

Name _____

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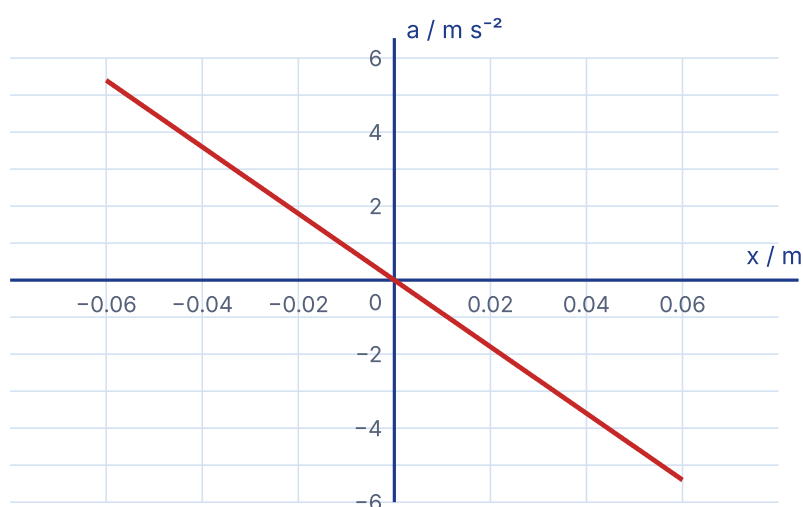
Score: _____ / 41

70 minutes · 41 marks · calculator and data booklet allowed

- Answer all the questions in the spaces provided.
- Show all your working. Marks are given for correct method.
- The marks for each part are shown in brackets [].
- Take $g = 9.8 \text{ m s}^{-2}$.

1. A glider between two springs [9 marks]

A glider of mass 0.40 kg on a horizontal air track is attached between two springs. The glider is pulled to one side and released. Friction is negligible. The graph shows how the acceleration a of the glider varies with its displacement x from the equilibrium position.



(a) **State** the conditions for simple harmonic motion (SHM). [2]

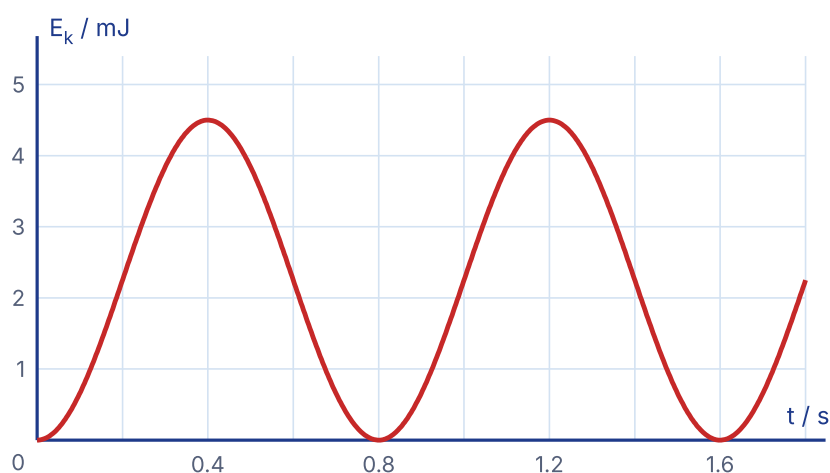
(b) **Explain**, using the graph, why the motion of the glider is simple harmonic. [2]

(c) **Determine** the period of the oscillation. [3]

- (d) **Calculate** the maximum speed of the glider. [2]

2. A simple pendulum [10 marks]

The bob of a simple pendulum has a mass of 0.20 kg. The bob is pulled to one side by a small angle and released at $t = 0$. The graph shows how the kinetic energy E_k of the bob varies with time t . Air resistance is negligible.



- (a) **Determine** the period of the pendulum. [2]

- (b) **Calculate** the length of the pendulum. [2]

- (c) **Calculate** the maximum speed of the bob. [2]

- (d) **Show** that the period of a simple pendulum does not depend on the mass of the bob. [2]

- (e) The bob is replaced by a bob of mass 0.40 kg. It is released from the same angle. **State** the effect of this change on (i) the period and (ii) the maximum kinetic energy. [2]

3. (HL) The needle of a sewing machine [10 marks]

The needle of a sewing machine moves up and down with simple harmonic motion. Its displacement x , in metres, from the centre of its motion is modelled by

$$x = 0.012 \sin(30t + 5\pi/6)$$

where t is the time in seconds. Upwards is positive.

- (a) **State** the amplitude and **calculate** the frequency of the oscillation. [2]

- (b) **Determine** the displacement of the needle at $t = 0$, and **state** its direction of motion at $t = 0$. [2]

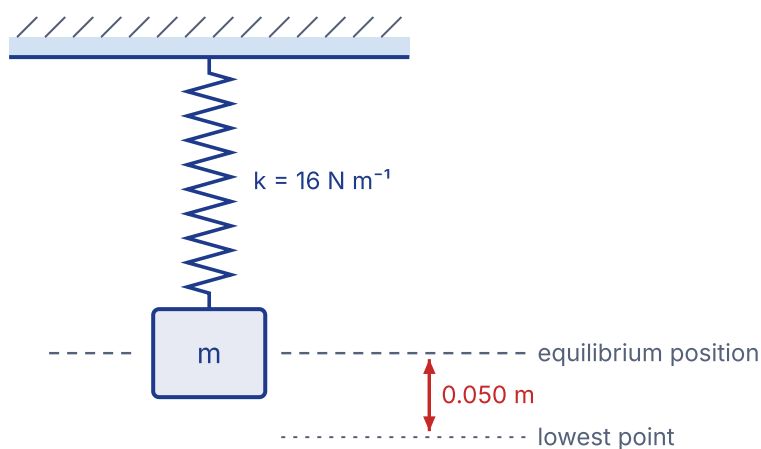
- (c) By differentiating the equation for x , **write down** the equations for the velocity v and the acceleration a of the needle. [2]

- (d) **Calculate** the velocity and the acceleration of the needle at $t = 0.050$ s. [2]

- (e) A second needle moves with $x = 0.012 \sin(30t + \pi/3)$. **Determine** the phase difference between the two needles, and the time from the moment the first needle is at its highest point to the moment the second needle next reaches its highest point. [2]

4. (HL) A mass on a vertical spring [12 marks]

A mass of 0.25 kg hangs at rest from a vertical spring of spring constant 16 N m^{-1} . The mass is pulled down 0.050 m below its equilibrium position and released. It oscillates vertically with simple harmonic motion, and the spring stays stretched all the time.



- (a) **Calculate** the extension of the spring when the mass hangs at rest. [1]

- (b) **Show** that the period of the oscillation is about 0.79 s. [2]

- (c) **Calculate** the total energy of the oscillation. [2]

- (d) **Describe** the energy transfers as the mass moves from the lowest point to the highest point. [2]

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- (e) A student says that the elastic potential energy stored in the spring at the lowest point is $\frac{1}{2}m\omega^2x_0^2$, the value in (c). **Explain** why this is not correct, and **calculate** the elastic potential energy stored in the spring at the lowest point. **[3]**

- (f) **State** the time between two successive moments when the kinetic energy of the mass is a maximum. **[1]**

- (g) **Calculate** the maximum speed of the mass. **[1]**
