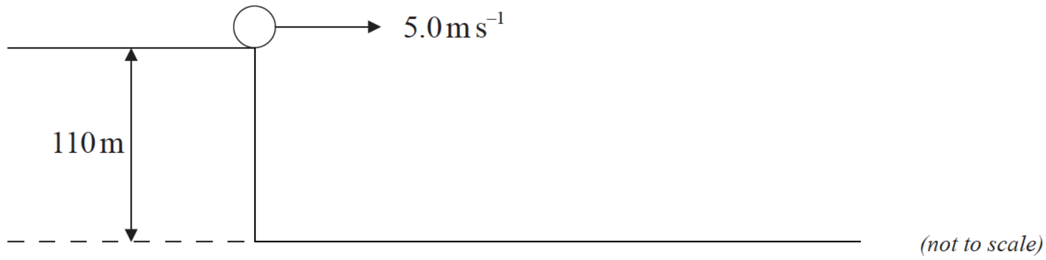
Kinematics 2020 *[69 marks]*

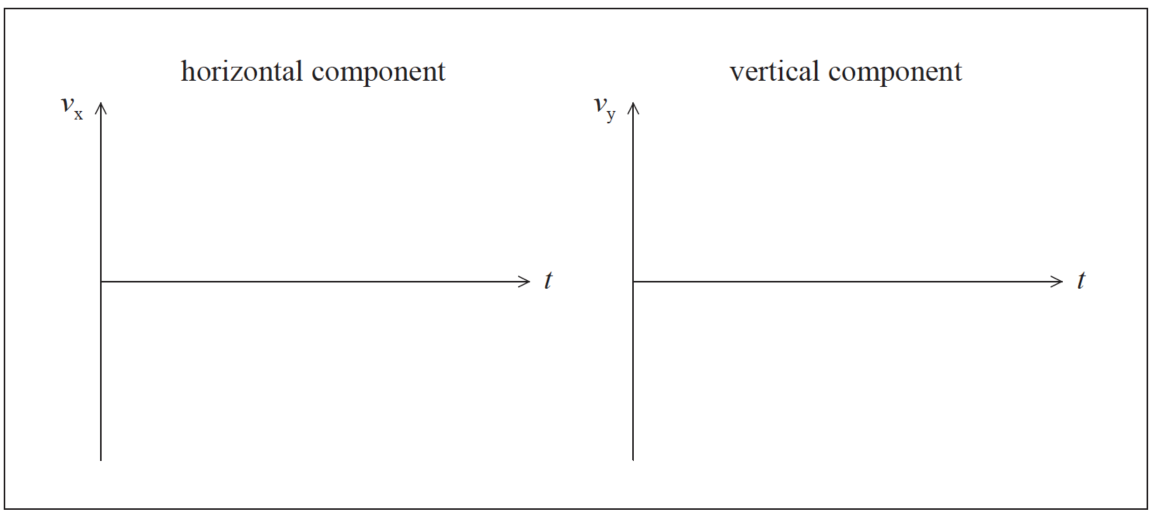
Part 2 Projectile motion

A ball is projected horizontally at 5.0ms^{-1} from a vertical cliff of height 110m. Assume that air resistance is negligible and use g=10ms^{-2}.



1a. (i) State the magnitude of the horizontal component of acceleration of the ball after it leaves the cliff. *[3 marks]*

