H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 Timed Practice

Higher 2

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS

9478/02

March 2026
1 hour 15 minutes

Candidate answers on the Question Paper.

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.
Answers **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 10
2	/10
3	/ 15
4	/ 10
Deduction	
Total	/45

This document contains **20** printed pages and **4** blank pages.

Data and Formula Sheet

speed of light in free space,
$c = 3.00 \times 10^{8}$ m s^{-1}

permeability of free space,
$m_o = 4\pi \times 10^{-7}$ H m^{-1}

permittivity of free space,
$e_o = 8.85 \times 10^{-12}$ F m^{-1}
$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}$ F m$^{-1})$

elementary charge,
$e = 1.60 \times 10^{-19}$ C

the Planck constant,
$h = 6.63 \times 10^{-34}$ J s

unified atomic mass constant,
$u = 1.66 \times 10^{-27}$ kg

rest mass of electron,
$m_e = 9.11 \times 10^{-31}$ kg

rest mass of proton,
$m_p = 1.67 \times 10^{-27}$ kg

molar gas constant,
$R = 8.31$ J K^{-1} mol^{-1}

the Avogadro constant,
$N_A = 6.02 \times 10^{23}$ mol^{-1}

the Boltzmann constant,
$k = 1.38 \times 10^{-23}$ J K^{-1}

gravitational constant,
$G = 6.67 \times 10^{-11}$ N m^{2}kg^{-2}

acceleration of free fall,
$g = 9.81$ m s^{-2}

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/ by a gas,	$W = p\,\Delta V$
pressure	$p = \frac{F}{A}$
gravitational potential,	$\phi = -\frac{GM}{r}$
temperature	T /K = T /°C +273.15
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$
	$= \pm\omega\sqrt{x_0^2 - x^2}$
Electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
capacitors in series	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel	$C = C_1 + C_2 + \ldots$
energy in a capacitor	$U = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$
charging a capacitor	$Q = Q_0\left[1 - e^{-\frac{t}{\tau}}\right]$
RC time constant	$\tau = RC$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage,	$x = x_o \sin \omega t$
magnetic flux density due to long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
energy states for quantum particle in a box	$E_n = \frac{h^2}{8mL^2}n^2$
radioactive decay,	$x = x_0 e^{-\lambda t}$
decay constant,	$\lambda = \frac{ln2}{t_{\frac{1}{2}}}$

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Answer **all** the questions in the spaces provided.

1 **(a)** Planet X is a uniform sphere with mass M and radius R. Point P lies on a straight line passing through the centre of the Earth, at a variable displacement x from the centre, as shown in Fig. 1.1.

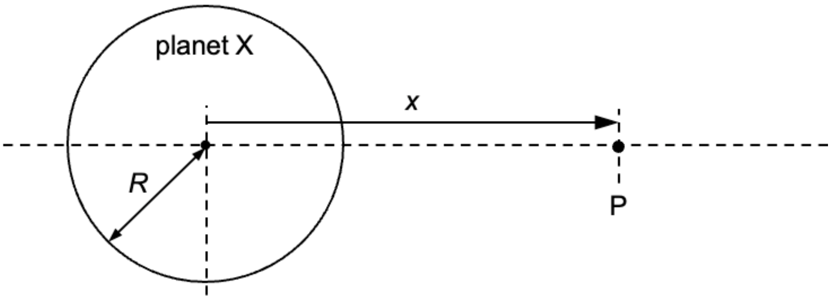

Fig. 1.1

Fig. 1.2 shows the variation with x of the gravitational potential at point P between $x = R$ and $x = 5R$.

