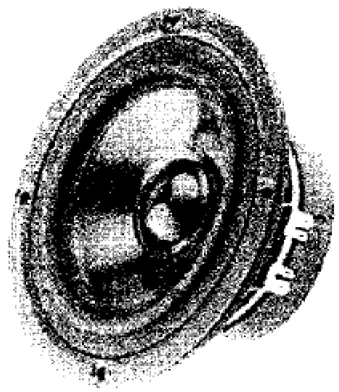
OSCILLATIONS

Please revise Topic 10: Oscillations (page 150-166) and answer the following questions:

1. 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.

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(2)

Calculate

(i) the maximum acceleration of the cone

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Maximum acceleration = ...

(ii) the maximum speed of the cone

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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.

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(2)

2. The following invention will allow you to play your music at top volume without annoying the neighbours:

> A layer of small lead spheres is embedded into rubber. If you line your room with this material then the transmitted sound will be significantly reduced. This coating is particularly effective with low frequency sounds, the ones which most annoy the neighbours, as these cause the spheres to resonate.
>
> Adapted from *New Scientist*, Vol.167, Issue 2256

Explain the phenomenon of resonance in the context outlined above and describe how the intensity of the transmitted sound is reduced.

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(Total 5 marks)

3. The teacher of a class arranges a visit to the manufacturer of "bouncy castles". The class assume, naturally, that this will be a good excuse to jump up and down on a large rubber pillow of air. The teacher explains that there are some principles of physics associated with bouncy castles, such as energy changes and oscillations when children are bouncing on it.

The speed at which a child collides with the rubber pillows is typically about 2.5 m s^{-1}.
The time period of the oscillation is typically about 6 s.
Write an illustrated article explaining the relevance of the two topics above to bouncy castles.
You should include estimates of quantities and use them in appropriate equations to confirm the estimates given above.

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(Total 7 marks)

4. Debbie complains on the internet:

> I have the loudest neighbours you've ever heard and they seem to be able to stay up ALL night. Their dog barks all the time, but their three main weapons are the guitar, the stereo and SURPRISE! They also have an alarm clock that's so loud that it sounds as if it's attached to the stereo.

James replies:

> Noise can be blocked out nowadays, with electronics and good soundproofing. The electronic device is just some sort of microphone that can pick up and analyse a sound. The device can produce the opposite frequencies and/or wavelengths of these sounds to balance them out.

Consider the phrase **good soundproofing**.

(1)

What type of material is best for soundproofing?

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(1)

Explain what makes this type of material good for soundproofing.

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(1)

James' reply shows some confusion about how electronic soundproofing works. Rewrite a short reply correctly explaining the physics of electronic sound reduction.

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(4)

The noise level that Debbie hears may be made worse by resonance occurring in the building structure.

Explain what is meant by the term **resonance** in the context of high noise levels in buildings.

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(2)

Name the process that reduces the amount of sound transmitted in this way.

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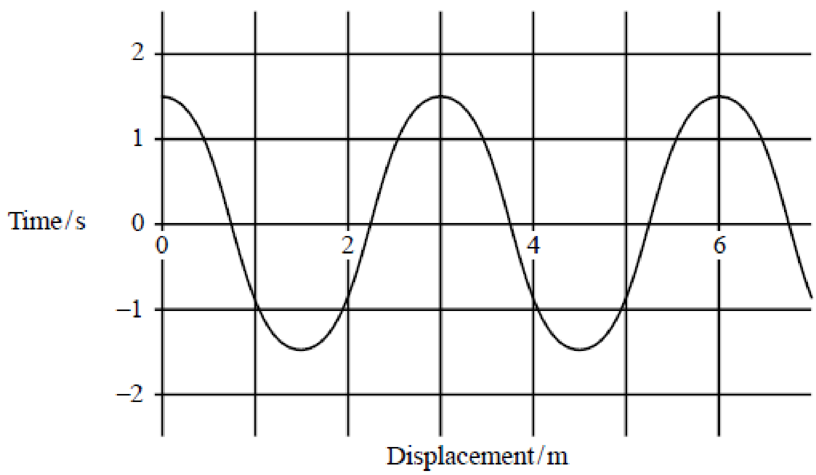
(1)

5. 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)

6. 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.