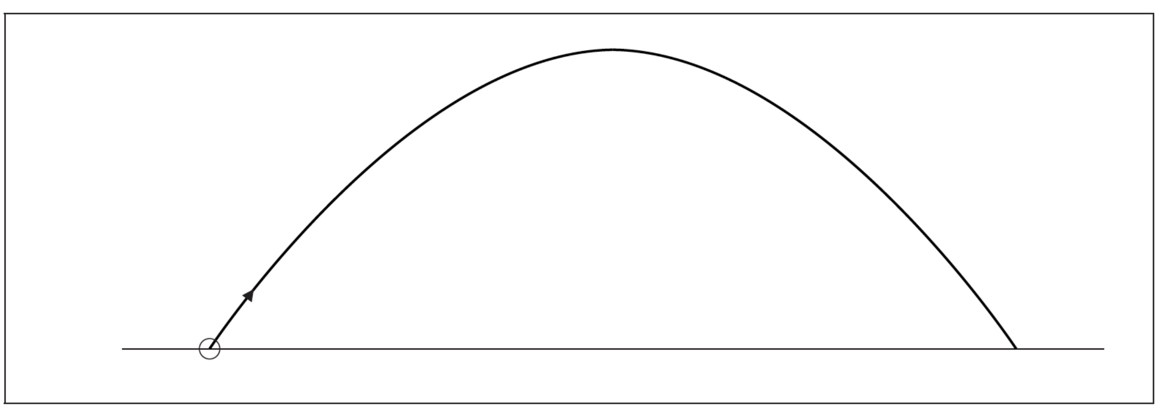
(ii) On the axes below, sketch graphs to show how the horizontal and vertical components of the velocity of the ball, v_x and v_y , change with time t until just before the ball hits the ground. It is not necessary to calculate any values.



1b. (i) Calculate the time taken for the ball to reach the ground. *[4 marks]*

(ii) Calculate the horizontal distance travelled by the ball until just before it reaches the ground.

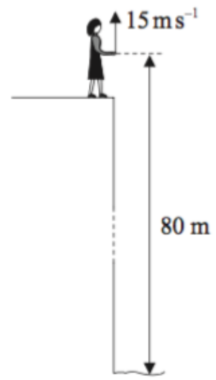
1c. Another projectile is launched at an angle to the ground. In the absence of air resistance it follows the parabolic path shown below. *[3 marks]*



On the diagram above, sketch the path that the projectile would follow if air resistance were not negligible.

This question is about kinematics.

Lucy stands on the edge of a vertical cliff and throws a stone vertically upwards.

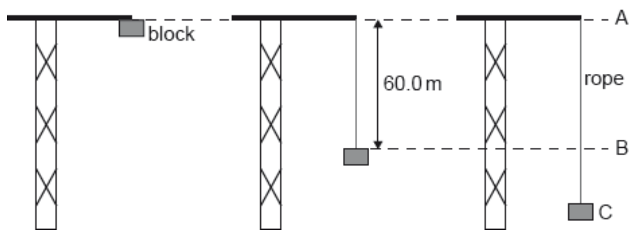


The stone leaves her hand with a speed of 15ms^{-1} at the instant her hand is 80m above the surface of the sea. Air resistance is negligible and the acceleration of free fall is 10ms^{-2}.

2a. Calculate the maximum height reached by the stone as measured from the point where it is thrown. *[2 marks]*

2b. Determine the time for the stone to reach the surface of the sea after leaving Lucy's hand. *[3 marks]*

An elastic climbing rope is tested by fixing one end of the rope to the top of a crane. The other end of the rope is connected to a block which is initially at position A. The block is released from rest. The mass of the rope is negligible.



