1 What is the angular speed of a car wheel of diameter 0.400 m when the speed of the car is 108 km h^{-1}?

A 75 rad s^{-1}

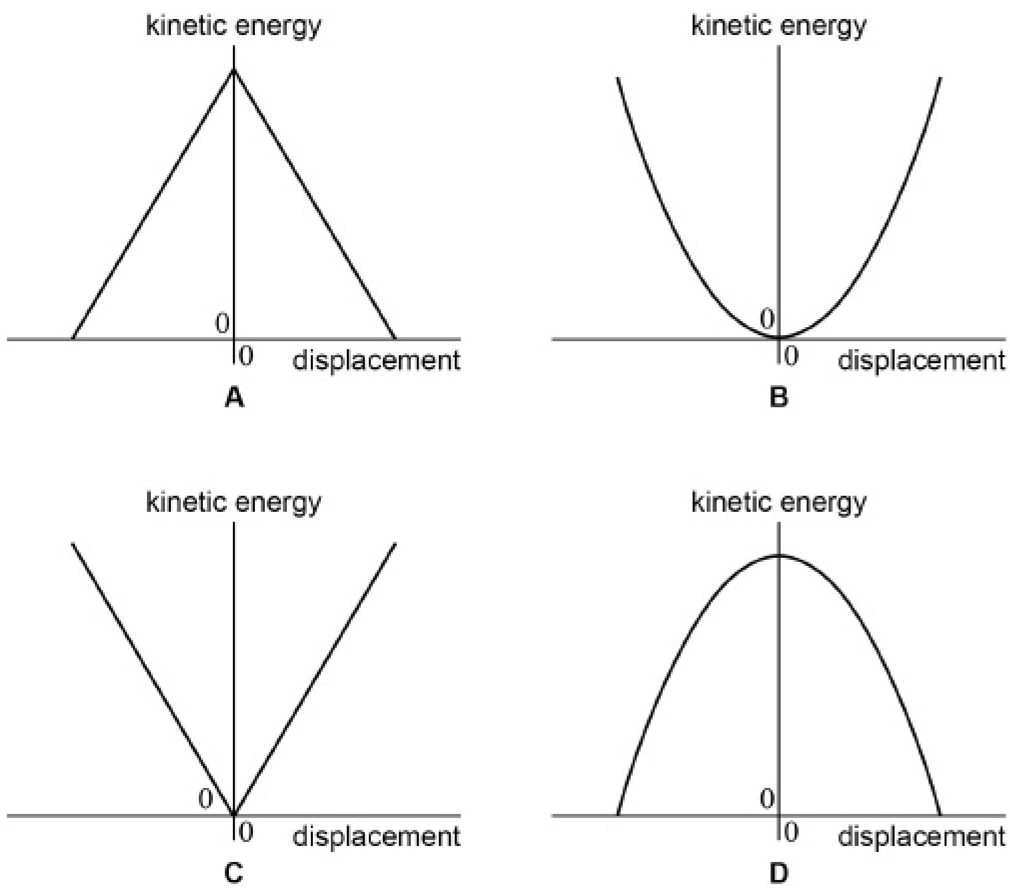
B 150 rad s^{-1}

C 270 rad s^{-1}

D 540 rad s^{-1}

(Total 1 mark)

2 Which graph best shows how the kinetic energy of a simple pendulum varies with displacement from the equilibrium position?



A ☐

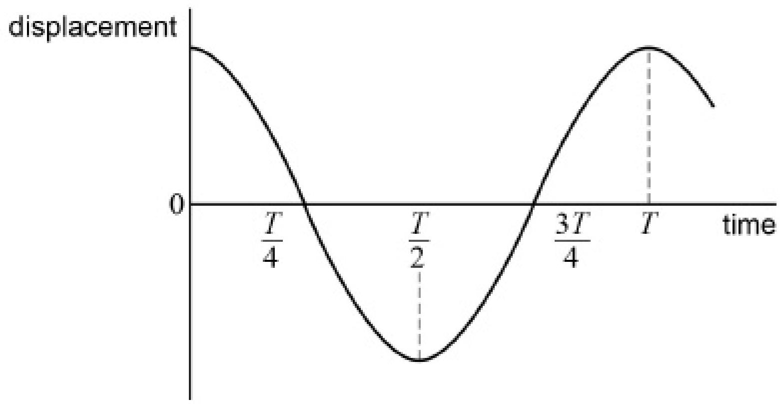
B ☐

C ☐

D ☐

(Total 1 mark)

3 The graph shows how the displacement of a particle performing simple harmonic motion varies with time.



Which statement is **not** correct?

