**Q1.** The nucleus of a radioactive isotope $X$ is at rest and decays by emitting an $\alpha$ particle so that a new nuclide $Y$ is formed.
Which one of the following statements about the decay is correct?

**A**     The momentum of $Y$ is equal and opposite to the momentum of the $\alpha$ particle.

**B**     The momentum of $Y$ is equal to the momentum of $X$.

**C**     The kinetic energy of $Y$ is equal to the kinetic energy of the $\alpha$ particle.

**D**     The total kinetic energy is the same before and after the decay.

**(Total 1 mark)**

**Q2.** The diagram below shows a bungee jumper of mass 75 kg about to step off a raised platform. The jumper comes to a halt for the first time when his centre of mass has fallen through a distance of 31 m.
The bungee rope has an unextended length of 19 m and a stiffness of 380 N m$^{-1}$.

Ignore the effects of air resistance and the mass of the rope in this question.
Treat the jumper as a point mass located at the centre of mass.
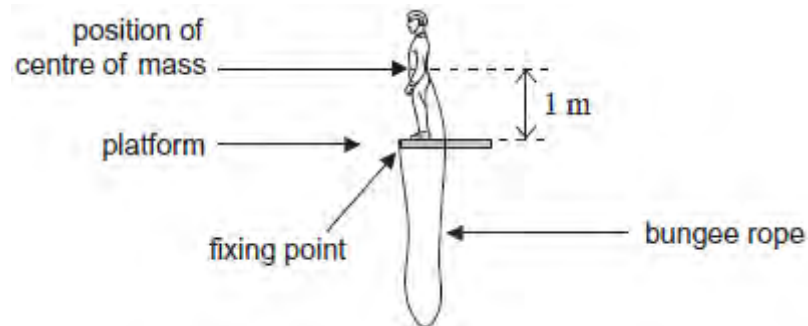


(a)    (i)    Calculate the extension of the bungee rope when the centre of mass of the jumper has fallen through 31 m.

extension ................................................ m

**(1)**

(ii)    Calculate the resultant force acting on the jumper when he reaches the lowest
        point in the jump.

                                    resultant force ................................................ N

**(2)**

(b)    Calculate the extension of the rope when the jumper's acceleration is zero.

                                    extension ................................................ m

**(2)**

(c)    The extension of the bungee rope is 5.0 m when the jumper's centre of mass has
       fallen through a distance of 25 m.

       Use the principle of conservation of energy to calculate the speed of the jumper in
       this position.

speed .......................................... m s$^{-1}$

**(4)**

(d)   The bungee jump operator intends to use a bungee rope of the same unextended length but with a much greater stiffness. The rope is to be attached in the same way as before.

Explain, with reference to the kinetic energy of the jumper, any safety concerns that may arise as the jumper is slowed down by the new rope.

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**(3)**
**(Total 12 marks)**

