Mixed questions [49 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.

1a. 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]

1b. 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]
1c. 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]

1d. 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]

1e. 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$^{-1}$.

1f. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. [2 marks]

1g. 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]
An electrical circuit is used during an experiment to measure the current \( I \) in a variable resistor of resistance \( R \). The emf of the cell is \( e \) and the cell has an internal resistance \( r \).

A graph shows the variation of \( \frac{1}{I} \) with \( R \).

2a. Show that the gradient of the graph is equal to \( \frac{1}{e} \).  

2b. State the value of the intercept on the \( R \) axis.
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.

3a. The block arrives at C with a speed of 0.90 ms\(^{-1}\). Show that the elastic energy stored in the spring is 670 J.

(ii) Calculate the speed of the block at A.

3b. Describe the motion of the block

(i) from A to B with reference to Newton's first law.

(ii) from B to C with reference to Newton's second law.
3c. 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]

3d. The spring decompression takes 0.42s. Determine the average force that the spring exerts on the block. [2 marks]

3e. 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]
A glider is an aircraft with no engine. To be launched, a glider is uniformly accelerated from rest by a cable pulled by a motor that exerts a horizontal force on the glider throughout the launch.

The glider reaches its launch speed of 27.0 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.

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.
4c. The cable is pulled by an electric motor. The motor has an overall efficiency of 23%. Determine the average power input to the motor.

4d. 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.

4e. 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.

Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions.
4f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight.

[2 marks]

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4g. 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.

[3 marks]