Cambridge International A Level

Cambridge International Examinations
Cambridge International Advanced Level

CANDIDATE NAME		
CENTRE NUMBER		
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5785590745

PHYSICS **9702/41**

Paper 4 A2 Structured Questions **October/November 2015**

2 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
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This document consists of **23** printed pages and **1** blank page.

DC (ST/CGW) 97085/2

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \mathrm{m\,F^{-1}})$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\dfrac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm\,\omega\sqrt{(x_0^{\,2} - x^2)}$
electric potential,	$V = \dfrac{Q}{4\pi\varepsilon_0 r}$
capacitors in series,	$1/C = 1/C_1 + 1/C_2 + \ldots$
capacitors in parallel,	$C = C_1 + C_2 + \ldots$
energy of charged capacitor,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{0.693}{t_{\frac{1}{2}}}$

Section A

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

1 A satellite of mass m_S is in a circular orbit of radius x about the Earth.

The Earth may be considered to be an isolated uniform sphere with its mass M concentrated at its centre.

(a) (i) Show that the kinetic energy E_K of the satellite is given by the expression

$$E_K = \frac{GMm_S}{2x}$$

where G is the gravitational constant. Explain your working.

[3]

(ii) State an expression, in terms of G, M, m_S and x, for the potential energy E_P of the satellite.

....[1]

(iii) Using answers from **(i)** and **(ii)**, derive an expression for the total energy E_T of the satellite.

E_T = ...[2]

(b) Small resistive forces acting on the satellite cause the radius of its circular orbit to change.

Use your answers in **(a)** to state, for the satellite, whether each of the following quantities increases, decreases or remains constant.

(i) total energy

....[1]

(ii) radius of orbit

....[1]

(iii) potential energy

....[1]

(iv) kinetic energy

....[1]

2 **(a)** State what is meant by an *ideal* gas.

....

....

....[2]

(b) The mean-square speed of the atoms of a fixed mass of an ideal gas at 32 °C is $1.9 \times 10^6\ m^2 s^{-2}$.

The gas is heated at constant volume to a temperature of 80 °C.

Determine

(i) the rise, in kelvin, of the temperature of the gas,

temperature rise = ... K [1]

(ii) the root-mean-square (r.m.s.) speed of the atoms at 80 °C.

r.m.s. speed = ... $m s^{-1}$ [3]

3 **(a)** State an expression, in terms of work done and heating, that is used to calculate the increase in internal energy of a system.

....

....

....[2]

(b) State and explain, in terms of your expression in **(a)**, the change, if any, in the internal energy

(i) of the water in an ice cube when the ice melts, at atmospheric pressure, to form a liquid without any change of temperature,

....

....

....

....[3]

(ii) of the gas in a tyre when the tyre bursts so that the gas suddenly increases in volume. Assume that the gas is ideal.

....

....

....

....[3]

4 **(a)** Distinguish between free oscillations and forced oscillations.

free oscillations: ....

....

forced oscillations: ....

....
[2]

(b) A trolley is held on a horizontal surface by means of two stretched springs, as shown in Fig. 4.1.

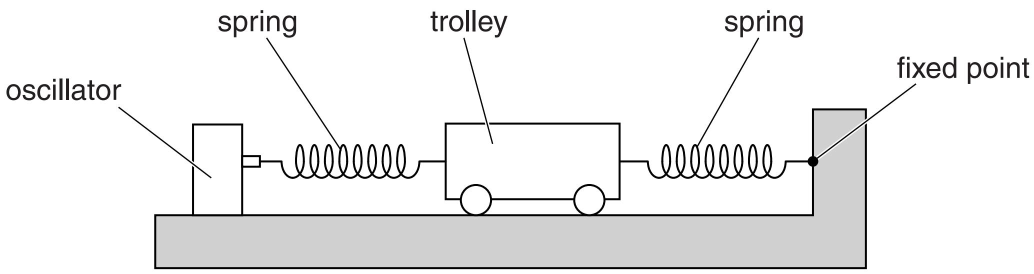

Fig. 4.1

One spring is attached to a fixed point. The other spring is attached to an oscillator that causes horizontal oscillations of the trolley.

The oscillator vibrates with a constant amplitude of vibration. The frequency of vibration of the oscillator is gradually increased from a very low value.

The variation with frequency f of the amplitude x_0 of vibration of the trolley is shown in Fig. 4.2.