A The speed of the particle is a maximum at time $\frac{T}{4}$ ⬭

B The potential energy of the particle is zero at time $\frac{3T}{4}$ ⬭

C The acceleration of the particle is a maximum at time $\frac{T}{2}$ ⬭

D The restoring force acting on the particle is zero at time T ⬭

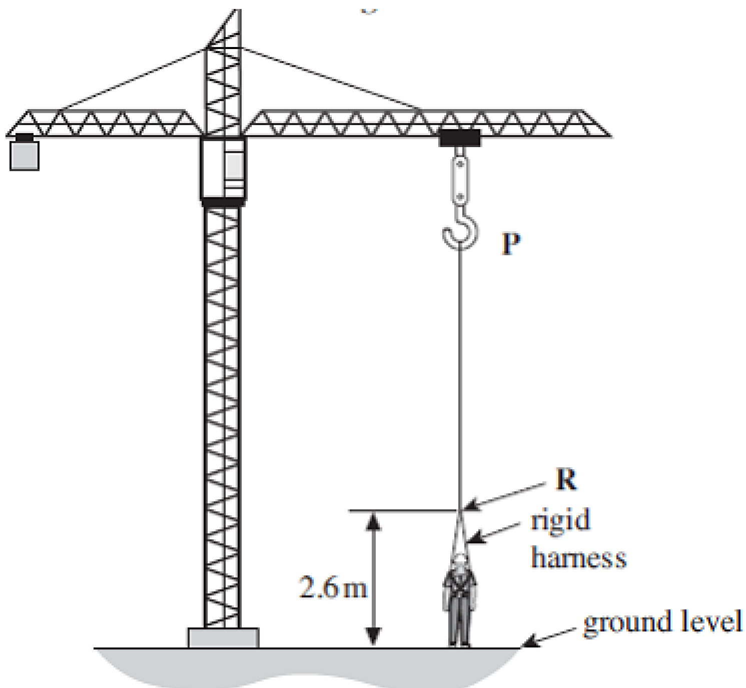
(Total 1 mark)

4

In a reverse bungee experience a 'rider' is catapulted high into the air.
A designer creates a less extreme version for more timid participants, as shown in the figure below.

The rider is strapped into a rigid harness attached to one end of an elastic rope **PR**. The rider and the rope behave in the same way as a mass-spring system.

The rider is initially held at rest at ground level. The top end of the rope, **P**, is raised to stretch the rope. The rider is then released and moves upwards, reaching a maximum height when the rope is at its unstretched (natural) length. The rider then oscillates vertically until eventually coming to rest, suspended above the ground.



The rope has an unstretched length of 20 m. When stretched, the rope obeys Hooke's law and has a stiffness of 92 Nm^{-1}. In the following questions ignore the mass of the rope.

(a) (i) The rider and harness have a total mass of 55 kg.
Calculate the overall length of the rope when the rider comes to rest, suspended above the ground, at the end of the ride.

____

____

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____

____

overall length ____________________ m

(3)

(ii) At the start of the ride, the lower end of the rope **R** is attached to the rigid harness at a point which is 2.6 m above the ground.

The top end of the rope, **P**, has to be adjusted so that the rope just becomes unstretched when the rider is at the highest point of the ride.
Determine the height of **P** above the ground.
Neglect air resistance in this part of the question.

____

____

____

height of point **P** ______________________ m

(1)

(b) (i) Show that the frequency of oscillation of the rider on the end of the rope is about 0.2 Hz.

____

____

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____

____

(3)

(ii) Calculate the maximum speed reached by the rider when the amplitude of the oscillation is 4.2 m.

____

____

____

____

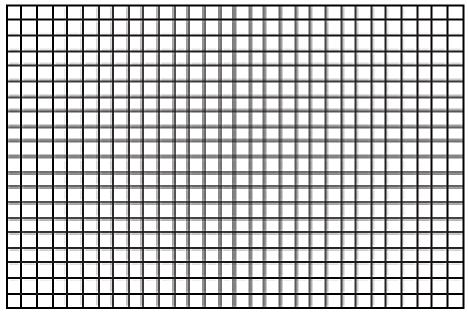
____

maximum speed ______________________ ms^{-1}

(2)

(iii) In practice, air resistance has an effect. Sketch below, a graph showing how you would expect the velocity to vary with time over the first two complete oscillations, from the instant the rider was released from ground level. Take an upward velocity as being positive.

Label the time axis with a suitable scale. No scale is required on the velocity axis.



(3)

(c) (i) A rider of greater mass now uses the ride. Explain how the height of **P** has to be changed to produce the same initial amplitude of oscillations as that for the previous rider.

(3)

(ii) A safety officer examines the design of the ride and thinks that, if the end **P** of the rope is raised too high so that the rope is stretched too much at the start, there is a risk that the rider could hit the ground after the first oscillation and suffer an injury. Describe what would happen to the rider during the ride in this case and explain why, even if air resistance is negligible, the safety officer’s concerns are unfounded.

(3)

(Total 18 marks)

5 To celebrate the Millennium in the year 2000, a footbridge was constructed across the River Thames in London. After the bridge was opened to the public it was discovered that the structure could easily be set into oscillation when large numbers of pedestrians were walking across it.

(a) What name is given to this kind of physical phenomenon, when caused by a periodic driving force?

____

(1)

(b) Under what condition would this phenomenon become particularly hazardous? Explain your answer.

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____

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(4)

(c) Suggest **two** measures which engineers might adopt in order to reduce the size of the oscillations of a bridge

measure 1 ____

____

measure 2 ____

____

(2)

(Total 7 marks)