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]

**Markscheme**

\[ \frac{1}{2}v^2 = 0.24gh \]

\[ v = 11.9 \text{ m s}^{-1} \]

Award GPE lost = 65 \(\times\) 9.81 \(\times\) 30 = «19130 J»

Must see the 11.9 value for MP2, not simply 12.

Allow \(g = 9.8 \text{ ms}^{-2}\).

1b. Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. [2 marks]

Distinguish between internal energy and temperature.

**Markscheme**

internal energy is the total KE «and PE» of the molecules/particles/atoms in an object

temperature is a measure of the average KE of the molecules/particles/atoms

Award [1 max] if there is no mention of molecules/particles/atoms.
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]

**Markscheme**

Arrow vertically downwards from dot labelled weight/W/mg/gravitational force/F\_g/F_{gravitational} AND arrow vertically upwards from dot labelled reaction force/R/normal contact force/N/F_N

\( W > R \)

Do not allow gravity.
Do not award MP1 if additional 'centripetal' force arrow is added.
Arrows must connect to dot.
Ignore any horizontal arrow labelled friction.
Judge by eye for MP2. Arrows do not have to be correctly labelled or connect to dot for MP2.

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]
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. 

1e. \[0 = 8.2^2 + 2 \times a \times 24\] therefore \(a = -1.40 \text{ m s}^{-2}\)

\[
\text{friction force} = ma = 65 \times 1.4 = 91 \text{ N}
\]

\[
\text{coefficient of friction} = \frac{91}{\frac{65}{9.81}} = 0.14
\]

Calculating 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\(^{-1}\).

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

\[
\text{Impulse} = \frac{1}{2}mv^2 - 0.5 \times 65 \times 8.2^2 = 2185 \text{ Ns}
\]

\[
\text{friction force} = \text{Impulse/distance} = 2185/24 = 91 \text{ N}
\]

\[
\text{coefficient of friction} = \frac{91}{\frac{65}{9.81}} = 0.14
\]
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]

**Markscheme**

- safety net extends stopping time
- $F = \frac{\Delta p}{\Delta t}$ therefore $F$ is smaller «with safety net»
- OR
- force is proportional to rate of change of momentum therefore $F$ is smaller «with safety net»
- Accept reverse argument.

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 $r$.

![Diagram of an electrical circuit with emf $E$, internal resistance $r$, and variable resistor $R$.]

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

2a. Show that the gradient of the graph is equal to $\frac{1}{r}$. [2 marks]

**Markscheme**

- $E = IR + Ir$
- $\frac{1}{I} = \frac{E}{R} + \frac{r}{R}$
- identifies equation with $y = mx + c$
- «hence $m = \frac{1}{r}$»
- No mark for stating data booklet equation
- Do not accept working where $r$ is ignored or $E = IR$ is used
- OWTTE
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. (i) 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.
Markscheme

(i) no force/friction on the block, hence constant motion/velocity/speed
(ii) force acts on block OR gravity/component of weight pulls down slope
velocity/speed decreases OR it is slowing down OR it decelerates

Do not allow a bald statement of “N2” or “F = ma” for MP1.
Treat references to energy as neutral.

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]

Markscheme

straight line through origin for at least one-third of the total length of time axis covered by candidate line followed by curve with decreasing positive gradient

Ignore any attempt to include motion before A.
Gradient of curve must always be less than that of straight line.

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.

**Markscheme**

\[ F \approx \Delta p / \Delta t = 55 \times 4.9 / 0.42 \]

\[ F = 642 \approx 640 \text{N} \]

Allow ECF from (a)(ii).

\[ F \ll = \Delta p / \Delta t \]

4a.

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.

**Markscheme**

Correct use of kinematic equation/equations

\[ 148.5 \text{ or } 149 \text{ or } 150 \text{ m} \]

Substitution(s) must be correct.

4b.

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.

**Markscheme**

\[ a = \frac{27}{11} \text{ or } 2.45 \text{ m s}^{-2} \]

\[ F = 160 = 492 \times 2.45 \]

1370 \text{ N}

Could be seen in part (a).

Award [0] for solution that uses \( a = 9.81 \text{ m s}^{-2} \).
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. [3 marks]

**Markscheme**

**ALTERNATIVE 1**

«work done to launch glider» = 1370 x 149 «= 204 kJ»

«work done by motor» = \( \frac{204 \times 100}{23} \)

«power input to motor» = \( \frac{204 \times 100}{23} \) \( \times \) \( \frac{1}{11} \) = 80 or 80.4 or 81 kW.

**ALTERNATIVE 2**

use of average speed 13.5 m s\(^{-1}\)

«useful power output» = force x average speed = 1370 x 13.5

power input = «1370 x 13.5 x \( \frac{100}{23} \)» = 80 or 80.4 or 81 kW.

**ALTERNATIVE 3**

work required from motor = KE + work done against friction = 0.5 x 492 x 27\(^2\) + (160 x 148.5) = 204 kJ

«energy input» = work required from motor \( \times \) \( \frac{100}{23} \)

power input = \( \frac{803000}{11} \) = 80.3 kW.

Award [2 max] for an answer of 160 kW.

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. [2 marks]

**Markscheme**

\( \omega = \frac{v}{r} = \frac{27}{1.2} = 45 \) rad s\(^{-1}\)

Do not accept Hz.

Award [1 max] if unit is missing.

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. [2 marks]

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]

**Markscheme**

- name Newton’s first law
- vertical/all forces are in equilibrium/balanced/add to zero
  - OR
  - vertical component of lift mentioned as equal to weight

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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]

**Markscheme**

- any speed and any direction quoted together as the answer
- quotes their answer(s) to 3 significant figures
- speed = 12.7 m s\(^{-1}\) or direction = 9.46 \(^{\circ}\) or 0.165 rad <below the horizontal> or gradient of \(-\frac{1}{6}\)