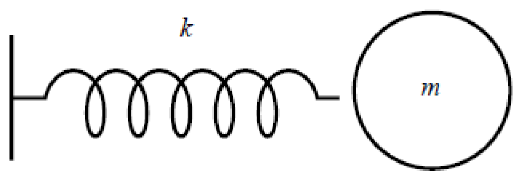
B The mirror stills shakes a lot at the same speed as before because the chewing gum does not change the damping.

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)

7. 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.

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(2)

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

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(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?

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.... **(1)**

(ii) State the condition for it to occur.

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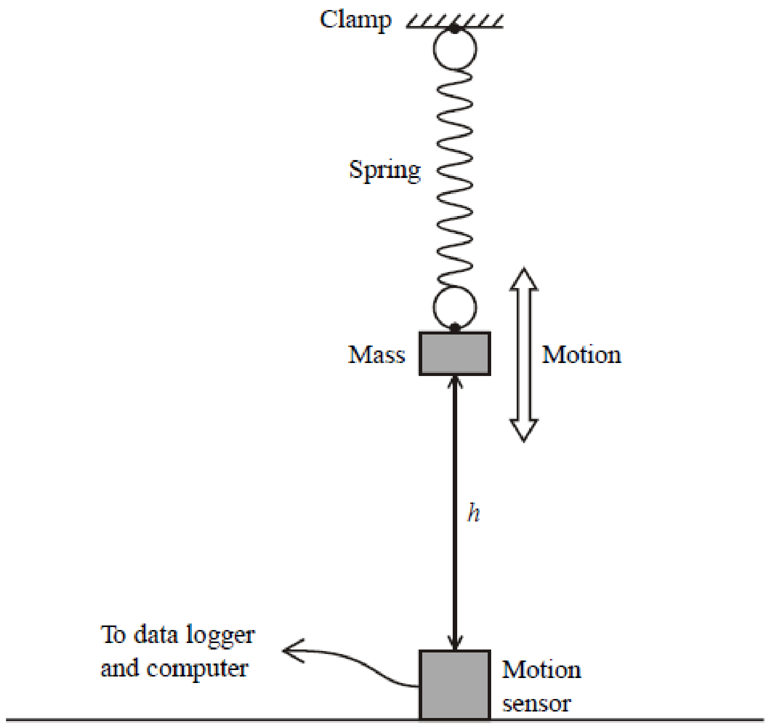
.... **(1)**

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

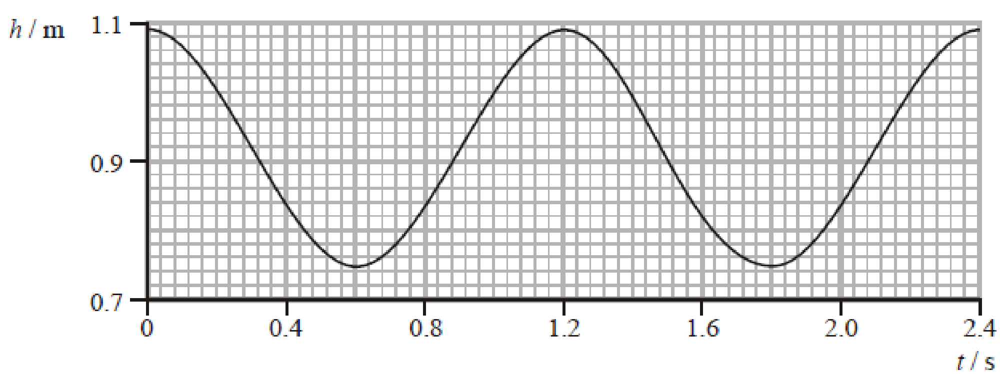
Frequency = ...