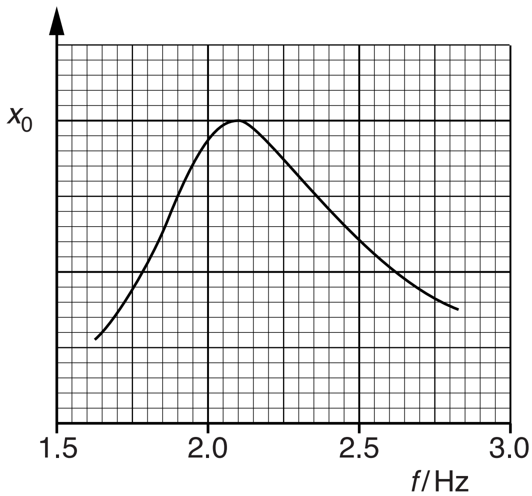

Fig. 4.2

Use Fig. 4.2 to state and explain

(i) the value of the natural frequency of vibration of the trolley,

....

....

....

....[3]

(ii) whether there are any frictional forces acting on the trolley.

....

....

....[1]

(c) The oscillator in **(b)** is now stopped.

The trolley is given a horizontal displacement of 4.7 cm along the line of the springs.
The trolley is then released.

Use information from Fig. 4.2 to estimate the maximum speed of the trolley.

speed = ... $m\,s^{-1}$ [2]

5 A charged particle P is situated in a vacuum at a distance x from the centre of a charged conducting sphere of radius r, as illustrated in Fig. 5.1.

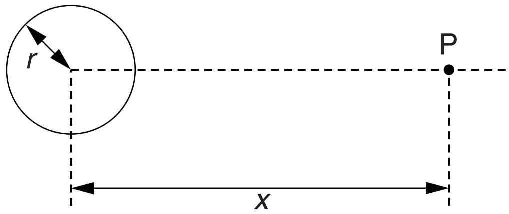

Fig. 5.1

For the particle P outside the conducting sphere, the charge on the sphere may be assumed to be a point charge at its centre.

(a) **(i)** State Coulomb's law.

....

....

....[2]

(ii) The sphere and the particle P are both charged positively.

1. State the direction of the force acting on particle P.

....[1]

2. State the position of particle P for the force to be maximum.

....[1]

3. Determine the ratio

$$\frac{\text{force on particle P at } x = r}{\text{force on particle P at } x = 4r}.$$

ratio = ... [2]

(b) When the charge on the sphere is 6.0×10^{-7} C, the electric field strength at the surface of the sphere is $1.5 \times 10^{6}\,\text{V m}^{-1}$.

Electrical breakdown (a spark) occurs when the electric field strength at the surface of the sphere exceeds $2.0 \times 10^{6}\,\text{V m}^{-1}$.

Determine the additional charge that may be added to the sphere before breakdown occurs.

charge = ... C [3]

6 **(a)** A particle has mass m, charge $+q$ and speed v.

State the magnitude and direction of the force, if any, on the particle when the particle is travelling along the direction of

(i) a uniform gravitational field of field strength g,

....

....[2]

(ii) a uniform magnetic field of flux density B.

....

....[1]

(b) Two charged horizontal metal plates, situated in a vacuum, produce a uniform electric field of field strength E between the plates. The field strength outside the region between the plates is zero.

The particle in **(a)** enters the region of the electric field at right-angles to the direction of the field, as illustrated in Fig. 6.1.

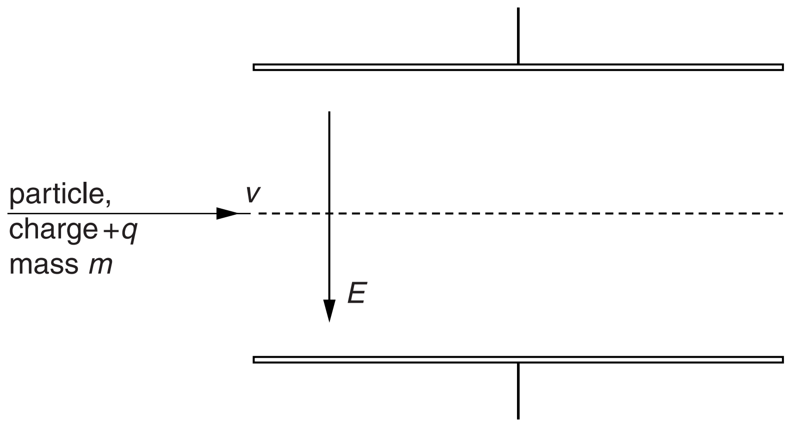

Fig. 6.1

A uniform magnetic field is to be applied in the same region as the electric field so that the particle passes undeviated through the region between the plates.

(i) State and explain the direction of the magnetic field.

....

....[2]

(ii) Derive, with explanation, the relation between the speed v and the magnitudes of the electric field strength E and the magnetic flux density B.

[3]

(c) A second particle has the same mass m and charge $+q$ as that in **(b)** but its speed is $2v$. This particle enters the region between the plates along the same direction as the particle in **(b)**.

On Fig. 6.1, sketch the path of this particle in the region between the plates. [2]

7 **(a)** By reference to the photoelectric effect, state what is meant by the *threshold frequency*.