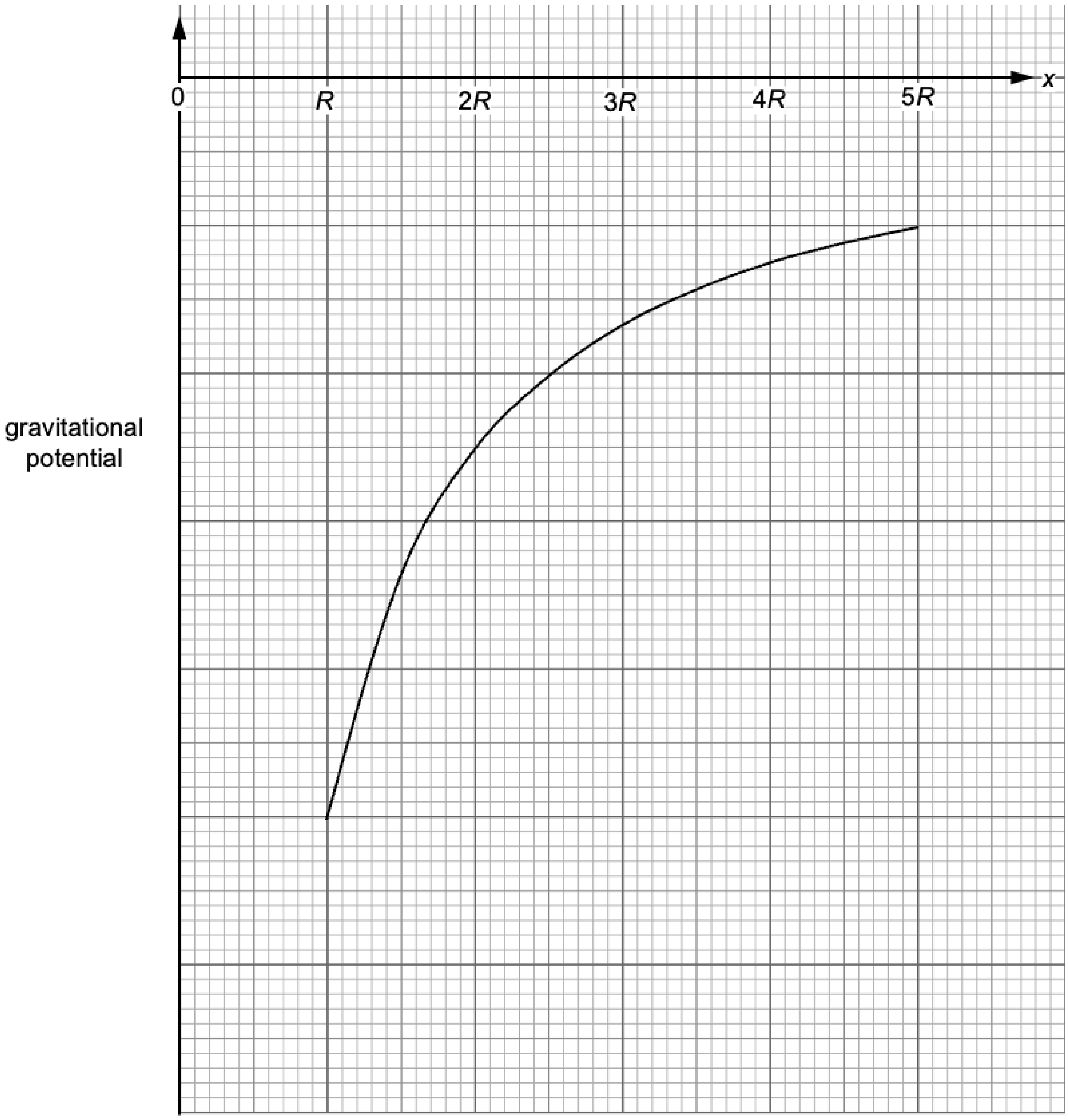

Fig. 1.2

By reference to the definition of gravitational potential, explain why gravitational potential is a negative quantity.

....

....

....

.... [2]

(b) Planet Y is another uniform sphere with radius R and half the mass of planet X.

The distance between the centre of the planets is $6R$. Point P is now on the straight line passing through the centres of the planet, as shown in Fig. 1.3.

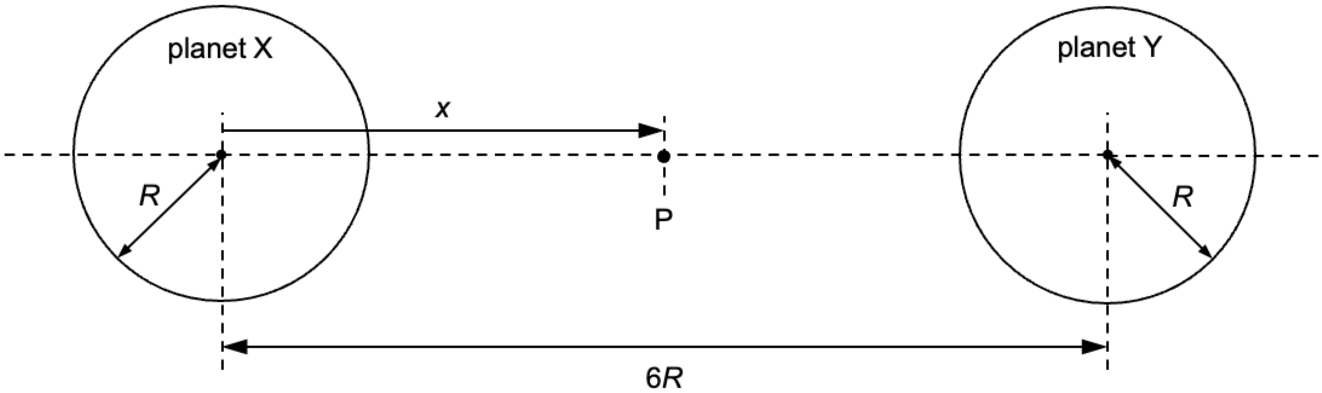

Fig. 1.3

(i) Show that the gravitational field strength at P is zero when $x = 3.5R$.

