Oscillations

1. A mass is hung from a spring and set into vertical oscillation. Which row in the table correctly shows the kinetic energy E_k of the mass at maximum displacement and the potential energy E_p of the mass at the equilibrium position.

	Maximum displacement position	**Equilibrium position**
A	E_k is a maximum	E_p is minimum
B	E_k is a maximum	E_p is a maximum
C	E_k is zero	E_p is a maximum
D	E_k is zero	E_p is minimum

(Total 1 mark)

2. A toy for cats consists of a plastic mouse of mass m attached to a spring. When the mouse is on a low-friction horizontal surface, with the spring attached to a rigid support as shown, it performs simple harmonic motion when given a small displacement x from its equilibrium position and released.

(a) Show that the acceleration of the mouse, a, is given by $a = -\left(\frac{k}{m}\right)x$, where k is the stiffness of the spring.

....

....

....

....

(2)

(b) The mouse has a mass m = 0.15 kg and the spring extends by 20 cm when the mouse is supported vertically by the spring.

Calculate the frequency of oscillation of the mouse if it is set into oscillation on a low friction horizontal surface.

....

....

....

....

....

....

....

....

Frequency = ...

(5)

(Total 7 marks)

3. Read this passage and answer the questions that follow.

The Millennium Bridge opened on 10 June 2000 as London's first new Thames crossing in more than 100 years. The bridge uses "lateral suspension" – an engineering innovation that allows suspension bridges to be built without tall supporting columns. Tens of thousands of people crossed the bridge on its opening day. The structure was designed to take the weight, but suddenly the bridge began to sway and twist in regular oscillations. The worst of the movement occurred on the central span where the edge of the bridge oscillated through a total distance of 70 mm.

To solve the problem the engineers decided to use damping mechanisms – giant shock absorbers to limit the bridge's response to external forces. They decided to use two systems: viscous dampers, similar to car shock absorbers, and tuned mass dampers. A tuned mass damper is a large mass stiffened by springs.

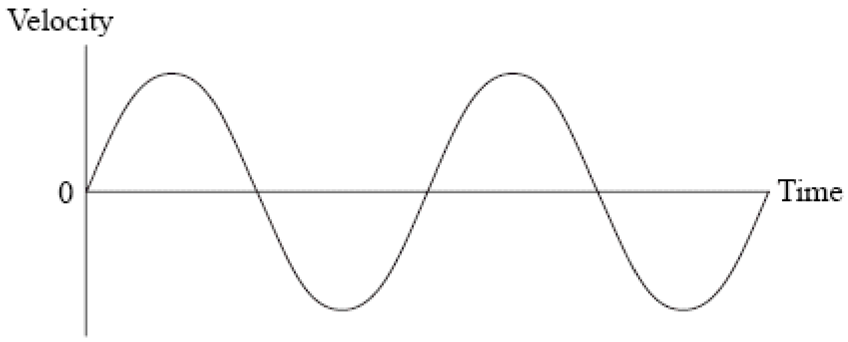
(a) Name the effect that results in a system being driven into large amplitude oscillations, and state the condition necessary for this to happen.

....

....

....
(2)

(b) The graph shows the variation of velocity with time at the edge of the central span of the bridge.



Mark on this graph:

(i) An instant X at which the displacement was a maximum.
(1)

(ii) An instant Y at which the acceleration was zero.
(1)

(c) Before modification the edge of the central span of the bridge oscillated with simple harmonic motion, and had a maximum acceleration of 0.89 m s^{-2}. Calculate the maximum velocity of the edge of the central span of the bridge.

....

....

....

....

....

....

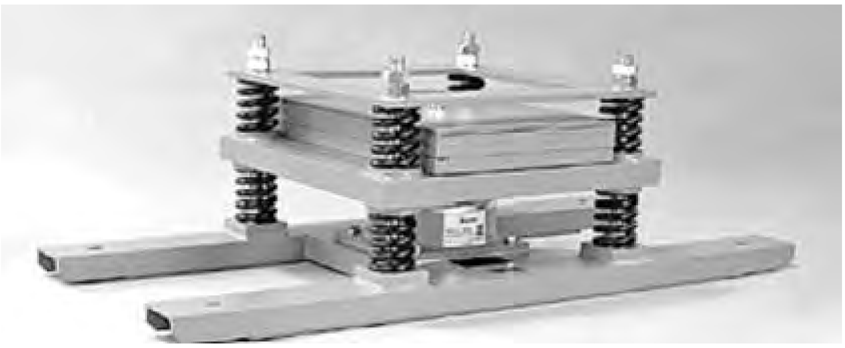
....

....

Maximum velocity = ...

(4)

(d) The photograph shows the tuned mass dampers which were fitted to the bridge. They are tuned to the natural frequency of oscillation of the bridge.



Discuss how the tuned mass dampers reduce the amplitude of the oscillations of the bridge and explain why they must be very heavily damped.

....

....

....

....

....

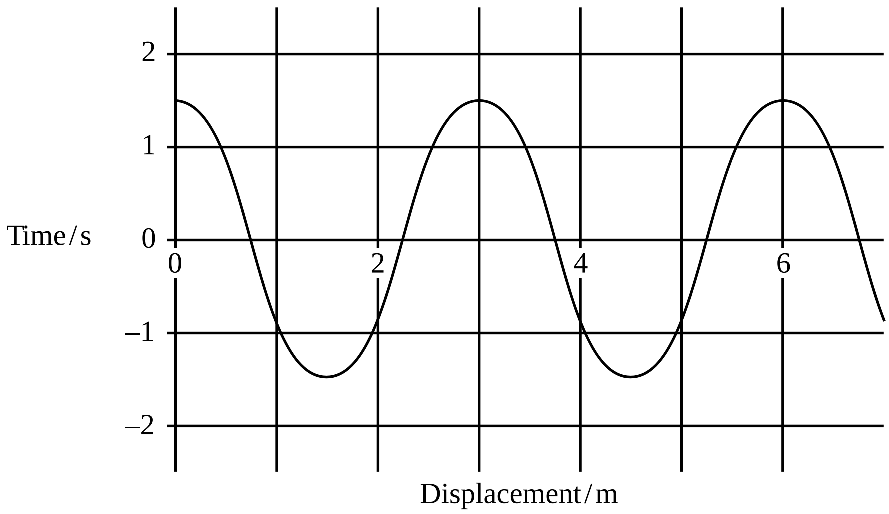
....

....

(3)

(Total 11 marks)

4. A child is playing on a swing. The graph shows how the displacement of the child varies with time.



The maximum velocity, in m s^{-1}, of the child is

A $\pi/2$

B π

C 2π

D 3π

(Total 1 mark)

5. A car driver notices that her rear view mirror shakes a lot at a particular speed. To try to stop it she sticks a big lump of chewing gum on the back of the mirror.

Which one of the following statements is correct?

A The mirror no longer shakes a lot because it is heavily damped.

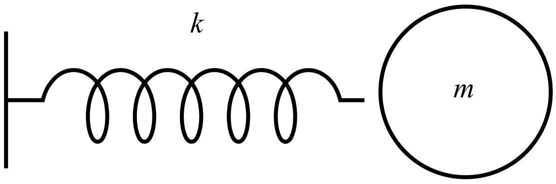
B The mirror stills shakes a lot at the same speed as before because the chewing gum does not change the damping.

C The mirror shakes a lot at a different speed because the chewing gum changes the damping.

D The mirror shakes a lot at a different speed because the chewing gum has changed the resonant frequency of the mirror.

(Total 1 mark)

6. Certain molecules such as hydrogen chloride (HCl) can vibrate by compressing and extending the bond between atoms. A simplified model ignores the vibration of the chlorine atom and just considers the hydrogen atom as a mass *m* on a spring of stiffness *k* which is fixed at the other end.



(a) (i) Show that the acceleration of the hydrogen atom, *a*, is given by $a = -\frac{kx}{m}$ where *x* is the displacement of the hydrogen atom.

....

....

....

....

(2)

(ii) Hence derive the equation $T = 2\pi\sqrt{m/k}$ for the period of natural oscillations of the hydrogen atom.

....

....

....

....

(2)

(b) Infrared radiation is used in chemical analysis.

Compared to other radiations, infrared radiation of wavelength 3.3 μm is strongly absorbed by hydrogen chloride gas. As a result of this absorption, the amplitude of oscillations of the hydrogen atoms significantly increases.

(i) What name is given to this phenomenon?

....

.... **(1)**

(ii) State the condition for it to occur.

....

.... **(1)**

(iii) Calculate the frequency of infrared radiation of wavelength 3.3 μm.

Frequency = ... **(2)**

(iv) Hence calculate the stiffness of the hydrogen chloride bond.

