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.

1a. 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.

1b. Determine the magnitude of the average resultant force acting on the block between B and C. [2 marks]
1c. 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.

1d. Calculate the magnitude of the average force exerted by the rope on the block between B and C. [2 marks]

1e. For the rope and block, describe the energy changes that take place between A and B. [1 mark]
1f. between B and C. [1 mark]

1g. 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 small ball of mass $m$ is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl.

The normal reaction force $N$ makes an angle $\theta$ to the horizontal.

2a. State the direction of the resultant force on the ball. [1 mark]
2b. On the diagram, construct an arrow of the correct length to represent the weight of the ball.

2c. Show that the magnitude of the net force $F$ on the ball is given by the following equation.

$$F = \frac{mg}{\tan \theta}$$
2d. The radius of the bowl is 8.0 m and $\theta = 22^\circ$. Determine the speed of the ball. [4 marks]

2e. Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl. [2 marks]
2f. A second identical ball is placed at the bottom of the bowl and the first ball is displaced so that its height from the horizontal is equal to 8.0 m. The first ball is released and eventually strikes the second ball. The two balls remain in contact. Determine, in m, the maximum height reached by the two balls.

3a. A girl on a sledge is moving down a snow slope at a uniform speed.

3a. Draw the free-body diagram for the sledge at the position shown on the snow slope.
3b. 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.

3c. 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.

3d. 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.
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.

3e. Show that the acceleration of the sledge is about –2 m s⁻².

3f. Calculate the distance along the slope at which the sledge stops moving. Assume that the coefficient of dynamic friction is constant.

3g. The coefficient of static friction between the sledge and the snow is 0.14. Outline, with a calculation, the subsequent motion of the sledge.
4a. From A to B, 24% of the gravitational potential energy transferred to kinetic energy. [2 marks]
Show that the velocity at B is 12 m s$^{-1}$.

4b. Some of the gravitational potential energy transferred into internal energy of the skis, [2 marks]
slightly increasing their temperature. Distinguish between internal energy and temperature.
4c. 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]

4d. 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]

4e. 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. 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. [3 marks]
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$^{-1}$.

4f. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. [2 marks]

4g. 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]
5a. The glider reaches its launch speed of $27.0\ \text{m s}^{-1}$ after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground.

5b. The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. Determine the average tension in the cable as the glider accelerates.
5c. The cable is pulled by an electric motor. The motor has an overall efficiency of 23%. Determine the average power input to the motor. [3 marks]

5d. The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 m s\(^{-1}\). Include an appropriate unit for your answer. [2 marks]
5e. After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider.

5f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight.

5g. At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m s\(^{-1}\). Calculate the velocity of the glider. Give your answer to an appropriate number of significant figures.
A company designs a spring system for loading ice blocks onto a truck. The ice block is placed in a holder H in front of the spring and an electric motor compresses the spring by pushing H to the left. When the spring is released the ice block is accelerated towards a ramp ABC. When the spring is fully decompressed, the ice block loses contact with the spring at A. The mass of the ice block is 55 kg.

Assume that the surface of the ramp is frictionless and that the masses of the spring and the holder are negligible compared to the mass of the ice block.

6a. (i) The block arrives at C with a speed of 0.90 m/s. Show that the elastic energy stored in the spring is 670 J. [4 marks]
(ii) Calculate the speed of the block at A.

6b. Describe the motion of the block [3 marks]
   (i) from A to B with reference to Newton's first law.
   (ii) from B to C with reference to Newton's second law.
6c. On the axes, sketch a graph to show how the displacement of the block varies with time from A to C. (You do not have to put numbers on the axes.) [2 marks]

6d. The spring decompression takes 0.42s. Determine the average force that the spring exerts on the block. [2 marks]

6e. The electric motor is connected to a source of potential difference 120V and draws a current of 6.8A. The motor takes 1.5s to compress the spring. Estimate the efficiency of the motor. [2 marks]