[2]

(ii) On Fig. 1.2, sketch the variation with x of the gravitational potential at point P between $x = R$ and $x = 5R$

1. due to planet Y only and label the graph as "Y", [2]

2. due to both planets and label the graph as "T". [2]

(c) A rock moves along the line joining the centres of the planets in **(b)**.

On Fig. 1.4, sketch the variation with x of the gravitational force F exerted on the rock between $x = R$ and $x = 5R$.

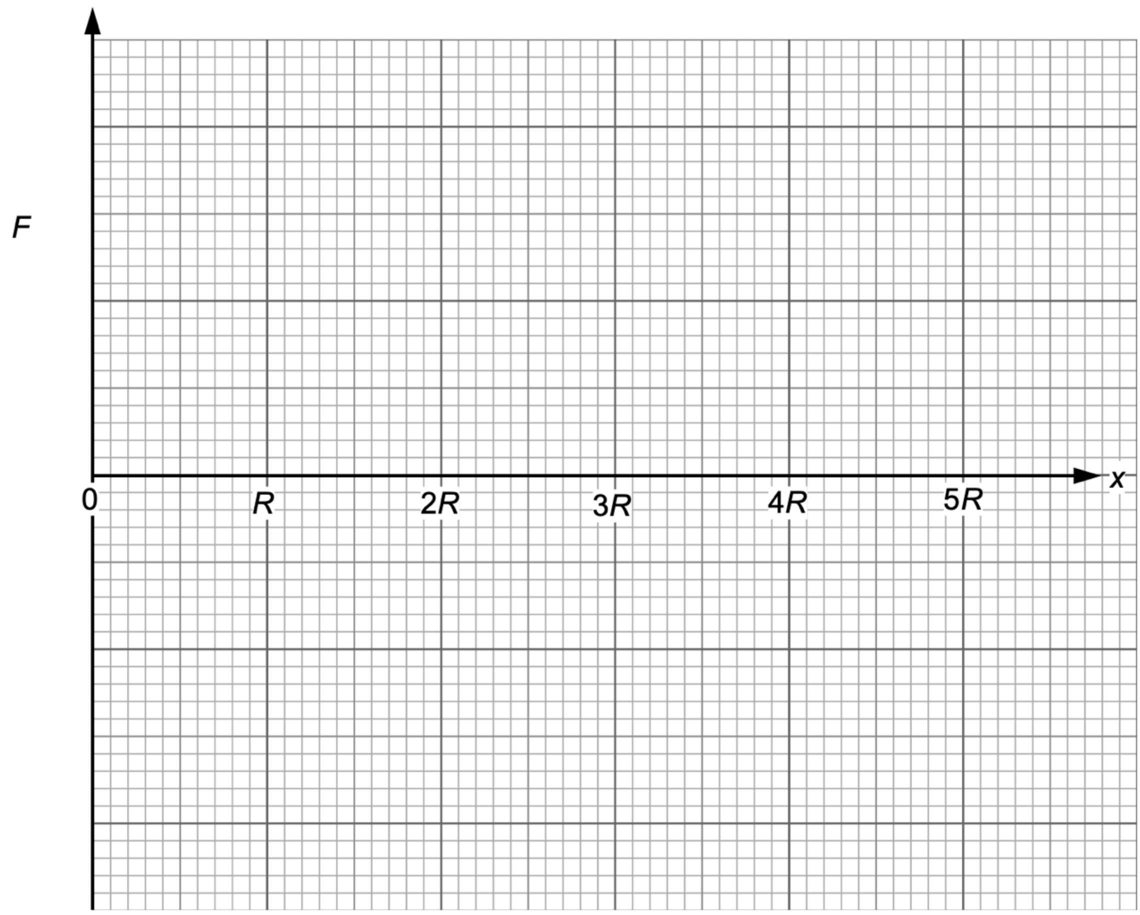

Fig. 1.4

[2]

[Total: 10]

2 **(a)** A fixed mass of water in a beaker is at atmospheric pressure and its initial temperature is 0°C. The temperature of the water is raised gradually by heating.