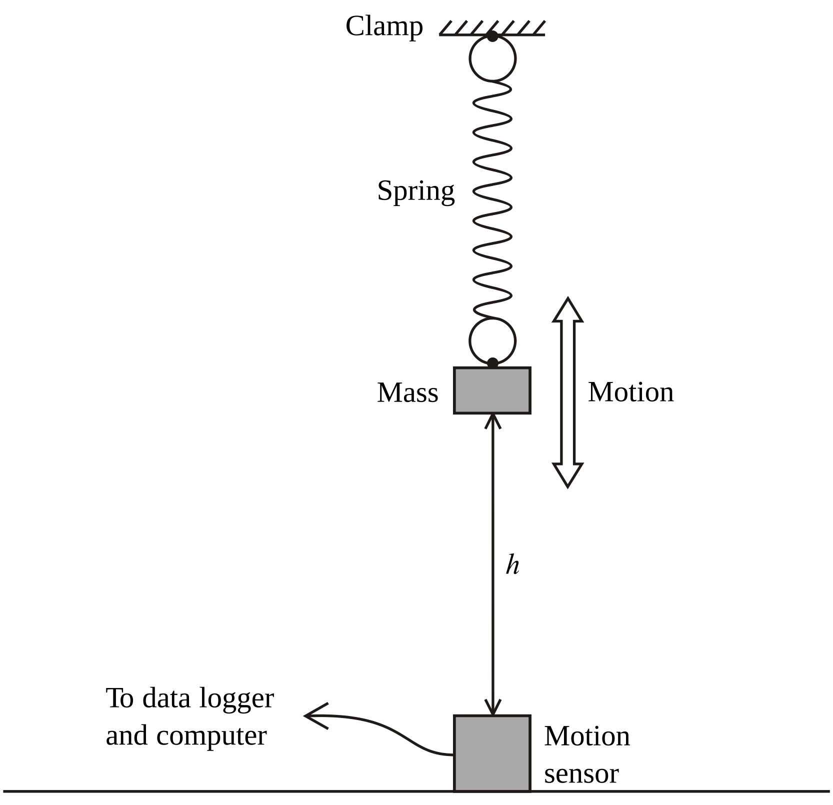
Mass of hydrogen atom = 1.67×10^{-27} kg

Stiffness = ...

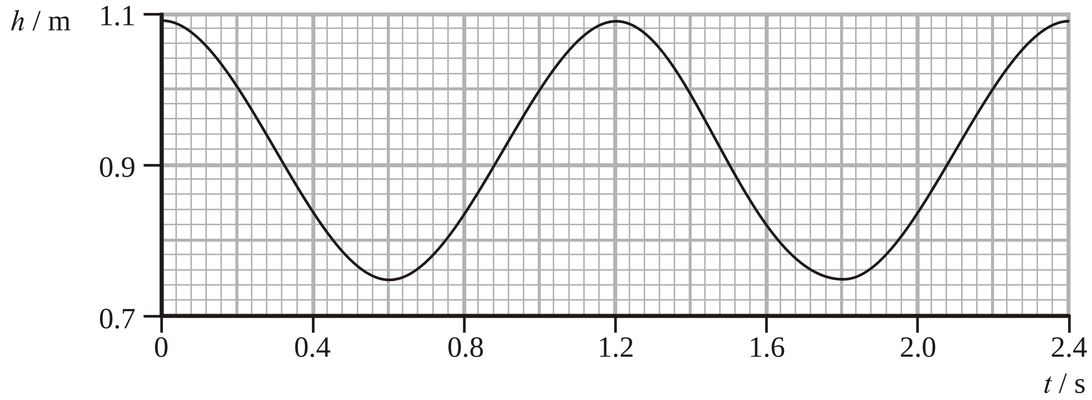
(3)

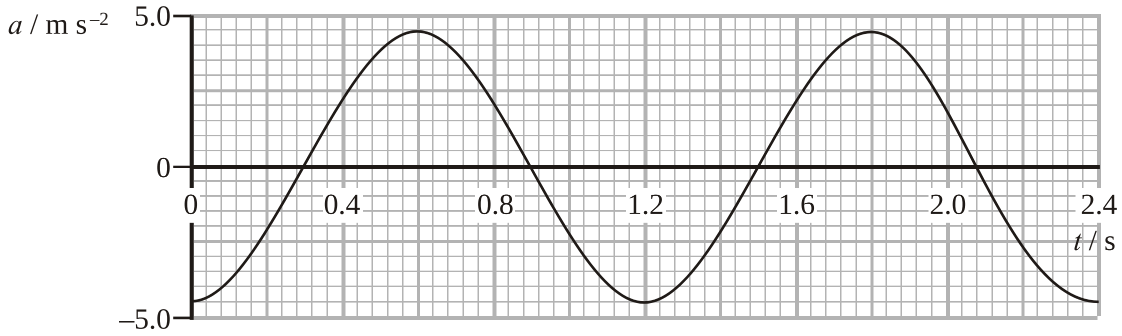
(Total 11 marks)

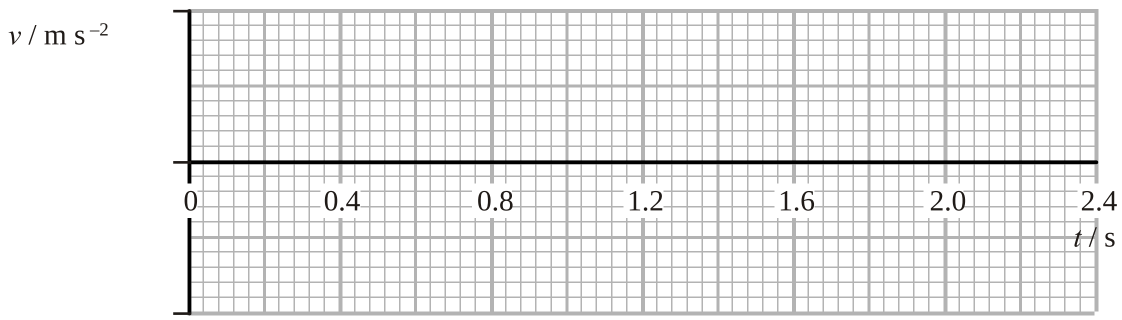
7. A motion sensor, connected through a data logger to a computer, is used to study the simple harmonic motion of a mass on a spring.



The data logger records how the height *h* of the mass above the sensor varies with the time *t*. The computer calculates the velocity *v* and acceleration *a* and displays graphs of *h*, *v* and *a* against *t*. Idealised graphs of *h* and *a* for two cycles are shown below.







(a) (i) Determine the amplitude and frequency of the motion.

....

....

Amplitude = ... Frequency = ...

(2)

(ii) Show that the maximum velocity of the mass is approximately 0.9 m s^{-1}.

....

....

....

(2)

(iii) Complete the above set of graphs by sketching the velocity-time graph for the same interval.

(2)

(b) (i) Define simple harmonic motion.

....

....

....

....

....

....

(2)

(ii) Describe how you would use data from the graphs of *h* and *a* against *t* to check that the motion of the mass was simple harmonic. (Note that you are not required to actually carry out the check.)

....

....

....

....

....

....

....

....

....

....

(4)

(Total 12 marks)

8. When a person walks across a suspended footbridge, the bridge can oscillate with increasing amplitude.

(a) Name the effect which causes this and state the condition needed for the amplitude to increase in this situation.

....

....

....

....

(2)

(b) In November 1940, the wind caused some alarming movement and twisting of the road bridge over Tacoma Narrows in the United States. The amplitude of the oscillations became so large that cars were abandoned on the bridge.

(i) Why can these oscillations be described as forced?

....

....

(1)

(ii) The vertical oscillations of the bridge can be modelled using the equations of simple harmonic motion. Calculate the maximum acceleration of the bridge when it was oscillating 38 times per minute and the amplitude of its oscillations was 0.90 m.

....

....

....

....

....

....

Maximum acceleration = ...

(2)

(iii) Use this value to explain why any car abandoned on the bridge would lose contact with the road's surface at a certain point in the oscillation. Identify this point.

....

....

....

(2)

(Total 7 marks)

9. (a) A mass hangs on a spring suspended from a fixed point. When displaced and released, the mass oscillates in a vertical direction. Describe how you could determine accurately the frequency f_0 of these oscillations. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

....

....

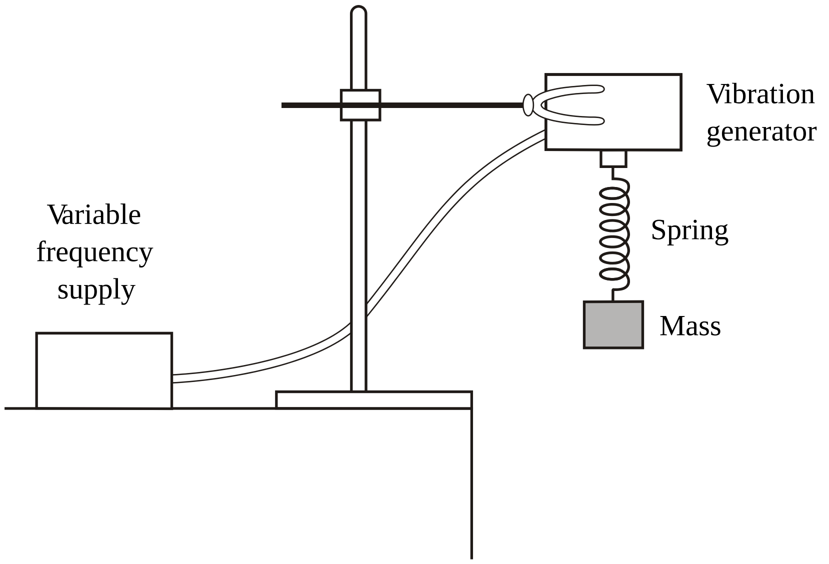
....

....

....

(4)

(b) The mass and spring are now attached to a vibration generator.



A short time after the vibration generator is turned on, the mass settles down and performs simple harmonic motion at the frequency of the generator.

(i) Label the axes below and sketch a graph showing how the amplitude of this oscillation changes as the frequency is varied up to and well beyond f_0. Mark the approximate position of f_0 on the frequency axis.

(3)

(ii) State the name of the phenomenon illustrated by your graph.