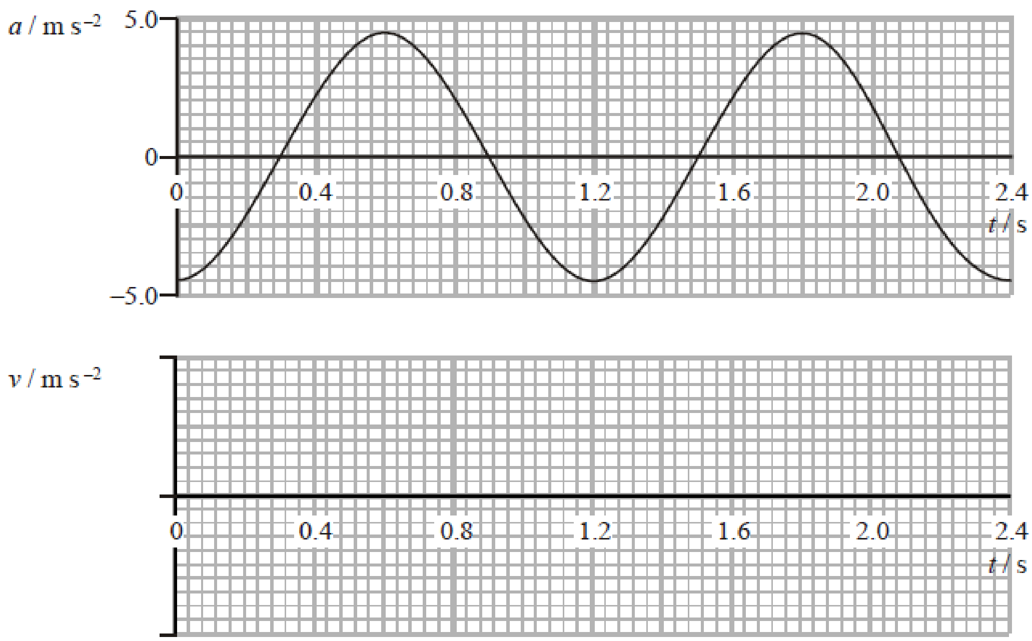
(2)

8. 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.

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Amplitude = ... Frequency = ...

(2)

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

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(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.

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(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.)

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(4)

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

The Ultimate Clock?

Why bother to improve atomic clocks?

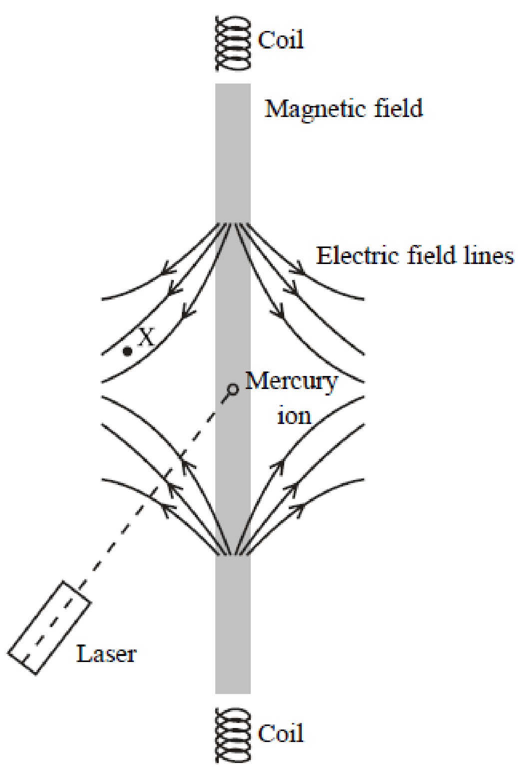
The duration of the second can already be measured to 14 decimal places. One reason for improving this precision is that the second is becoming the fundamental unit. Units such as the metre and ampere already can be defined in terms of the second. The kilogram could also be defined using the equation $\Delta E = c^2 \Delta m$. 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.

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(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.

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(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.

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(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.

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(3)

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

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g = ...

(4)

-: The End :-