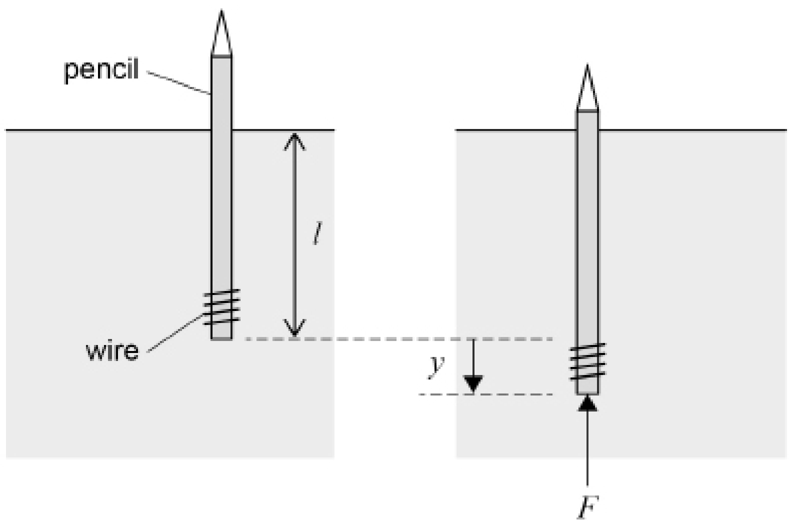
Q1.

A pencil is weighted with a thin coil of wire. The volume of the wire is negligible. **Figure 1** shows the pencil and wire floating in equilibrium in water.

Figure 1 **Figure 2**



In **Figure 1** the combined weight of the pencil and wire is equal to an upwards force called the buoyancy force. The length of the pencil that is submerged is l.
A student pushes the pencil down through a displacement y as shown in **Figure 2**.
The buoyancy force is now greater than the weight.
There is a resultant upward force F acting on the pencil when the student releases it.
The magnitude of F for any value of y is given by

$$F = A\rho gy$$

where A is the cross-sectional area of the pencil
ρ is the density of water
g is the acceleration due to gravity.

The pencil is pushed down and released. The pencil then oscillates vertically about the equilibrium position.

(a) Show that the pencil moves with simple harmonic motion.

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(2)

(b) The time period T of the vertical oscillations is given by

$$T = 2\pi\sqrt{\frac{l}{g}}$$

The measured value of l in **Figure 2** is 85 mm.
The pencil is pushed down 5.0 mm and released.

Calculate the maximum acceleration of the pencil.

maximum acceleration = ____________________ m s^{-2}

(2)

A ship floating in the sea can be modelled by the pencil floating in water.
The ship can oscillate vertically. These oscillations are called heave oscillations.

Wave motion causes forced oscillations of the ship. Under certain conditions, heave resonance may then occur.

(c) Explain what is meant by resonance.

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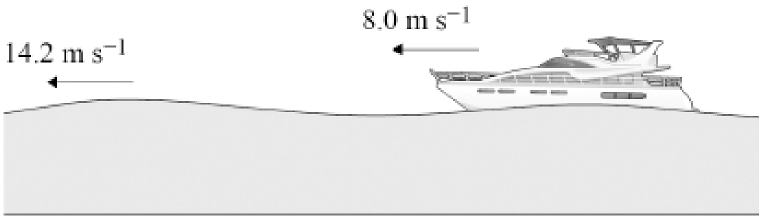
(2)

(d) **Figure 3** shows a ship moving through continuous waves of wavelength 118 m and velocity 14.2 m s^{-1}.

The ship is moving steadily at 8.0 m s^{-1} relative to the seabed in the same direction as the waves.

Figure 3



The natural frequency of heave oscillations of the ship is 0.13 Hz.

A crew member needs an emergency operation. The ship's doctor is confident that she can do the operation if the ship remains fairly steady.

There are two options:

- stop the ship's motors and loosely anchor the ship to the seabed
- continue to sail the ship at 8.0 m s^{-1} in the same direction.

Deduce which is the better option.
Support your answer with a calculation.