(i) The water is supplied with thermal energy *E*, so that its temperature increases to 8°C. There is no net change in the volume of the water.

Use the first law of thermodynamics to complete Table 2.1 for this process.

Table 2.1

work done on water	thermal energy supplied to water	increase in internal energy of water
	+*E*	

[1]

(ii) The water is now heated so that its temperature increases by a further 8°C to a final temperature of 16°C. This process causes the volume of the water to increase so that work *W* is done.

You may assume that the change in internal energy is the same as in **(b)(i)**.

Use the first law of thermodynamics to complete Table 2.2 for this process.

Table 2.2

work done on water	thermal energy supplied to water	increase in internal energy of water

[2]

(iii) The specific heat capacity of the water is calculated from the energy transferred by heating per unit mass per unit change in temperature.

Suggest, with a reason, how the average specific heat capacity of water between 8°C and 16°C compares with its average value between 0°C and 8°C.

……..

…………………………………………………………………………………………………… [1]

(iv) Explain why it is incorrect to assume that the change in internal energy for **(b)(i)** and **(b)(ii)** are equal.

……..

…………………………………………………………………………………………………… [1]

(b) Using the first law of thermodynamics, explain why the internal energy of the following situations increases.

(i) A spring is stretched at constant temperature within its elastic limit

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……………………………………………………………………………………………… [2]

(ii) A sample of water when it evaporates from a rain puddle on a hot day.

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……………………………………………………………………………………………… [3]

[Total: 10]

3 **(a)** Fig. 3.1 shows an electric guitar with six strings of different thickness. The sounds are amplified by electronic pickups (microphones), and an amplifier to convert the vibration of its strings into electrical signals and ultimately reproduced by loudspeakers as sound.

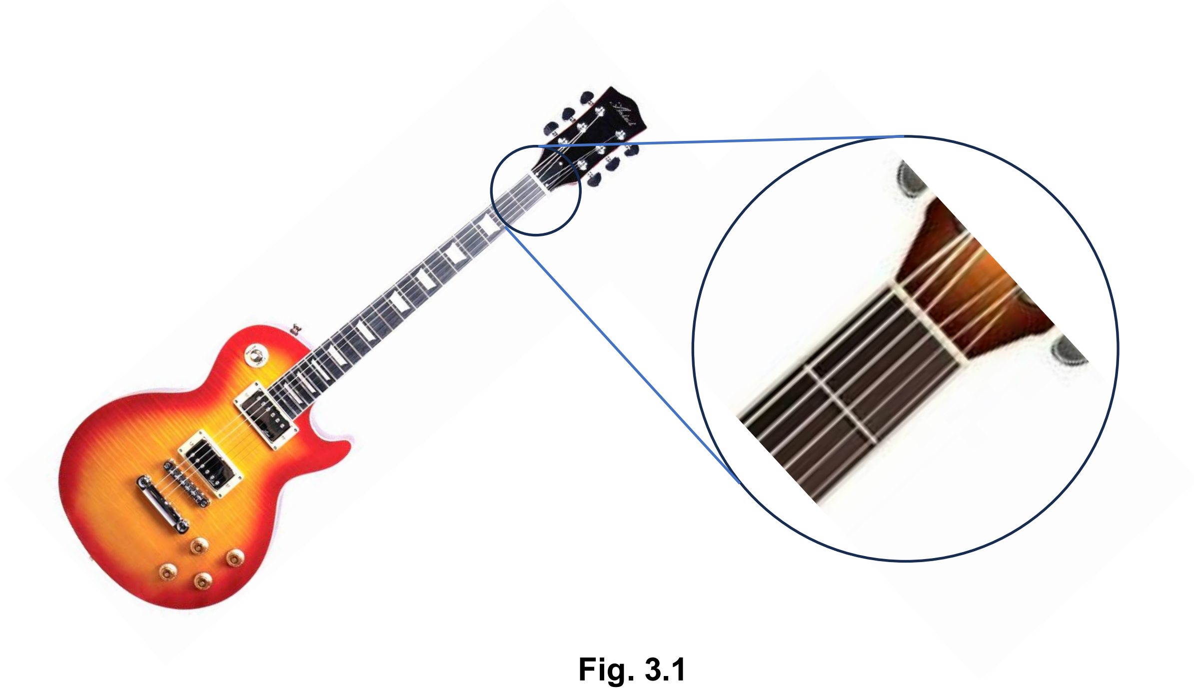

Fig. 3.1

(i) State the conditions required for the formation of stationary waves.

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……………………………………………………………………………………………………..