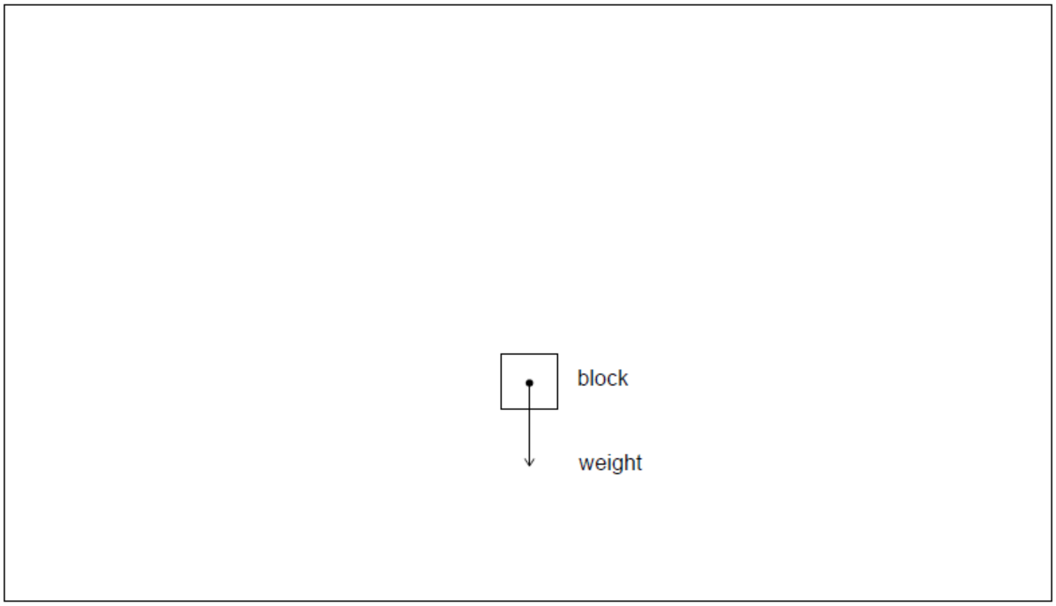
The unextended length of the rope is 60.0 m. From position A to position B, the block falls freely.

3a. At position B the rope starts to extend. Calculate the speed of the block at position B. *[2 marks]*

At position C the speed of the block reaches zero. The time taken for the block to fall between B and C is 0.759 s. The mass of the block is 80.0 kg.

3b. Determine the magnitude of the average resultant force acting on the block between B and C. *[2 marks]*

3c. Sketch on the diagram the average resultant force acting on the block between B and C. The arrow on the diagram represents the weight of the block. *[2 marks]*



3d. Calculate the magnitude of the average force exerted by the rope on the block between B and C. *[2 marks]*

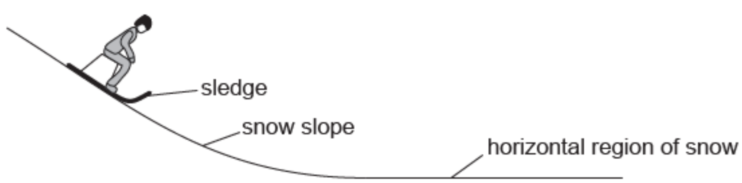
For the rope and block, describe the energy changes that take place

3e. between A and B. *[1 mark]*

3f. between B and C. *[1 mark]*

3g. The length reached by the rope at C is 77.4 m. Suggest how energy considerations could be used to determine the elastic constant of the rope. *[2 marks]*

A girl on a sledge is moving down a snow slope at a uniform speed.



4a. Draw the free-body diagram for the sledge at the position shown on the snow slope. *[2 marks]*

4b. After leaving the snow slope, the girl on the sledge moves over a horizontal region of snow. Explain, with reference to the physical origin of the forces, why the vertical forces on the girl must be in equilibrium as she moves over the horizontal region. *[3 marks]*

4c. When the sledge is moving on the horizontal region of the snow, the girl jumps off the sledge. The girl has no horizontal velocity after the jump. The velocity of the sledge immediately after the girl jumps off is 4.2 m s^{-1}. The mass of the girl is 55 kg and the mass of the sledge is 5.5 kg. Calculate the speed of the sledge immediately before the girl jumps from it. *[2 marks]*

4d. The girl chooses to jump so that she lands on loosely-packed snow rather than frozen ice. Outline why she chooses to land on the snow. *[3 marks]*

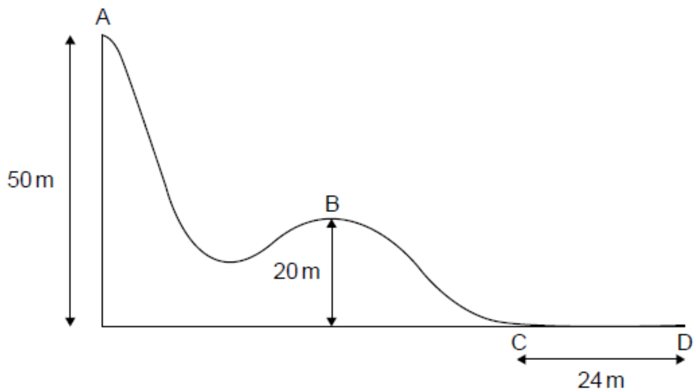
The sledge, without the girl on it, now travels up a snow slope that makes an angle of 6.5° to the horizontal. At the start of the slope, the speed of the sledge is 4.2 m s^{-1}. The coefficient of dynamic friction of the sledge on the snow is 0.11.