....

(1)

(iii) This phenomenon can cause problems in the design of footbridges. Explain why.

....

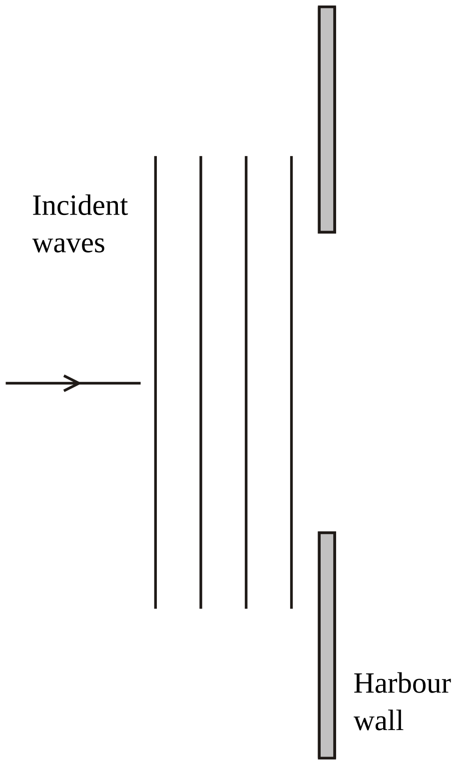
....

....

....

(2)
(Total 10 marks)

10. The diagram shows successive crests of sea waves approaching a harbour entrance.

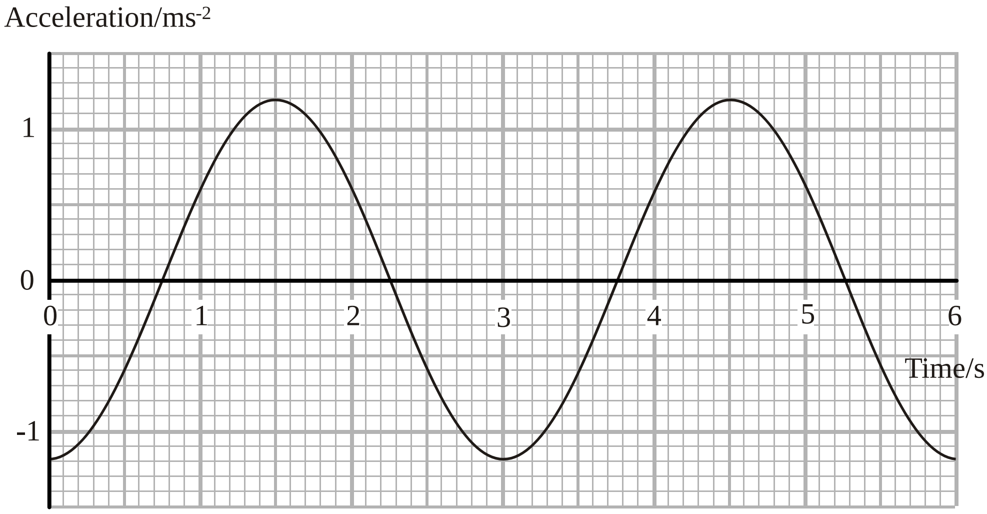


(a) Complete the diagram to show the pattern of waves you would expect to see inside the harbour.

(3)

(b) The waves are being studied by means of a buoy anchored in the harbour. As the waves pass the buoy they make it perform simple harmonic motion in the vertical direction. A sensor inside the buoy measures its acceleration.

The graph below shows how this acceleration varies with time.



(i) State values for the period and maximum acceleration of the buoy.

Period = ... s

Maximum acceleration = ... m s^{-2}

(1)

(ii) Calculate the amplitude of oscillation of the buoy.

....

....

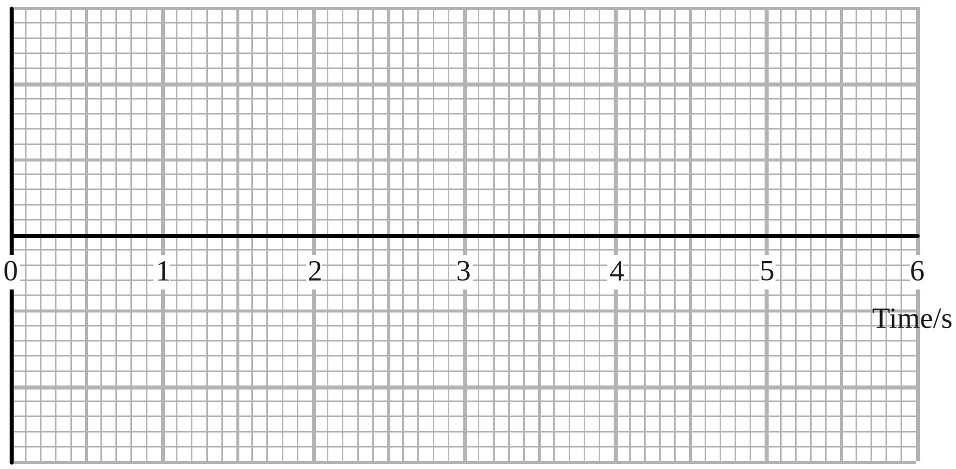
....

....

Amplitude = ...

(3)

(iii) On the grid below, sketch a graph of the displacement of the buoy against time, over the same interval of time as the acceleration graph.



(3)
(Total 10 marks)

11. Buildings situated close to railway lines should be constructed in a manner which minimises noise and vibrations from passing trains.

(a) Vibrations could cause parts of the building to resonate. Describe the meaning of the word **resonate** in this context.

....

....

....

....

(2)

(b) Some buildings, which are subject to vibrations, are constructed on springs.

(i) Suggest how springs could prevent these buildings from vibrating.

....

....

....

....

(2)

(ii) It is said that such buildings would also suffer less damage in the event of an earthquake. Comment on this statement.

....

....

(1)
(Total 5 marks)

12. Read the following passage carefully and then answer the questions.

The Ultimate Clock?

Why bother to improve atomic clocks?

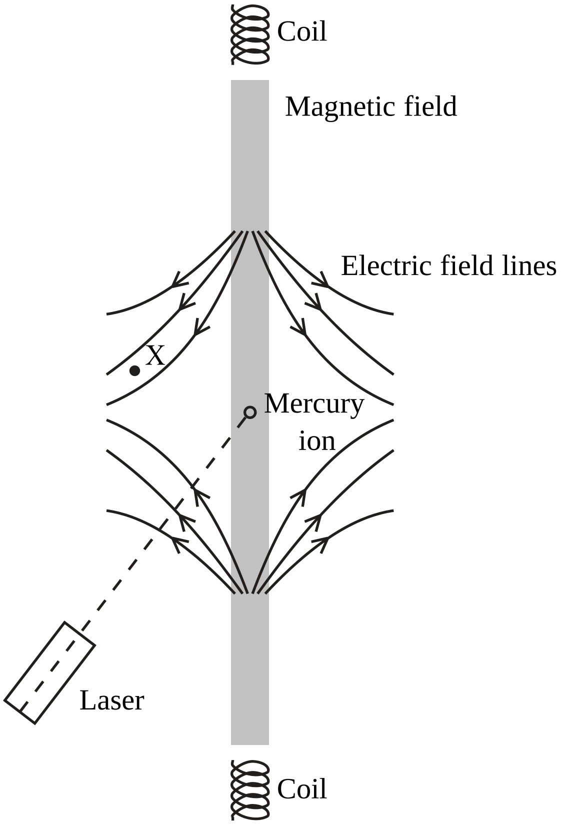
The duration of the second can already be measured to 14 decimal places. One reason for improving this precision is that the second is becoming the fundamental unit. Units such as the metre and ampere already can be defined in terms of the second. The kilogram could also be defined using the equation $\Delta E = c^2\Delta m$. A given mass Δm has an equivalent energy ΔE which could be written as the number of photons of a particular frequency that would have the same total energy.

How do different clocks work?

Most clocks have an oscillator and a mechanism for counting the oscillations and converting this count into seconds. In a grandfather clock, the oscillations of a pendulum of a fixed length, hence fixed time period, are counted by gears and displayed by hands on a face. In a quartz watch, an oscillating voltage is applied across a quartz crystal surface, which causes the crystal to oscillate at a particular frequency. These oscillations then produce regular pulses which are counted and displayed by a digital circuit.

Design for an ultimate clock

In a mercury atomic clock, atoms of mercury are ionized leaving them with a positive charge. They can then be trapped by a combination of electric fields and a magnetic field as shown.



[Adapted from an article in Scientific American, Sept. 2002: *Ultimate Clocks* by W. Wayt Gibbs.]

The laser emits ultra violet radiation (uv). A particular frequency causes an outer electron in a mercury ion to jump between energy levels. The laser frequency is adjusted until this effect is detected. The frequency of uv radiation which causes this effect is known accurately. If the number of cycles of this radiation can be detected and counted, then a period of one second can be measured with a high degree of precision.

The following is an extract from a student's plan for a practical which will involve timing the period of an oscillation of a pendulum mass on the end of a length of string. "I will start the stop clock as soon as I have released the mass from its highest position and then stop the stop clock when the mass passes through the same position again."

(a) The student was told he should make his measurements more precise. State one way in which he could do this.

....

....

(1)

(b) The following table of his results shows how the period T varies with the length l of the pendulum.

l/m	T/s	
0.20	1.00	
0.40	1.35	
0.60	1.62	
0.80	1.85	
1.00	2.06	
1.20	2.24	

State the precision of the length measurements and comment on its suitability.