…………………………………………………………………………………………………… [2]

(ii) The top string produces a note of fundamental frequency 440 Hz. The velocity of wave travelling along the guitar string is 528 m s^{-1}.

1. Show that the effective length of the string is 0.60 m.

[1]

2. The amplitude of the vibrating guitar string is 3.3 mm.

Determine the maximum velocity of the vibrating string when the whole string is momentarily at the equilibrium position.

maximum speed = ………………………….. m s^{-1}[2]

3. Fig 3.2 shows the top guitar string with its two ends fixed in place.

An experienced guitarist is able to lightly touch on the string to change the tone when the string is plucked. The frequency measured is 1760 Hz.

Draw the profile of this stationary wave in Fig. 3.2, showing clearly how you derived it.

Fig 3.2

[2]

(iii) It was observed that when top string is plucked, the bottom string vibrates but not the other four strings. Explain the observation.

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…………………………………………………………………………………………………… [3]

(b) The output of the electric guitar is fed into a loudspeaker. The loudspeaker emits hemispherical sound waves of mean power 200 W as shown in Fig 3.3. A small microphone is placed at a distance 10.0 m from the loudspeaker.

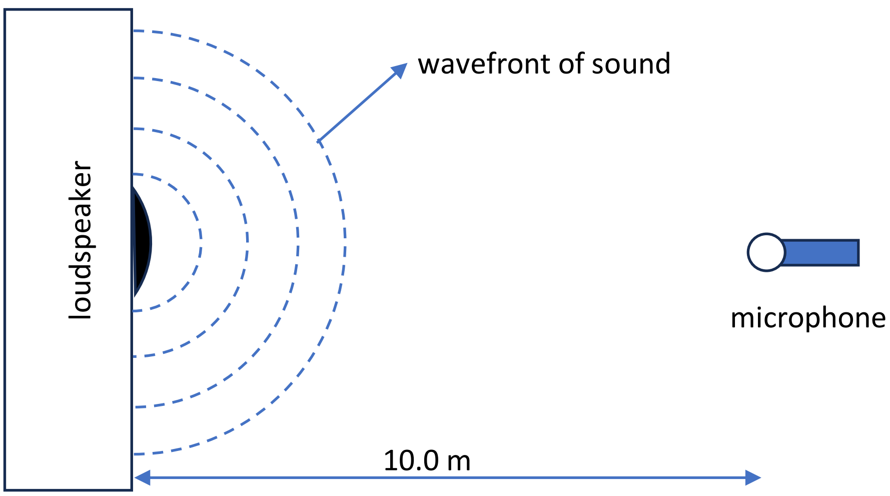

Fig. 3.3

(i) Determine the mean intensity I of the sound wave detected by the microphone.

I = ………………………….. W m^{-2} [3]

(ii) Loudspeakers in the school hall are identical. During one experiment, two of these speakers are connected to an electric guitar playing a note of a single frequency. The loudspeakers are then tilted facing each other.

Suggest two reasons why a stationary wave may not form between the two loudspeakers.

1. ……………………………………………………………………………………………..

……………………………………………………………………………………………..

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2. ……………………………………………………………………………………………..

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……………………………………………………………………………………..……[2]

[Total: 15]

4 Fig 4.1 shows two microwave transmitters **A** and **B** 0.20 m apart. The transmitters emit microwaves of frequency 10 GHz, of equal amplitude and in phase. A microwave detector is placed at **O** at a distance of 4.0 m from **AB**. **O** is at equidistant from **A** and **B**.

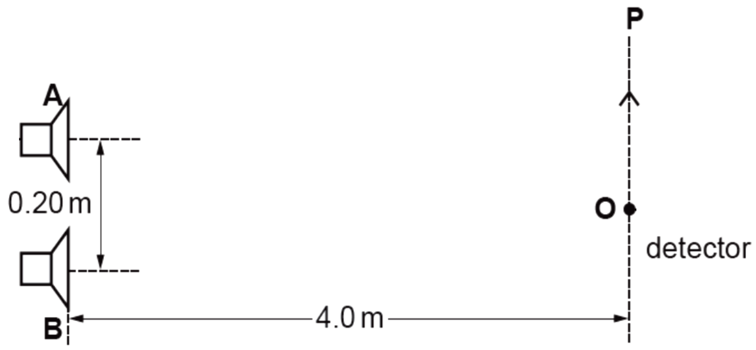

Fig. 4.1 (not to scale)

Interference of the waves from the two transmitters is detected only when the transmitters are coherent.

(a) **(i)** **1.** Explain why the amplitude of the detected signal changes when the detector is moved in the direction **OP**.