....

....

....[2]

(b) Electrons are emitted from a metal surface when light of a particular wavelength is incident on the surface.
Explain why the emitted electrons have a range of values of kinetic energy below a maximum value.

....

....

....

....[2]

(c) The wavelength of the incident radiation is λ.
The variation with $1/\lambda$ of the maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is shown in Fig. 7.1.

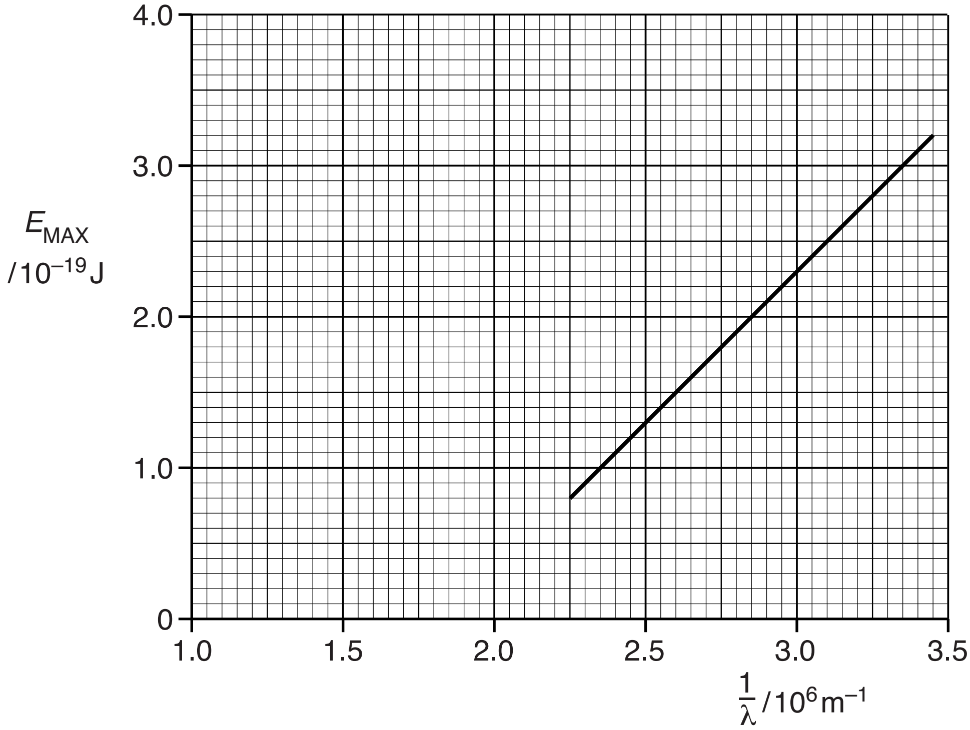

Fig. 7.1

(i) Use Fig. 7.1 to determine, without reference to the work function energy, the threshold frequency f_0.

f_0 = ... Hz [2]

(ii) Use your answer in **(i)** to calculate the work function energy Φ.

Φ = ... J [2]

(d) Caesium metal has a work function energy of 2.2×10^{-19} J.

On the axes of Fig. 7.1, sketch a graph to show the variation with $1/\lambda$ of E_{MAX} for caesium metal. [2]

8 **(a)** Distinguish, for an atom, between a nucleus and a nucleon.

nucleus: ....

....

nucleon: ....

....
[3]

(b) Radon gas is a naturally occurring radioactive gas with a half-life of 3.8 days.

The activity of radon gas in a room is found to be 97 Bq in each 1.0 m^3 of air.

(i) Calculate

1. the decay constant, in s^{-1}, of radon,

decay constant = ... s^{-1} [2]

2. the number of radon atoms giving rise to an activity of 97 Bq.

number = ... [2]

(ii) A volume of $2.5 \times 10^{-2}\,m^3$ of air in the room contains 1.0 mol of molecules.

Determine the ratio, for $1.0\,m^3$ of air,

$$\frac{\text{number of radon atoms}}{\text{number of air molecules}}.$$

ratio = ... [2]

Section B

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

9 A battery of e.m.f. 6.0 V and negligible internal resistance is connected to three resistors, each of resistance 2.0 kΩ, and a thermistor, as shown in Fig. 9.1.

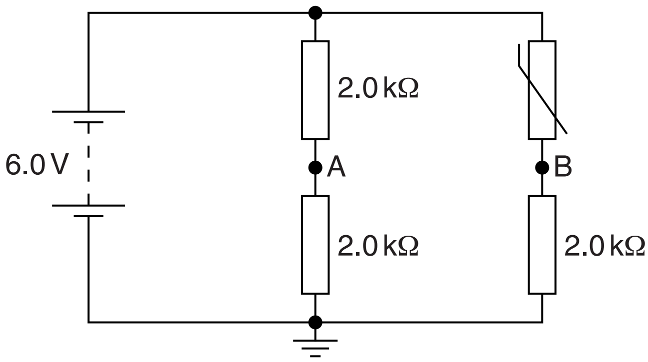

Fig. 9.1

The thermistor has resistance 2.8 kΩ at 10 °C and resistance 1.8 kΩ at 20 °C.