....

....

....

....

(2)

(c) The student reads that the equation relating these two quantities is

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

where g is a constant.

(i) Plot a suitable graph to test how well the data fit this relationship. You may wish to use the extra column in the table above.

(Allow one sheet of graph paper

(6)

(ii) State and explain whether the graph verifies this relationship.

....

....

....

....

(2)

(d) An extract from the student's evaluation reads "I wasn't sure exactly where to measure the length to".

Discuss what your graph tells you about this student's problem with this measurement.

....

....

....

....

....

(3)

(e) Determine the gradient of your graph and use it to calculate the value of the constant *g*.

....

....

....

....

g = ...

(4)
(Total 18 marks)

13. (a) Define simple harmonic motion.

....

....

....

(2)

(b) (i) A 120 g mass performs simple harmonic motion when suspended from a spring that has a spring constant of 3.9 N m^{-1}. Calculate the period *T*.

....

....

T = ...

(2)

(ii) The simple harmonic motion is started by displacing the mass 15 cm from its equilibrium position and then releasing it. Calculate the maximum speed of the mass.

....

....

Maximum speed = ...

(2)

(iii) Calculate the maximum acceleration of the mass.

....

....

Maximum acceleration = ...

(2)

(iv) The 120 g mass is replaced by a wooden block. When the block performs simple harmonic motion the period is 1.4 s. Calculate the mass of the block.

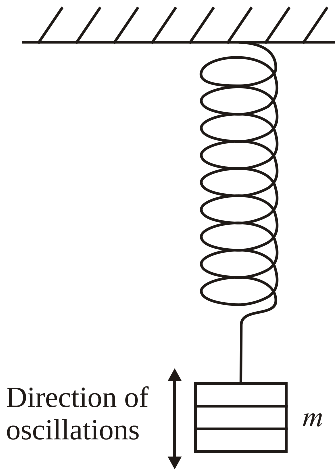
....

....

Mass of block = ...

(2)
(Total 10 marks)

14. A spring of negligible mass and spring constant, *k*, has a load of mass, *m*, suspended from it. A student displaces the mass and releases it so that it oscillates vertically.



(a) The student investigates the variation of the time period, T, of the vertical oscillations with m.

Describe how he could verify experimentally that $T \propto \sqrt{m}$. Include any precautions the student should take to make his measurements as accurate as possible. You may be awarded a mark for the clarity of your answer.

....

....

....

....

....

....

....

....

....

....

....

....

(5)

(b) The student connects the mass-spring system to a vibrator and signal generator to demonstrate resonance. Explain fully, with respect to this system, what is meant by the terms **natural frequency** and **resonance.**

Natural frequency: ....

....

....

....

....

Resonance: ....

....

....

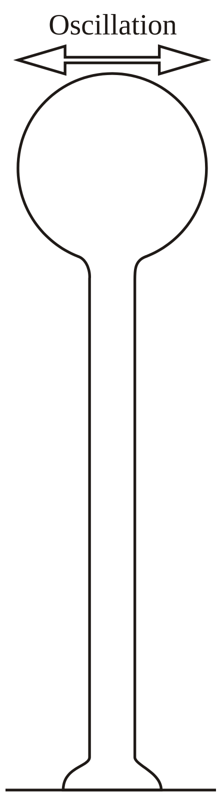
....

....

(4)

(Total 9 marks)

15. A water tower consists of a massive tank of water supported on a vertical column. It oscillates sideways with simple harmonic motion when shaken by longitudinal earthquake waves.



Water tower

(a) What is meant by a **longitudinal** wave?

....

....

....

....

(2)

(b) The water tower could collapse when shaken by earthquake waves of a particular frequency. Explain how this could happen.

....

....

....

....

....

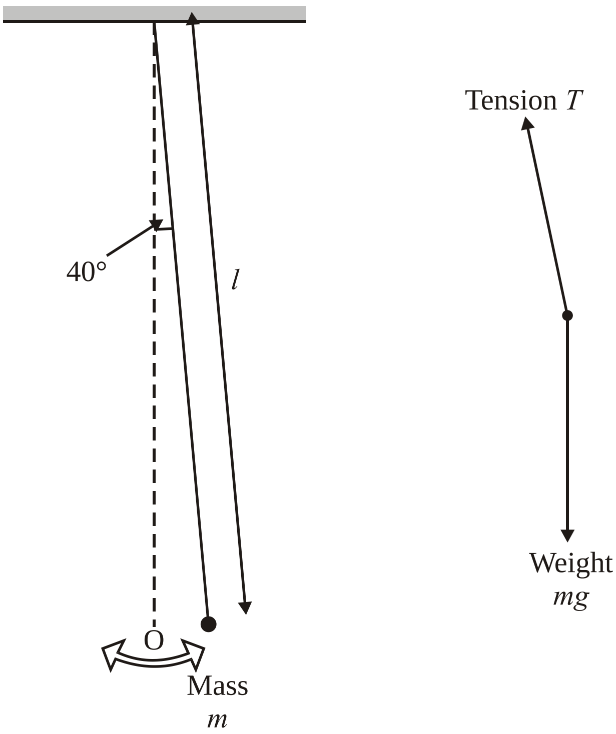
....

....

(3)

(Total 5 marks)

16. A simple pendulum of length *l* consists of a small mass *m* attached to the end of a thread. The other end is fixed. The mass is slightly displaced through an angle of 4.0° and then released so that it oscillates along a small arc with centre O.



The free-body force diagram for the oscillating mass at its maximum displacement is drawn alongside.

(i) Add to the free-body force diagram the component of weight that is equal in magnitude to the tension *T* at this instant. Label it A.

(1)

(ii) Add to the same diagram the component of weight that acts perpendicularly to the line of action of the tension. Label it B.

(1)

(iii) Determine the magnitude of the instantaneous acceleration of the mass.

....

....

Acceleration = ...

(2)

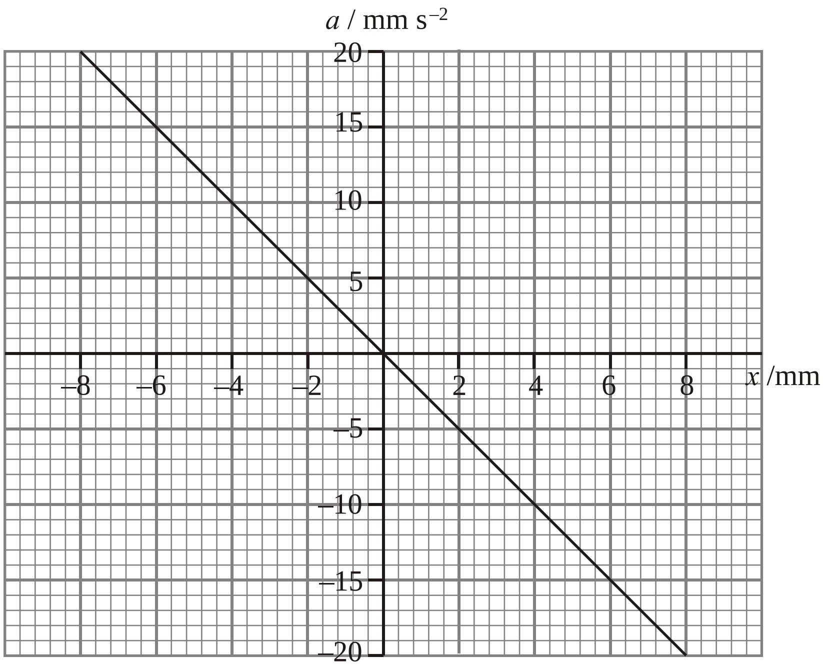
(iv) State the direction of this acceleration.

....

(1)

(Total 5 marks)

17. The graph shows how the acceleration *a* varies with displacement *x* for a particle undergoing simple harmonic motion.



Calculate the gradient of this graph.

....

....

Gradient = ...

Use your value to deduce the frequency for this motion.

....

....

....

Frequency = ...

(4)

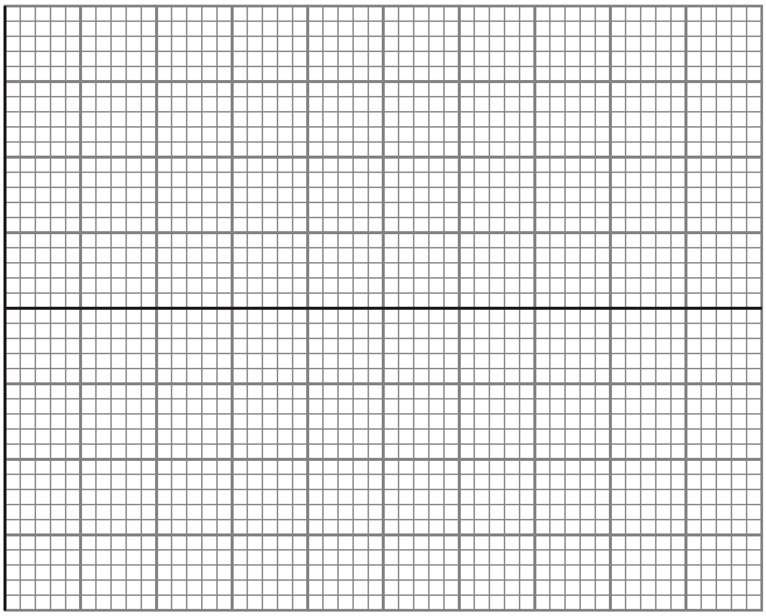
Hence, write down the period of the motion.