**Q3.** The following figure shows a roller coaster car which is accelerated from rest to a speed of 56 m s$^{-1}$ on a horizontal track, **A**, before ascending the steep part of the track. The roller coaster car then becomes stationary at **C**, the highest point of the track. The total mass of the car and passengers is 8300 kg.
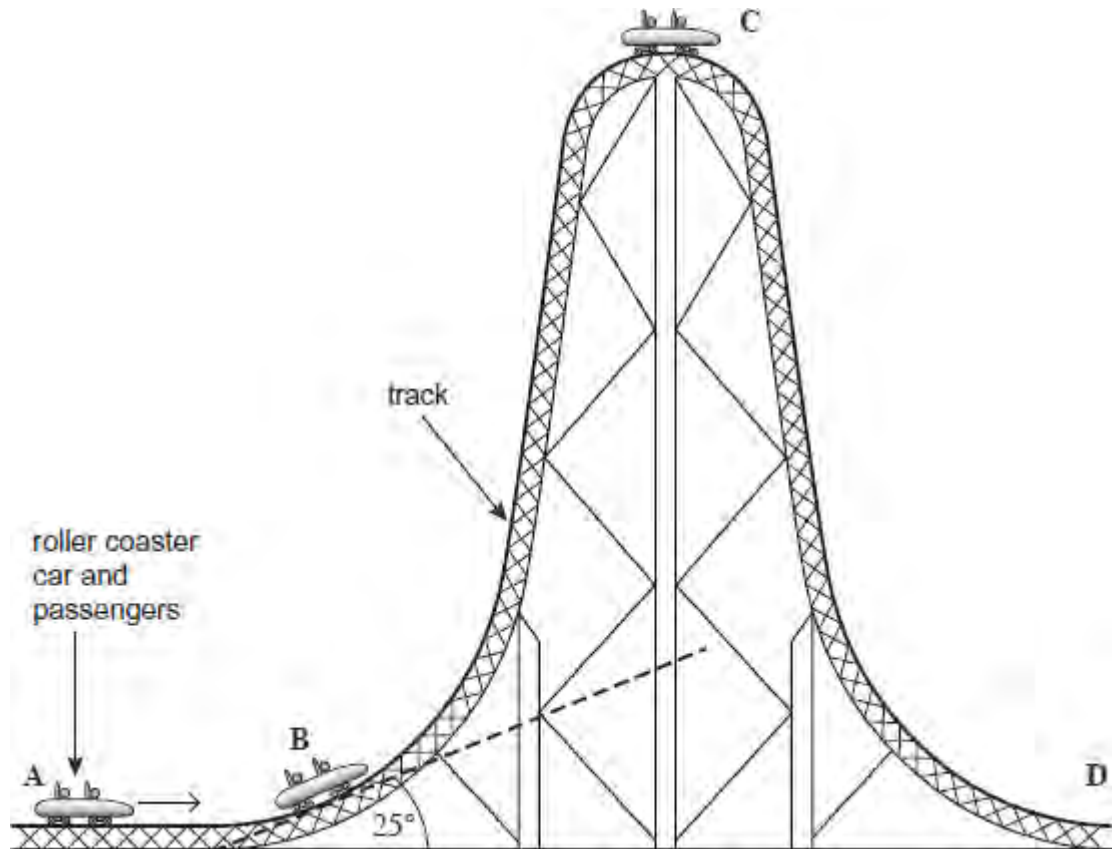
(a)    The angle of the track at **B** is 25° to the horizontal. Calculate the component of the weight of the car and passengers acting along the slope when the car and passengers are in position **B** as shown in the image above.

component of weight .......................................... N

**(2)**

(b)    (i)    Calculate the kinetic energy of the car including the passengers when travelling at 56 m s⁻¹.

kinetic energy .......................................... J

**(2)**

(ii)    Calculate the maximum height above **A** that would be reached by the car and passengers if all the kinetic energy could be transferred to gravitational potential energy.

maximum height ........................................ m

**(2)**

(c)   The car does not reach the height calculated in part (b).

(i)   Explain the main reason why the car does not reach this height.

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**(2)**

(ii)  The car reaches point $C$ which is at a height of 140 m above $A$. Calculate the speed that the car would reach when it descends from rest at $C$ to its original height from the ground at $D$ if 87% of its energy at $C$ is converted to kinetic energy.