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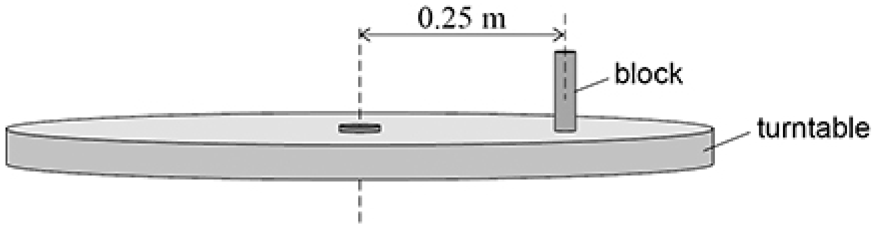
(3)
(Total 9 marks)

Q2.

A teacher sets up a demonstration to show the relationship between circular motion and simple harmonic motion (SHM).

She places a block on a turntable at a point 0.25 m from its centre, as shown in **Figure 1**.

Figure 1



The turntable rotates with an angular speed of $1.8\ \text{rad s}^{-1}$ and the block does not slip.

(a) Calculate the time taken for the turntable to complete one revolution.

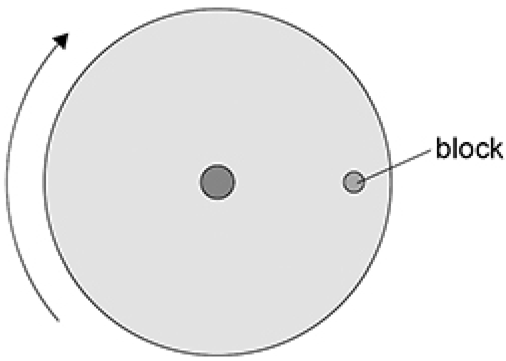
time = ________________ s

(2)

(b) **Figure 2** shows a plan view of the turntable and block.
The turntable rotates in a clockwise direction.

Draw an arrow on **Figure 2** to show the direction of the resultant force on the block.

Figure 2



(1)

(c) The mass of the block is $0.12\ \text{kg}$.

Calculate the magnitude of the resultant force on the block.

magnitude of force = ________________ N

(2)

(d) Describe, with reference to one of Newton's laws of motion, the evidence that a resultant force is acting on the block.

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(2)

(e) The teacher adjusts the angular speed of the turntable so that the block completes one rotation every $2.50\ \text{s}$.
She sets up a simple pendulum above the centre of the turntable so that it swings in phase with the movement of the block.

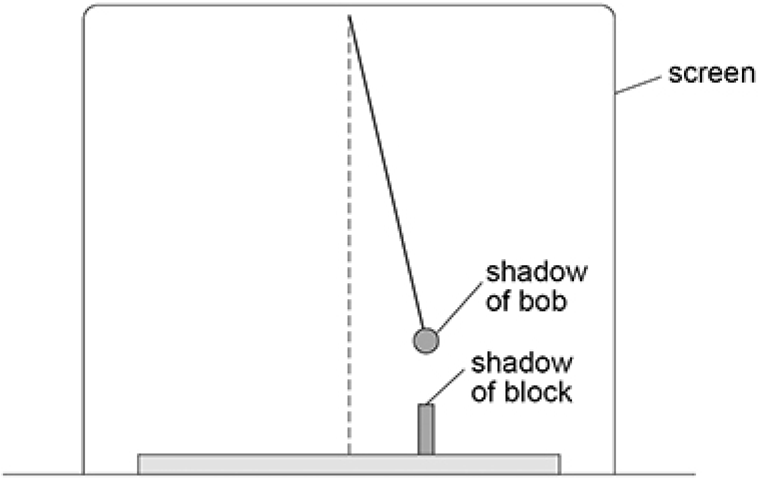
Calculate the length of the simple pendulum.

length = ________________ m

(2)

(f) A lamp is used to project shadow images of the block and pendulum bob on a screen.
Both shadows appear to move with SHM across the screen.
Figure 3 shows the images on the screen at one instant.

Figure 3



Initially the shadows move in phase with the same amplitude.

Air resistance affects the motion of the pendulum.

Suggest the effect this has on the amplitude relationship and the phase relationship between the moving shadows.

amplitude ____
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phase ____

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(2)
(Total 11 marks)