....

(1)

On the grid below sketch a graph of acceleration against time for this motion. Assume that the displacement is zero and the velocity is positive at $t = 0$.

Add suitable scales to the axes. Draw at least two complete cycles.



(3)
(Total 8 marks)

18. The oscillations of a child on a swing are approximately simple harmonic. State the conditions which are needed for simple harmonic motion.

....

....

....
(2)

Why is the child's motion only **approximately** simple harmonic?

....

....
(1)

The child completes six oscillations of amplitude 1.2 m in 20 s.

(i) Calculate the period and the frequency of the oscillations.

....

....

Period = ...

Frequency = ...

(ii) The quantity ω in the equations for simple harmonic motion is defined as $2\pi f$, where f is the frequency of the oscillations.

Calculate ω for these oscillations.

....

....

ω = ...

(iii) Calculate the child's acceleration when the displacement is maximum.

....

....

Acceleration = ...

(5)

Explain how pushing a child on a swing can be an example of resonance.

....

....

....

....

(2)
(Total 10 marks)

where x is the displacement of the hydrogen atom.

....

....

....

....

(2)

(ii) Hence derive the equation $T = 2\pi\sqrt{m/k}$ **19.** Define simple harmonic motion (s.h.m.).

....

....

....

....

(2)

A mass on a spring is displaced 0.036 m vertically downwards from its equilibrium position. It is then released. As it passes upwards through its equilibrium position a clock is started. The mass takes 7.60 s to perform 20 cycles of its oscillation.

Assuming that the motion is s.h.m., it can be described by the equation

$$x = x_0 \sin 2\pi ft$$

where x is the displacement in the upward direction and t the time since the clock was started. What are the values of x_0 and f in this case?

x_0 = ...

....

....

f = ...

(3)

Use the equation to calculate the displacement when t = 1.00 s.

....

....

x = ...

(1)

In practice, simple harmonic motion is not a perfect model of the motion of the mass, and so the equation above does not predict the displacement correctly. Explain how and why the motion differs from that predicted by the equation.

....

....

....

....

(2)
(Total 8 marks)

20. If an oscillating system is made to perform *forced oscillations* at a frequency close to its *natural frequency*, then *resonance* occurs.

Describe how you could demonstrate qualitatively the meanings of the terms in italics.
Include a diagram of the apparatus you would use.

....

....

....

....

....

....

....

....

....

....

....

....

(Total 7 marks)

(iii) Calculate the frequency of infrareδ ραδιατιον οφ ωαϖελενγτη 3.3 ⌠m.

Frequency = ...

(2)

(iv) Hence calculate the stiffness of the hydrogen chloride bond.

Mass of hydrogen atom = 1.67×10^{-27} kg

Stiffness = ...

(3)

(Total 11 marks)

21. (a) (i) A body can be said to be moving with simple harmonic motion when

$$a = -(2\pi f)^2 x$$

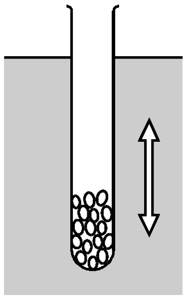
State what *a*, *f* and *x* represent in this equation and explain the significance of the minus sign.

(4)

(ii) Calculate the maximum speed of an electron which is oscillating with simple harmonic motion in a mains wire at 50 Hz with an amplitude of 8.0 μm.

(3)

(b) The diagram shows a weighted test tube of cross-sectional area *A* and mass *m* which is oscillating vertically in water.



The frequency *f* of the oscillations, which can be considered to be independent of their amplitude, is given by

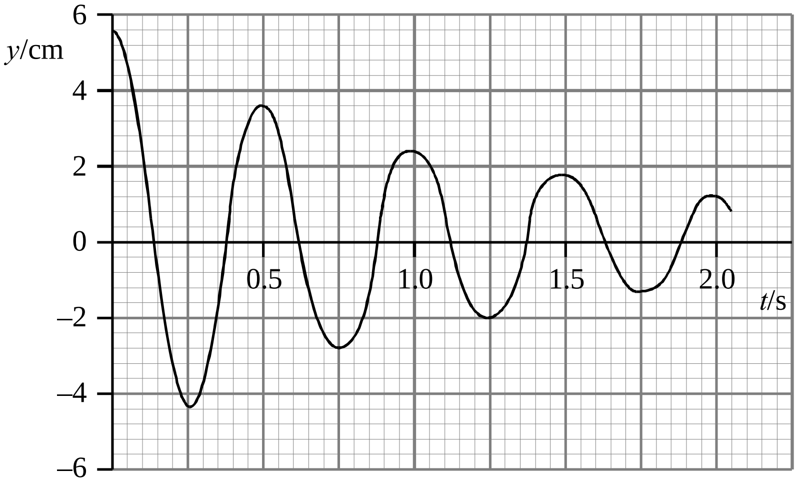
$$2\pi f = \sqrt{\frac{A\rho g}{m}}$$

where ρ is the density of the water and *g* is the acceleration of free fall.

(i) Show that this equation is homogeneous with respect to units.

(2)

(ii) The graph shows how the vertical displacement y of the test tube varies with time *t*. This shows that the oscillations of the test tube are damped. The damping is thought to be exponential.



By taking measurements from the graph, discuss whether the damping is exponential in this case.

(3)
(Total 12 marks)

22. A mass oscillating on a spring, is an example of simple harmonic motion.

State the conditions required for simple harmonic motion to occur.

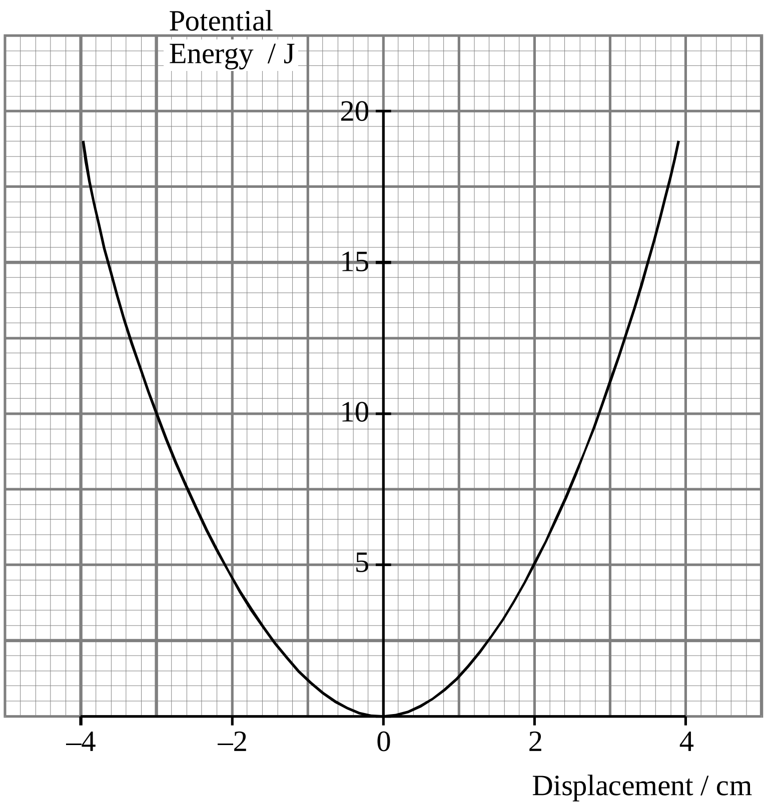
....

....

....

(2)

The graph shows how the potential energy varies with displacement for a particular mass and spring,



On the same axes draw a graph showing how the total energy of the mass-spring system varies with displacement, assuming no energy loss.

(1)

Use the graph to calculate

(i) the kinetic energy of the mass when the displacement is 2.0 cm,

....

....

....

(ii) the stiffness, k, of the spring.

....

....

....

(5)
(Total 8 marks)

23. Define simple harmonic motion (s.h.m.).

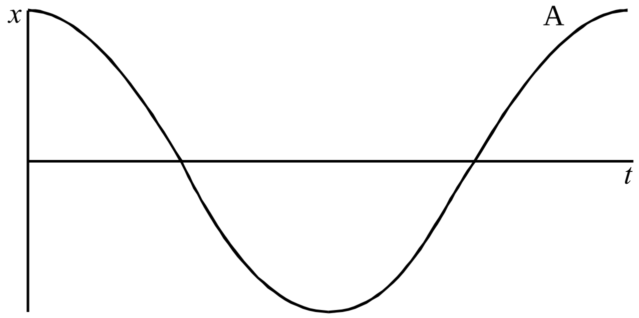
....

....

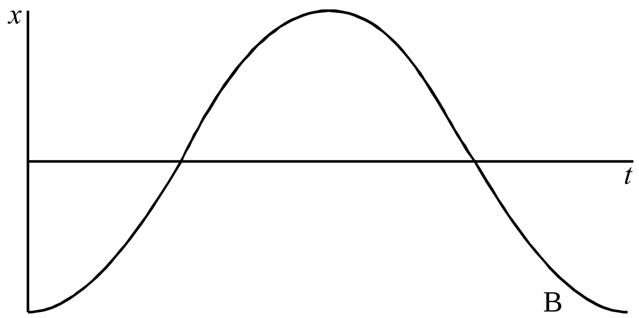
....

(2)

On graph (i), the curve labelled A shows how the displacement x of a body executing simple harmonic motion varies with time t.
On graph (ii), the curve labelled B shows how the acceleration a of this body varies over the same time interval.