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…………………………………………………………………………………………… [3]

2. Calculate the distance between adjacent maximum and minimum signals.

distance = ………………………….. m [3]

(ii) State the effect on the signal detected at **O** when each of the following changes is made independently:

1. The amplitude of the waves emitted from **A** is increased.

……………………………………………………………………………………………………

…………………………………………………………………………………………… [1]

2. The two microwave transmitters **A** and **B** emits waves that are anti-phase to each other.

………………………………………………………..……………………………………..

………………………………………………………………………………………………. [1]

(b) Transmitter **A** is moved a small distance in the direction **AR** with the detector fixed at **O** as show in Fig. 4.2.

The amplitude of the detected signal decreases to a minimum before increasing again.

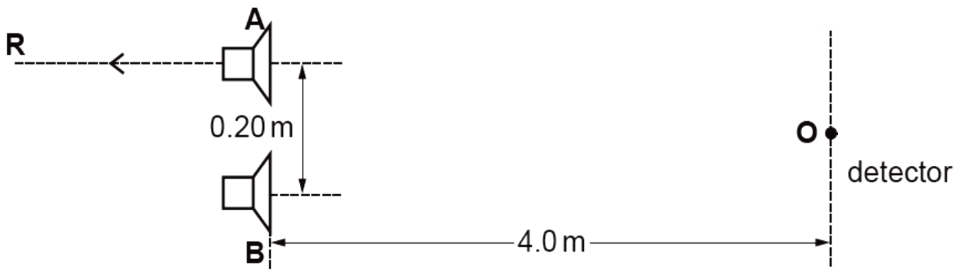


Fig. 4.2 (not to scale)

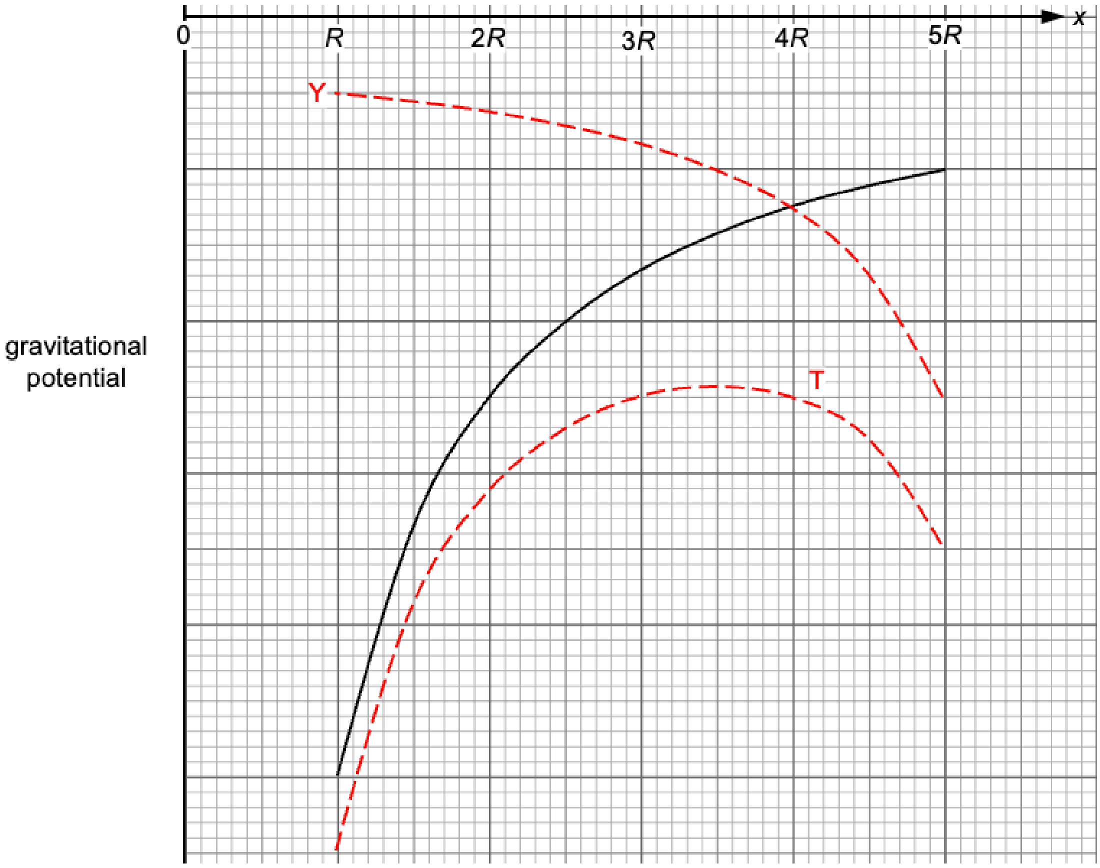
Calculate the distance **A** is moved to cause this minimum signal at **O**.