(a) Calculate the potential

(i) at point A,

potential = ... V [1]

(ii) at point B for the thermistor at 10 °C,

potential = ... V [2]

(iii) at point B for the thermistor at 20 °C.

potential = ... V [1]

(b) The points A and B in Fig. 9.1 are connected to the inputs of an ideal operational amplifier (op-amp), as shown in Fig. 9.2.

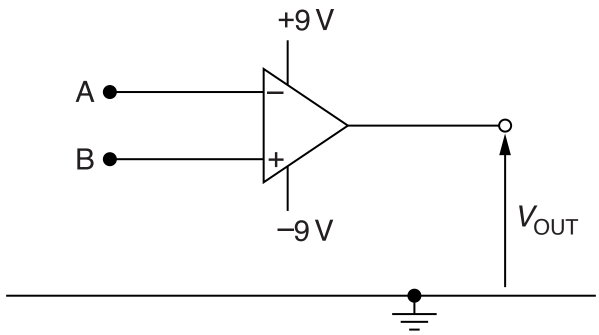

Fig. 9.2

The thermistor is warmed from 10 °C to 20 °C.

State and explain the change in the output potential V_{OUT} of the op-amp as the thermistor is warmed.

....

....

....

....

....

....[4]

10 **(a)** Explain what is meant by the *sharpness* and by the *contrast* of an X-ray image.

sharpness: ....

....

contrast: ....

....
[2]

(b) A parallel X-ray beam of intensity I is incident on a medium of thickness x, as illustrated in Fig. 10.1.

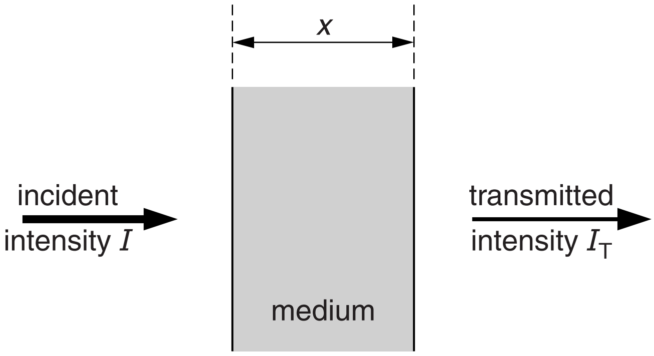

Fig. 10.1

The transmitted intensity is I_T.

Data for the linear absorption (attenuation) coefficient μ for 80 keV X-rays in bone and in muscle are given in Fig. 10.2.

	μ / cm^{-1}
bone	3.0
muscle	0.27

Fig. 10.2

(i) State, with reference to the production of X-rays, what is meant by *80 keV X-rays*.

....

....

....[2]

(ii) Calculate the ratio I_T/I for 80 keV X-rays passing through a thickness of 1.4 cm of bone.

ratio = ... [2]

(c) An X-ray image of the upper leg of a student is produced.
Part of the X-ray beam passes through a comparatively large thickness of muscle and part through some muscle and the leg bone.

Use data from Fig. 10.2 to suggest whether the image has good contrast.

....

....

....

....

....[3]

11 A carrier wave is frequency modulated.

(a) Describe what is meant by *frequency modulation*.

....

....

....[2]

(b) The sinusoidal carrier wave has a frequency of 750 kHz and an amplitude of 5.0 V.
The carrier wave is frequency modulated by a sinusoidal signal of frequency 7.5 kHz and amplitude 1.5 V.
The frequency deviation of the carrier wave is 20 kHz V^{-1}.

Determine, for the frequency-modulated carrier wave,

(i) the amplitude,

amplitude = ... V [1]

(ii) the minimum frequency,

minimum frequency = ... kHz [1]

(iii) the maximum frequency,

maximum frequency = ... kHz [1]

(iv) the number of times per second that the frequency changes from its minimum value to its maximum value and then back to the minimum value.

number = ... s^{-1} [1]

12 **(a)** When infra-red radiation passes along an optic fibre, it is attenuated.

(i) State what is meant by *attenuation*.

....

....[1]

(ii) The infra-red radiation is transmitted as a series of pulses.

State and explain two advantages of the digital, rather than the analogue, transmission of information.

1. ....

....

....

2. ....

....

....

[4]

(b) The input light power to an optic fibre of length 36 km is 145 mW. The output light power is 29 mW.

Calculate, in dB km^{-1}, the attenuation per unit length of the optic fibre.

attenuation per unit length = ... dB km^{-1} [2]

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