Graph (i)



Graph (ii)

Add to **either** graph a curve labelled C showing how the velocity of this body varies over the same time interval.
Which pair of curves illustrates the definition of simple harmonic motion?

....

(3)
(Total 5 marks)

24. The speaker shown below is used to produce the bass notes in a music system.

The cone moves with simple harmonic motion and it emits a single-frequency sound of 100 Hz. When it is producing a loud sound, the cone moves through a maximum distance of 2.0 mm.

The equation that mathematically describes the displacement of the cone is
$x = 1.0 \times 10^{-3} \cos 628\, t$.

Show that the data for this speaker lead to the numbers in the equation above.

....

....

....

....

(2)

Calculate

(i) the maximum acceleration of the cone

....

....

Maximum acceleration = ...

(ii) the maximum speed of the cone

....

....

Maximum speed = ...

(3)

On the grid below sketch the acceleration-time graph for two cycles of vibration of this speaker cone used under these conditions. Add suitable numerical scales to the two axes.

(3)

Explain why designers ensure that bass speakers have a natural frequency of oscillation much greater than 100 Hz.

....

....

....

....

(2)
(Total 10 marks)

25. Define simple harmonic motion (s.h.m.).

....

....

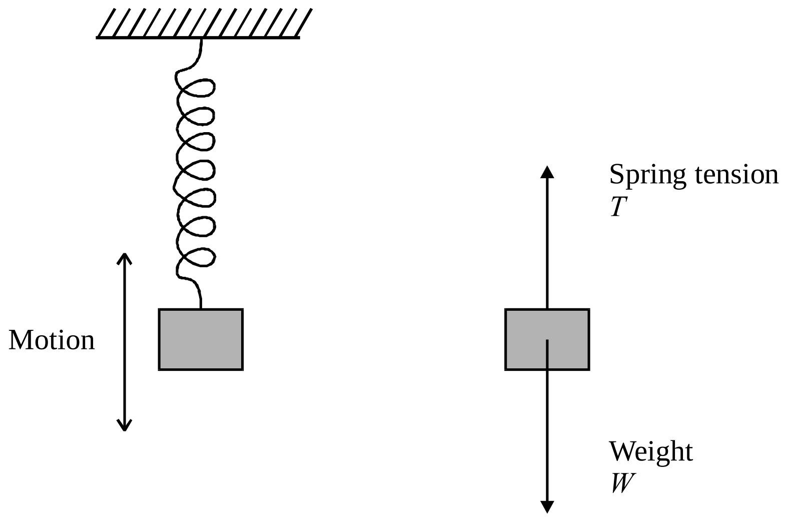
....

....

(2)

Figure (i) shows a mass performing vertical oscillations on the end of a spring. Figure (ii) is a free-body force diagram for the mass.

Figure (i) **Figure (ii)**



The tension T is proportional to the extension of the spring. In the equilibrium position, $T = W$.

With reference to the relative magnitudes of T and W at different points in the motion, explain why the mass oscillates. You may be awarded a mark for the clarity of your answer.

....

....

....

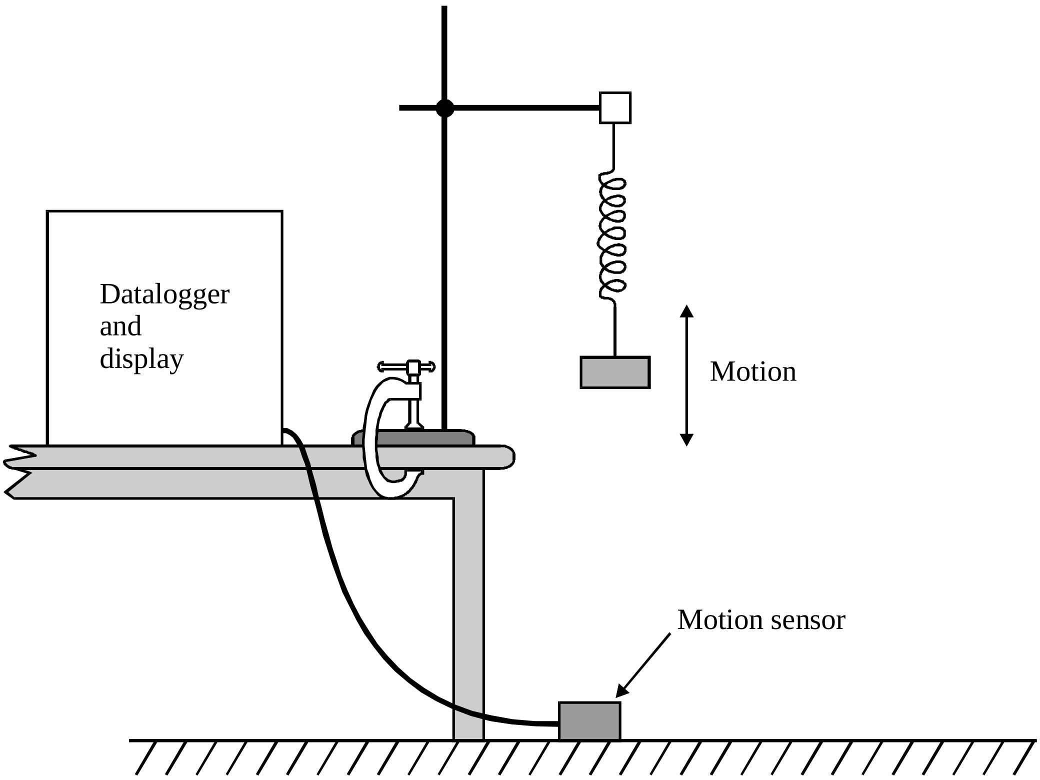
....

....

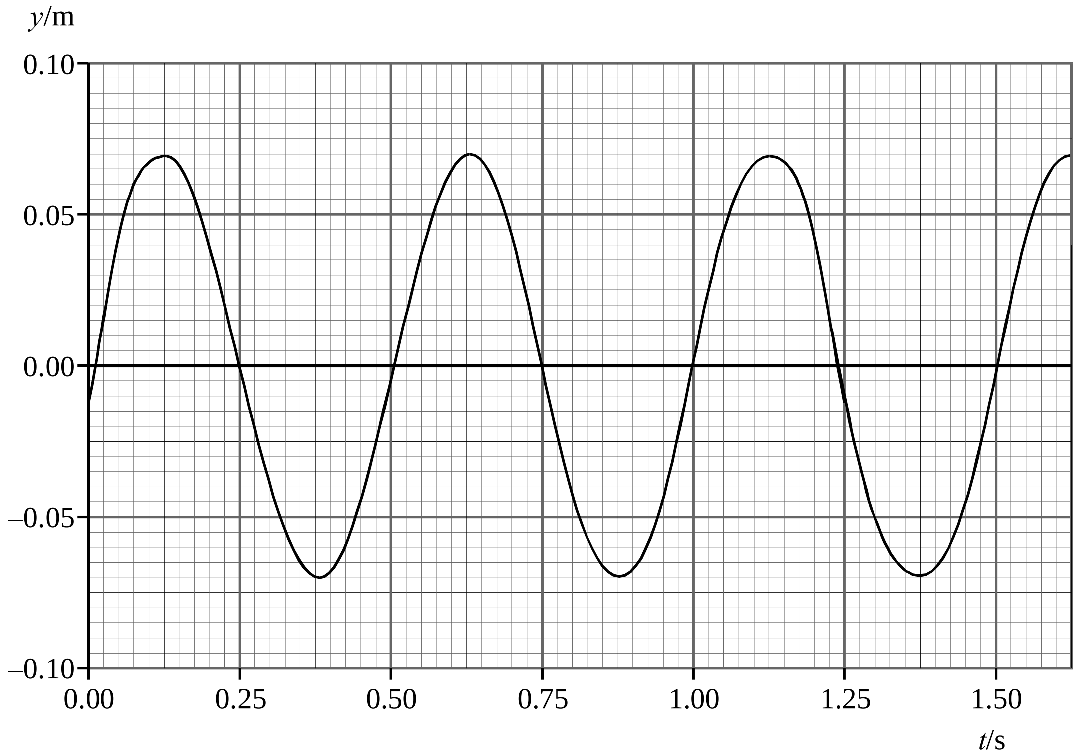
....

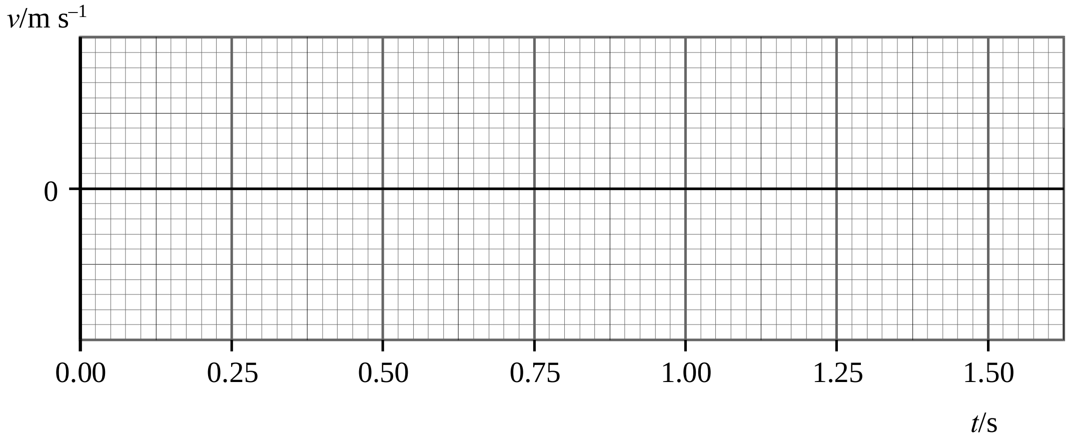
(4)

A datalogger, display and motion sensor are set up to study the motion of the mass. (The motion sensor sends out pulses which enable the datalogger to register the position of the mass.)