speed .................................... m s$^{-1}$

**(2)**
**(Total 10 marks)**

**Q4.**A snowboarder slides down a slope, as shown in the diagram below. Between **B** and **C** her acceleration is uniform.
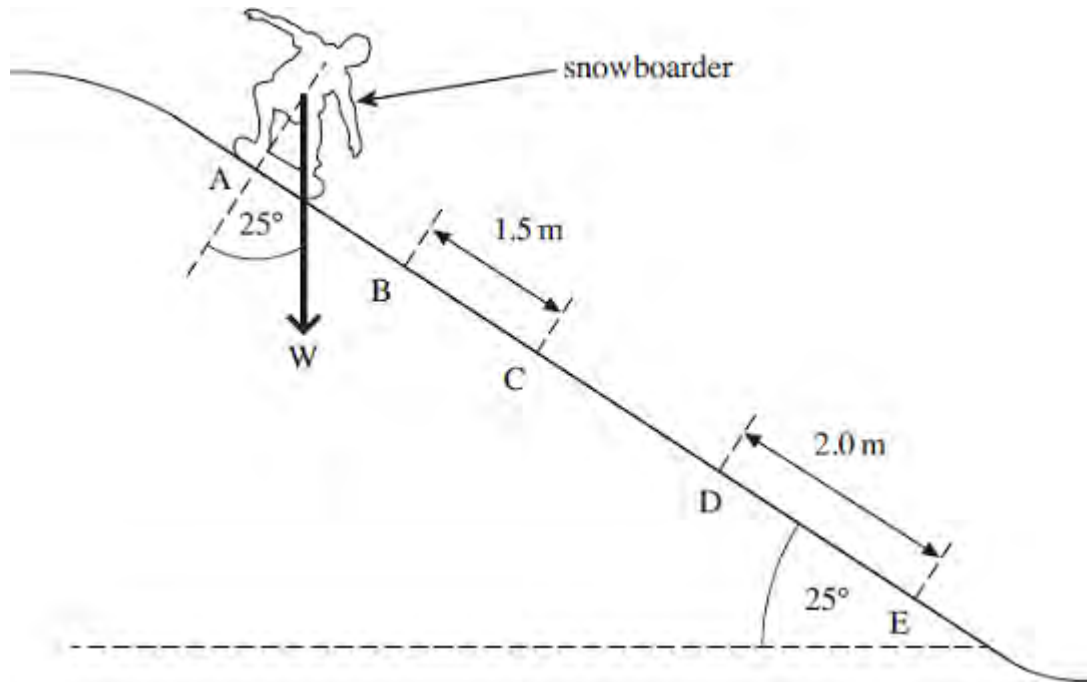
(a)    The snowboarder travels 1.5 m from B to C in a time of 0.43 s and her velocity down the slope at C is 5.0 ms⁻¹.

Calculate her velocity down the slope at B.

velocity = ........................... ms⁻¹

**(3)**

(b)    The combined mass of the snowboarder and snowboard is 75 kg and the angle of the slope is 25°

(i)    Calculate the component of the weight of the snowboarder and snowboard acting down the slope.

weight component = ................................. N

**(2)**

(ii)    At D the snowboarder has reached a constant velocity. She moves a distance

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of 2.0 m at constant velocity between D and E.

Calculate the work done against resistive forces as she moves from D to E.

work done = .................................. J

**(1)**

(c)   State and explain what happens to the gravitational potential energy lost between D and E.

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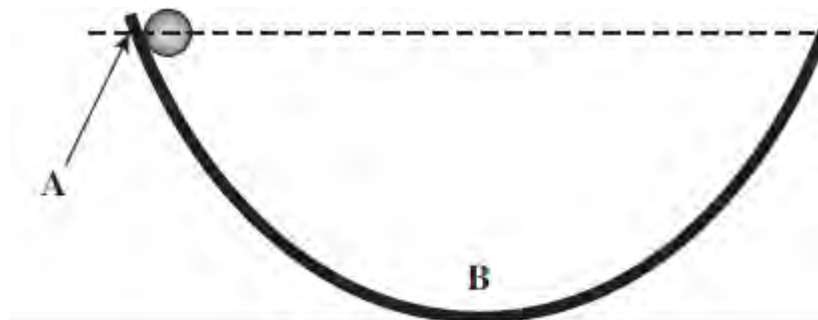
**(3)**
**(Total 9 marks)**

**Q5.**      In the 17ᵗʰ century, when thinking about forces, Galileo imagined a ball moving in the absence of air resistance on a frictionless track as shown in **Figure 1**.

**Figure 1**



(a)   Galileo thought that, under these circumstances, the ball would reach position **C** if released from rest at position **A**. Position **C** is the same height above the ground as **A**.