distance = ………………………….. m [2]

[Total: 10]

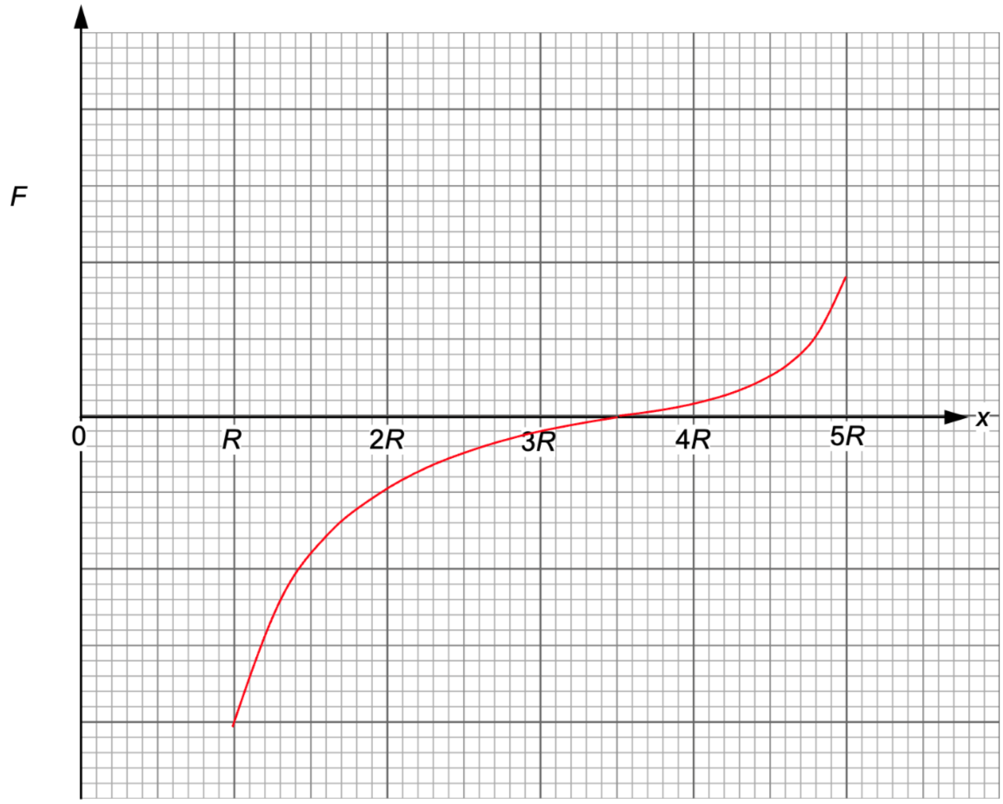
Mark scheme

1	**(a)**		gravitational potential is zero at infinity	B1
			gravitational force is attractive so work done by external force (on test mass) is negative as distance decreases	B1
			so potential is negative	
	(b)	**(i)**	zero when magnitude of field strength due to each planet at P is equal $\frac{GM}{x^2} = \frac{G\left(\frac{1}{2}M\right)}{(6R-x)^2}$	M1
			with correct manipulation to obtain $x = \frac{6R}{1+1/\sqrt{2}} = \frac{6R}{1+0.7071}$	C1
			so $x \approx 3.5R$	A0
		(ii)	**1.** <u>smooth</u> and <u>negative</u> curve with increasing negative gradient as *x* increases	M1
			passing through (*R*, –0.5 sq), (4*R*, –1.25 sq) and (5*R*, –2.5 sq)	A1
			2. smooth and negative curve with turning point at *x* = 3.5*R* AND potential at turning point approximately equal to sum of potential due to two planets	B1
			curve begins at *R* and ends at 5*R* AND the potential at these points equal to sum of potential due to two planets	B1



(c) F starts from negative values crosses $F = 0$ at $x = 3.5R$ and increases to positive values B1

magnitude of F at R > magnitude of F at $5R$ B1



2 **(a)** **(i)** work done = 0 AND increase in internal energy = +E B1

(ii) work done = –W AND increase in internal energy = +E B1

thermal energy = increase in internal energy – work done (i.e. E + W) B1

(iii) more thermal energy supplied in **(a)(ii)** than **(a)(i)** so specific heat capacity is greater between 8 °C and 16 °C (than between 0 °C and 8 °C) B1