The datalogger produces on the display graphs of displacement *y* and velocity *v* against time *t*. The diagram below shows an idealised version of the displacement–time graph. On the lower axes, sketch the velocity–time graph which you would expect to see. (No scale is required on the *v* axis.)





(2)

Using information from the displacement–time graph, calculate as accurately as possible the maximum velocity of the mass.

....

....

....

....

....

....

Maximum velocity = ...

(4)
(Total 12 marks)

26. An earthquake produces waves which travel away from the epicentre (the source) through the body of the Earth. The particles of the Earth oscillate with simple harmonic motion as the waves pass carrying energy away from the source.

State the conditions which must occur for the motion of the particles to be simple harmonic.

....

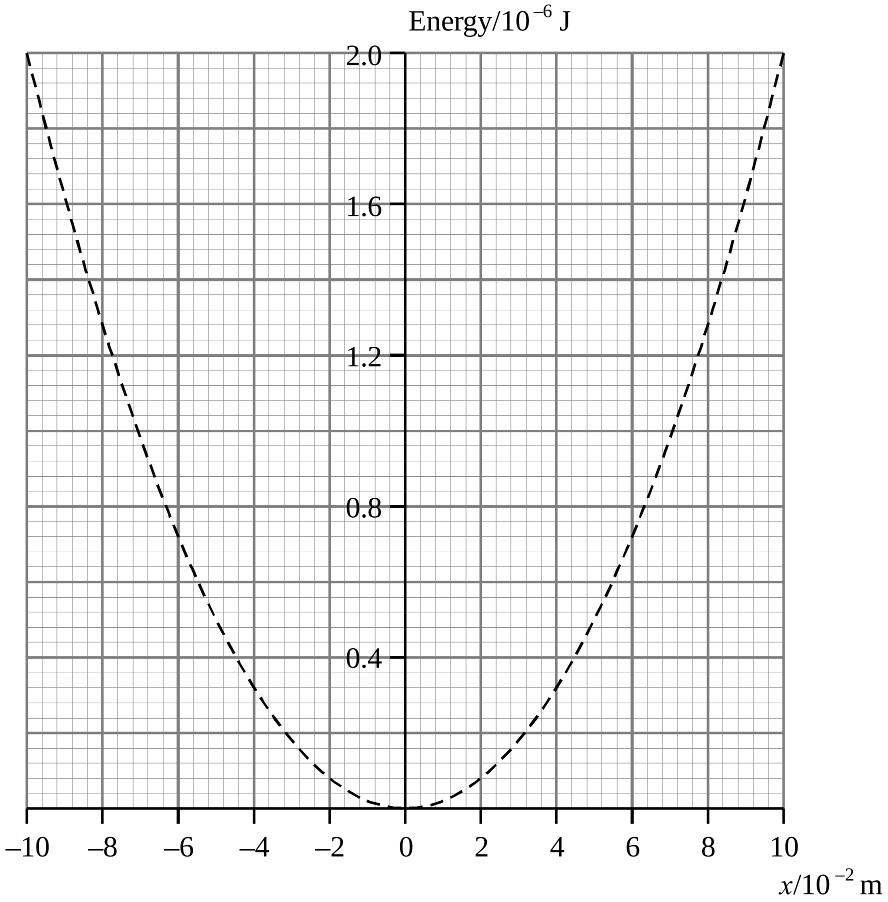
....

....

....

(2)

The graph below shows the variation of potential energy E_p with displacement x of a particle 100 km from the epicentre.



Add to the graph labelled lines which show the variation with displacement of

(i) the kinetic energy E_k of the particle,

(ii) the total energy T of the particle.

(2)

Calculate the constant k where k is the stiffness of the "bonds" between particles oscillating within the Earth.

....

....

....

....

Stiffness = ...

(2)

The radiant energy flux of light is given by:

$$F = \frac{L}{4\pi d^2}$$

Assume the intensity of the waves produced by this earthquake decreases with distance from the epicentre in a similar way.

Draw a line on the previous graph to show the variation in potential energy of a similar particle 150 km from the epicentre.

....

....

....

....

(3)
(Total 9 marks)

27. Good suspension in a car helps prevent resonance in the various parts of the car such as the seats and mirrors. Each part has its own frequency of vibration.

What is this frequency called?

....

(1)

Explain the term *resonance.*

....

....

....

....

(2)

Different frequencies of vibration can be applied to a system. Sketch a graph on the axes below to show the variation of amplitude with applied frequency for a vibrating system. Label your graph line A.

Mark the resonant frequency on the applied frequency axis.

Add a second line to show the effect of additional damping on this system. Label this line B.

(4)

How does *good suspension in a car help prevent resonance in the various parts of the car*?

....

....

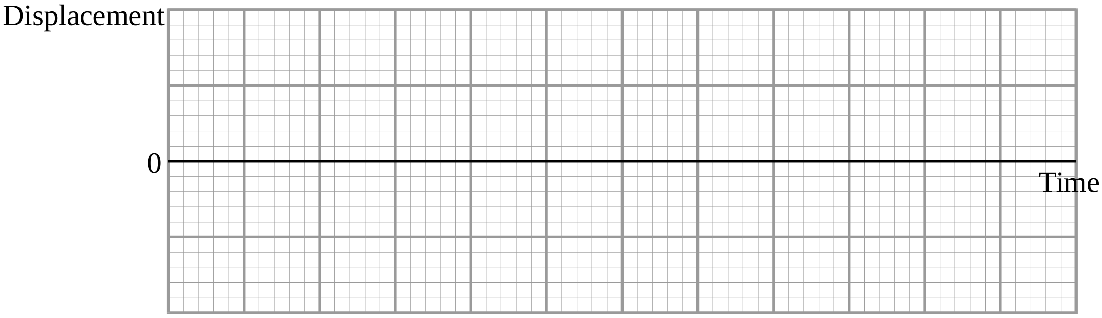
....

....

(2)
(Total 9 marks)

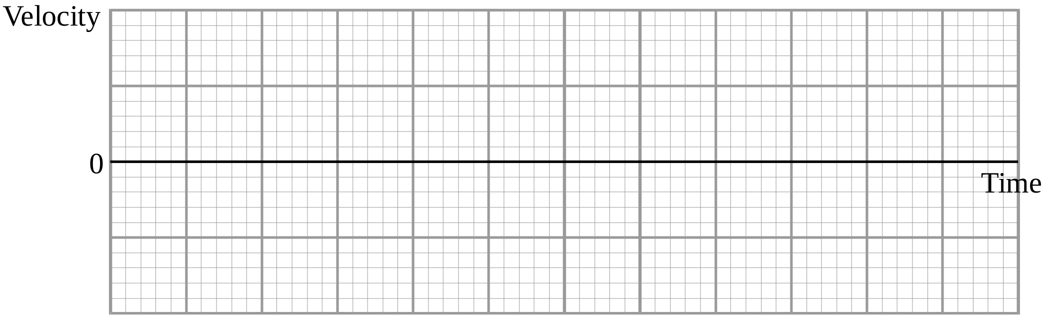
28. A toy is suspended at the end of a long spring from the ceiling above a baby's cot. When it is pulled down slightly and then released it oscillates up and down with simple harmonic motion.

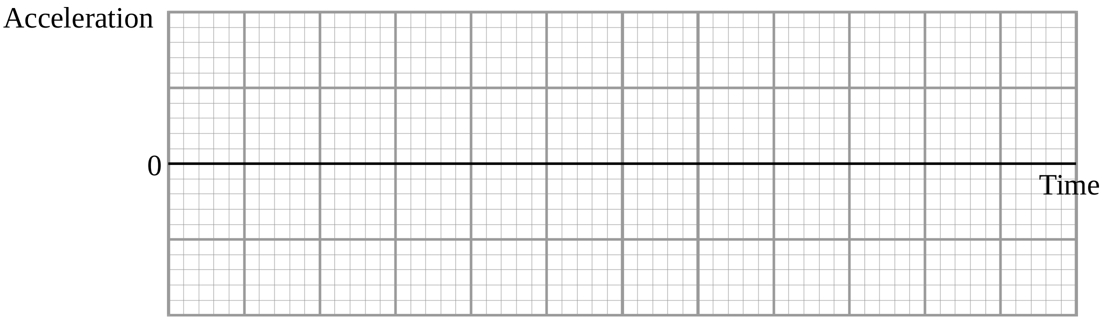
On the axes below, sketch a displacement-time graph for the first three oscillations of the toy. Assume that the effects of air resistance are negligible. Let zero displacement be at the mid-point of the oscillation.



(2)

Sketch velocity-time and acceleration-time graphs for the same three oscillations.