4e. Show that the acceleration of the sledge is about –2 m s^{-2}. *[3 marks]*

4f. Calculate the distance along the slope at which the sledge stops moving. Assume that the coefficient of dynamic friction is constant. *[2 marks]*

4g. The coefficient of static friction between the sledge and the snow is 0.14. Outline, with a calculation, the subsequent motion of the sledge. *[2 marks]*

The diagram below shows part of a downhill ski course which starts at point A, 50 m above level ground. Point B is 20 m above level ground.

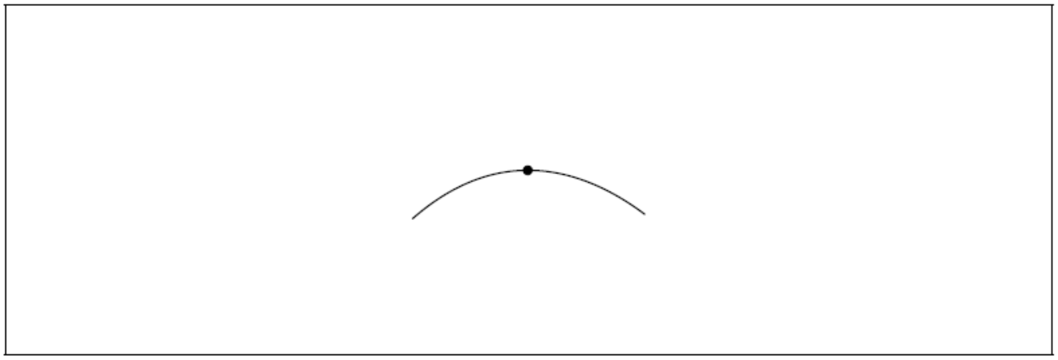


A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

5a. From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. Show that the velocity at B is 12 m s^{-1}. *[2 marks]*

5b. Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. Distinguish between internal energy and temperature. *[2 marks]*

5c. The dot on the following diagram represents the skier as she passes point B.
Draw and label the vertical forces acting on the skier. *[2 marks]*



5d. The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. *[3 marks]*

5e. The skier reaches point C with a speed of 8.2 m s^{-1}. She stops after a distance of 24 m at point D. *[3 marks]*

Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected.

At the side of the course flexible safety nets are used. Another skier of mass 76 kg falls normally into the safety net with speed 9.6 m s^{-1}.

5f. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. *[2 marks]*

5g. Explain, with reference to change in momentum, why a flexible safety net is less likely to harm the skier than a rigid barrier. *[2 marks]*

Part 2 Momentum

6a. State the law of conservation of momentum. *[2 marks]*

6b. Far from any massive object, a space rocket is moving with constant velocity. The engines of the space rocket are turned on and it accelerates by burning fuel and ejecting gases. Discuss how the law of conservation of momentum relates to this situation. *[3 marks]*

6c. Jane and Joe are two ice skaters initially at rest on a horizontal skating rink. They are facing each other and Jane is holding a ball. Jane throws the ball to Joe who catches it. The speed at which the ball leaves Jane, measured relative to the ground, is 8.0 m s^{-1}. The following data are available. *[4 marks]*

Mass of Jane = 52 kg
Mass of Joe = 74 kg
Mass of ball = 1.3 kg

Use the data to calculate the

(i) speed v of Jane relative to the ground immediately after she throws the ball.

(ii) speed V of Joe relative to the ground immediately after he catches the ball.