Using ideas about energy, explain why Galileo was correct.
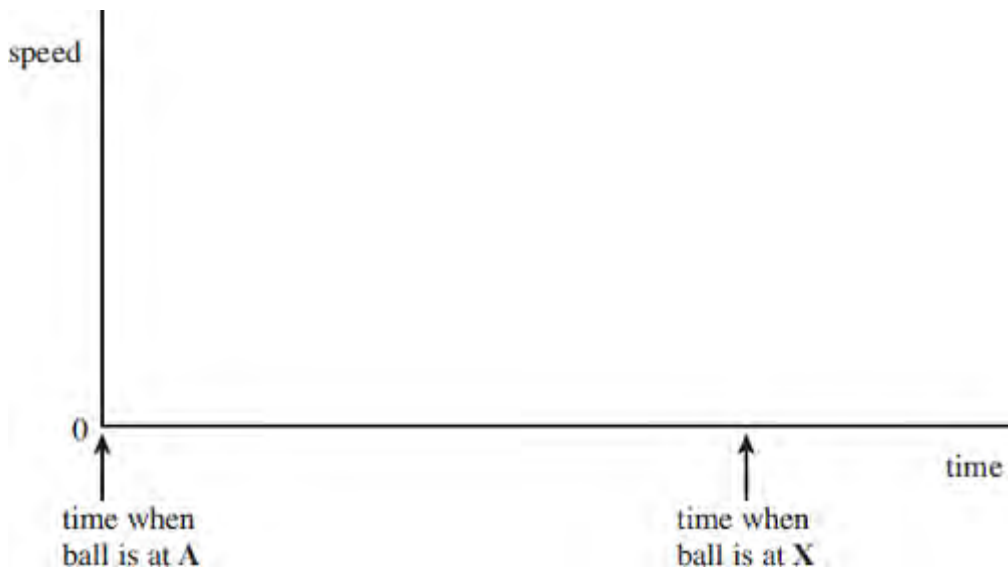
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**(3)**

(b)     Galileo then imagined that the track was changed, as shown in **Figure 2**.

**Figure 2**



moving b

The slope beyond **B** was now horizontal.

On the axes below, sketch a speed – time graph for the ball from its release at **A** until it reaches the position **X** shown in **Figure 2**. Indicate on your graph the time when the ball is at **B**.



**(3)**

(c)     Newton later published his three laws of motion.

Explain how Newton's first law of motion is illustrated by the motion of the ball between **B** and **X**.
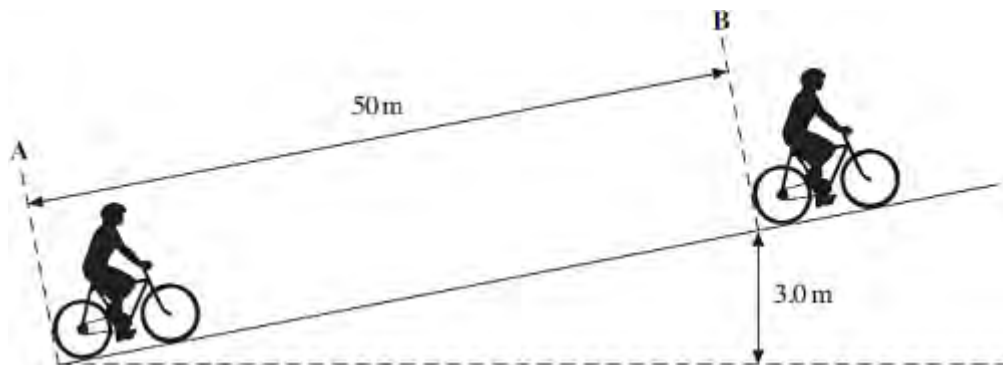
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**(2)**
**(Total 8 marks)**


**Q6.** An 'E-bike' is a bicycle that is assisted by an electric motor. The figure below shows an E-bike and rider with a total mass of 83 kg moving up an incline.



(a)     (i)     The cyclist begins at rest at **A** and accelerates uniformly to a speed of 6.7 m $s^{-1}$ at **B**.
The distance between **A** and **B** is 50 m.
Calculate the time taken for the cyclist to travel this distance.

answer = .................................. s

**(2)**

(ii) Calculate the kinetic energy of the E-bike and rider when at **B**. Give your answer to an appropriate number of significant figures.

answer = ................................. J

**(2)**

(iii) Calculate the gravitational potential energy gained by the E-bike and rider between **A** and **B**.

answer = ................................. J

**(2)**

(b) Between **A** and **B**, the work done by the electric motor is 3700 J, and the work done by the cyclist pedalling is 5300 J.

(i) Calculate the wasted energy as the cyclist travels from **A** to **B**.

answer = ................................. J

**(2)**

(ii) State **two** causes of this wasted energy.

Cause 1 ................................................................................................

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Cause 2 ................................................................................................

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**(2)**
**(Total 10 marks)**