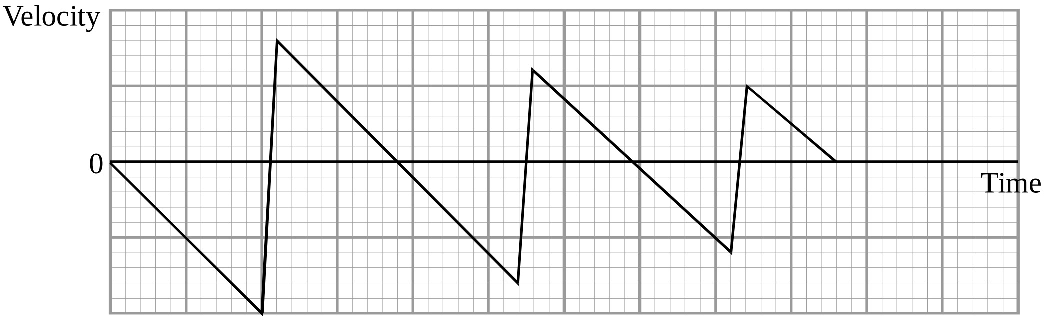
(2)

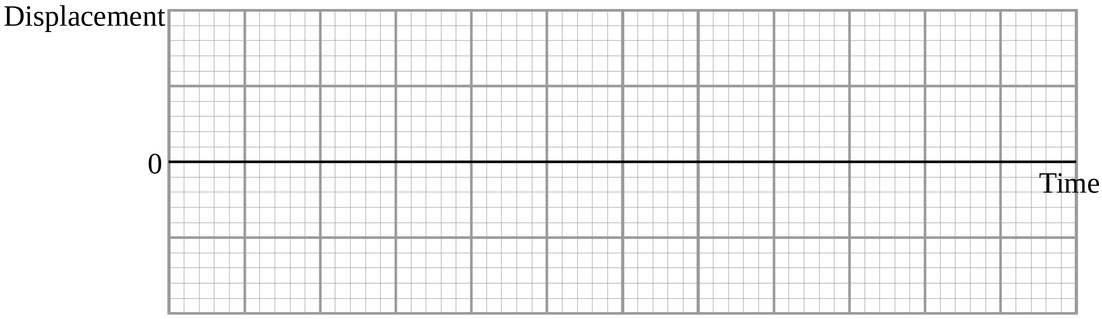
State two requirements for the toy to move with simple harmonic motion (SHM).

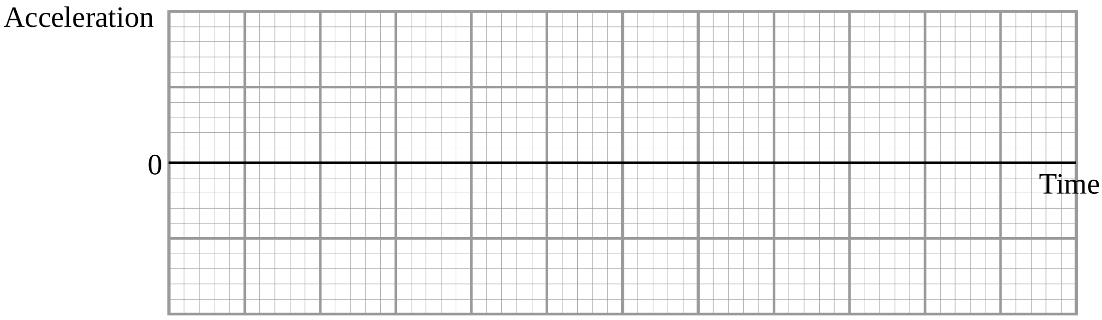
(2)

An older child bounces a rubber ball up and down on a hard floor. She releases the ball and allows it to bounce three times before catching it again. The velocity-time graph for this motion is shown below.

Draw displacement-time and acceleration-time graphs on the axes below for the same three bounces of this ball. Let zero displacement be floor level.







(4)

State and explain whether this ball is bouncing with simple harmonic motion,

....

....

....

....

(2)
(Total 12 marks)

29. A motorist notices that when driving along a level road at 95 km h^{-1} the steering wheel vibrates with an amplitude of 6.0 mm. If she speeds up or slows down, the amplitude of the vibrations becomes smaller

Explain why this is an example of resonance.

....

....

....

....

....

(3)

Calculate the maximum acceleration of the steering wheel given that its frequency of vibration is 2.4 Hz.

....

....

....

....

Acceleration =..

(2)
(Total 5 marks)

30. Fill in the gaps in the sentences below.

A body oscillates with simple harmonic motion when the resultant force *F* acting on it and its

displacement *x* are related by the expression ....

The acceleration of such a body is always directed ....

The acceleration of the body is a maximum when its displacement is...............................

and its velocity is .... when its displacement is zero.

(4)

A mass of 0.08 kg suspended from a vertical spring oscillates with a period of 1.5 s. Calculate the force constant of the spring.

....

....

....

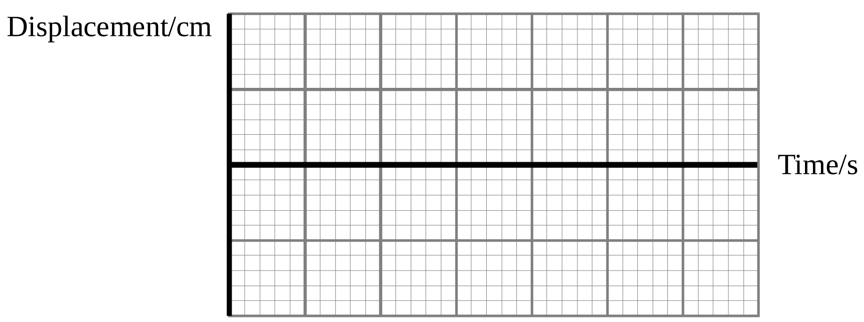
....

Force constant = ...

(2)
(Total 6 marks)

31. A sewing machine needle moves vertically with simple harmonic motion. The difference between the highest and lowest positions of the point of the needle is 3.6 cm. The needle completes 20 stitches per second.

On the grid below sketch a displacement–time graph for the point of the sewing machine needle. Show at least one complete cycle and add a scale to both axes.



(3)

Calculate the maximum speed of the needle.

.............................……...

.............................……...

.............................……...

Maximum speed = ...

(2)

On your graph mark with an M two places where the needle moves with this maximum speed.

(1)
(Total 6 marks)

32. A student was studying the motion of a simple pendulum the time period of which was given by $T = 2\pi \sqrt{l/g}$.

He measured T for values of l given by

l/m = 0.10, 0.40, 0.70, 0.70, 1.00

and plotted a graph of T against $\sqrt{l}$ in order to deduce a value for g, the free-fall acceleration. Explain why these values for l are poorly chosen.

....

....

....

(1)

How would the student obtain a value of g from the gradient of the graph?

....

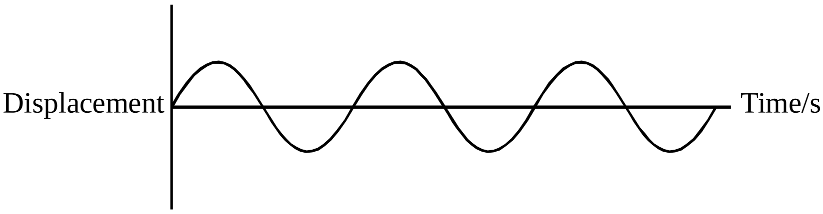
....

....

....

(2)

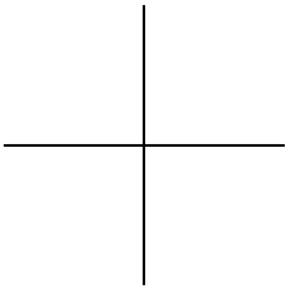
The graph below shows three cycles of oscillation for an undamped pendulum of length 1.00 m.



Add magnitudes to the time axis and on the same axes show three cycles for the same pendulum when its motion is lightly air damped.

(4)
(Total 7 marks)

33. A body oscillates with simple harmonic motion. On the axes below sketch a graph to show how the acceleration of the body varies with its displacement.



(2)

How could the graph be used to determine *T*, the period of oscillation of the body?

....

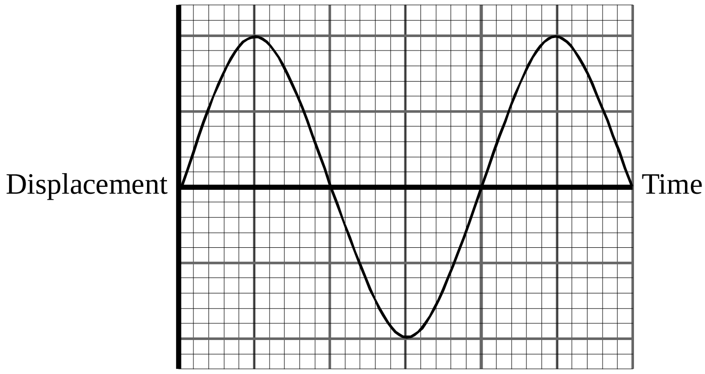
....

....

....

(2)

A displacement-time graph from simple harmonic motion is drawn below.



The movement of tides can be regarded as simple harmonic, with a period of approximately 12 hours.

On a uniformly sloping beach, the distance along the sand between the high water mark and the low water mark is 50 m. A family builds a sand castle 10m below the high water mark while the tide is on its way out. Low tide is at 2.00 p.m.

On the graph

(i) label points L and H, showing the displacements at low tide and the next high tide,

(ii) draw a line parallel to the time axis showing the location of the sand castle,

(iii) add the times of low and high tide.

(3)

Calculate the time at which the rising tide reaches the sand castle.

....

....

....

....

Time ....

(3)
(Total 10 marks)