(iv) volume / average separation between molecules increases in **(b)(ii)** which increases the potential energy of the water B1

(b) **(i)** heat supplied (to spring) = mass × specific heat capacity × change in temperature is zero at constant temperature B1

work is done to stretch spring (increases the average distance between the particles which increases the potential energy of spring) B1

so internal energy increases (by first law)

(ii) (thermal) energy transferred / heat is supplied to water from surrounding B1

work is done by the water (or negative work is done on the water) when it expands against atmosphere (or molecules push against atmosphere to escape) as it vaporises B1

more (thermal) energy transferred / heat supplied than work done so internal energy increases B1

3 **(a)** **(i)** A stationary wave is formed when two progressive waves of the same type of equal amplitude, equal frequency (or wavelength) and same speed B1

meet when they travel in opposite directions B1

(ii) **1.** $v = f\lambda$

$528 = 440\,\lambda$ M1

$\lambda = 1.2$ m

Length = l/2 = 0.6 m A0

2. $V_{max} = w\,x_0 = 2\pi f\,x_0$ M1

$= 2\pi\,(440)\,(3.3 \times 10^{-3})$

$= 9.12$ m s^{-1} A1

3. $v = f\lambda$

$528 = 1760\,\lambda$

$\lambda = 0.3$ m B1

Draw 2 λ B1

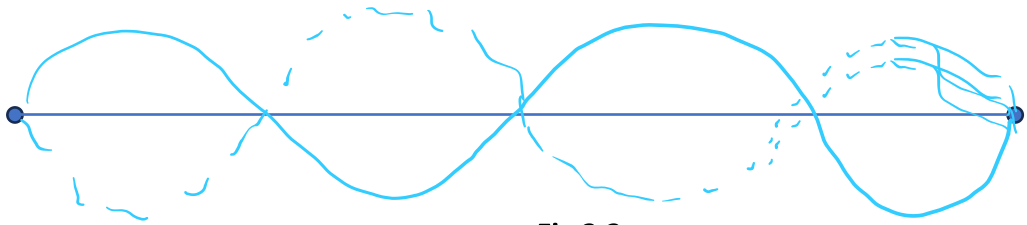


Fig 3.2

(iii) When the top string is plucked, the air around it/body of guitar vibrated in the same frequency as that of the top string. B1

The bottom string must have a natural frequency that matches the frequency of the vibrating air/body of guitar. Thus resonance occurs and the bottom string vibrates too. B1

The others does not vibrates simply because their natural frequency is not the same as the frequency of the vibrating air/body of guitar. B1

(b) **(i)** Area of the wavefront = ½ $(4\pi r^2) = 200\,\pi$ C1

Intensity = P/A $= 200 / (200\,\pi)$ M1

$= 0.318$ W m^{-2} A1

(ii)

- If the 2 identical loudspeakers are far apart, their amplitudes may be significantly different at all points (except the mid point/middle section).

- Waves reflections from all surfaces will superpose with the 2 waves from the loudspeakers.
- Air in the medium is not stationary (e.g. fan blowing air from one speaker to another, one wave has a smaller, and one has a larger frequency than the original frequency).

Any 2 of 3 reasons

4 (a) (i) 1.

The path difference between the signal changes along OP. B1

When the path difference is equal = nλ, where n is an integer, constructive interference takes place, and the resultant amplitude is the sum of the individual amplitudes. B1

When the path difference is equal = (n-1/2)λ, where n is an integer, destructive interference takes place, and the resultant amplitude is the difference of the 2 amplitudes. B1

2.

$\lambda = \frac{c}{f} = \frac{3.00\times10^{8}}{1.0\times10^{10}} = 0.030$ m M1

$\Delta x = \lambda\frac{D}{a} = 0.030 \times \frac{4.0}{0.20} = 0.60$ m C1

Distance = $\frac{\Delta x}{2} = 0.30$ m

A1

(ii) 1. The intensity of signal will increase at O. B1

2. O will be a point of zero intensity. B1

(b)

Let the distance moved be *d*,

$\Delta x = \sqrt{(d+4.0)^2 + 0.1^2} - \sqrt{(4.0)^2 + 0.1^2}$

For minimum signal, $\Delta x = \frac{\lambda}{2}$,

$\sqrt{(d+4.0)^2 + 0.1^2} - \sqrt{(4.0)^2 + 0.1^2} = 0.15$ C1

d = 0.15 m A1

OR

Since distance to the detector is much larger than the distance between the transmitters, B1

d = $\Delta x = \frac{\lambda}{2} = 0.15$ m A1

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