Name	Class	Index Number

PIONEER JUNIOR COLLEGE
JC2 Preliminary Examination

PHYSICS **9646/03**
Higher 2

Paper 3 Longer Structured Questions

24 September 2013

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

You are advised to spend about one hour on each section.

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			
1		/	8
2		/	8
3		/	8
4		/	8
5		/	8
6		/	20
7		/	20
8		/	20
Total		/	80

This document consists of **23** printed pages.

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,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
	$= (1/(36\pi)) \times 10^{-9}\ \mathrm{F\,m^{-1}}$
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,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $= \pm\omega\sqrt{x_0{}^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas,	$E = \frac{3}{2}kT$
resistors in series,	$R = R_1 + R_2 + ...$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
transmission coefficient,	$T = \exp(-2kd)$ where $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** questions in this section.

1 A ball is thrown vertically upwards with a velocity of 25 $m\,s^{-1}$ from ground level and then falls back to its starting point. Fig. 1.1 shows the variation with time of the velocity of the ball.

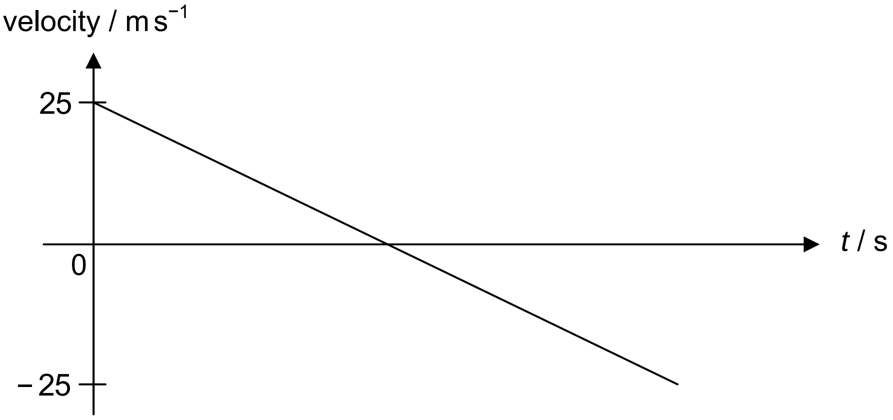

Fig. 1.1

(a) Use Fig. 1.1 to determine

(i) the time taken by the ball to reach the maximum height,

time = ... s [2]

(ii) the maximum height reached by the ball.

height = ... m [1]

(b) (i) On Fig. 1.1, sketch a graph of the motion of the ball if air resistance is not negligible. [2]

(ii) Explain clearly how your answers in **(a)** will change.

....

....

....

.... [3]

2 **(a)** State the *principle of superposition*.

....

....

.... [2]

(b) Sound produced by the loudspeaker shown in Fig. 2.1 has a frequency of 4.0×10^3 Hz. The sound waves arrive at the microphone M via two different paths, LXM and LYM. The left-tube is fixed in position, while the right-tube is a sliding-section. At position M, the sound waves from the two paths interfere.

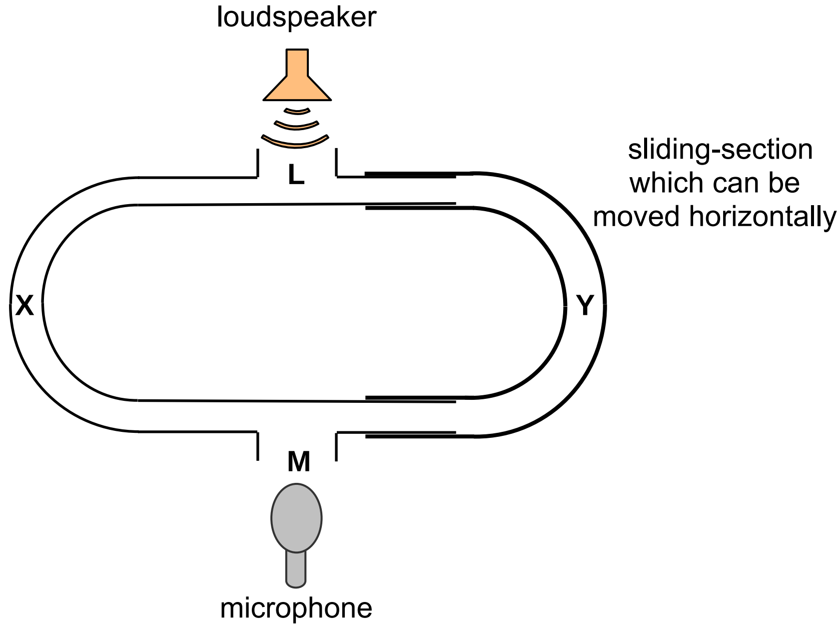

Fig. 2.1

Initially, the lengths of paths LXM and LYM are equal. The sliding-section is then pulled out horizontally to the right by a distance of 0.020 m, and the loudness at microphone M changes from a maximum to a minimum.

(i) Determine the path difference between the two waves after the sliding-section is pulled out.

path difference = ... m [1]

(ii) Calculate the speed at which sound travels through the tubes.

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

(iii) When the opening at M is sealed, explain why a standing wave can be set up in the tube.

....

....

....

....

.... [3]

3 Fig. 3.1 shows how the resistance of a light-dependent resistor (LDR) varies with the intensity of the light incident on it.

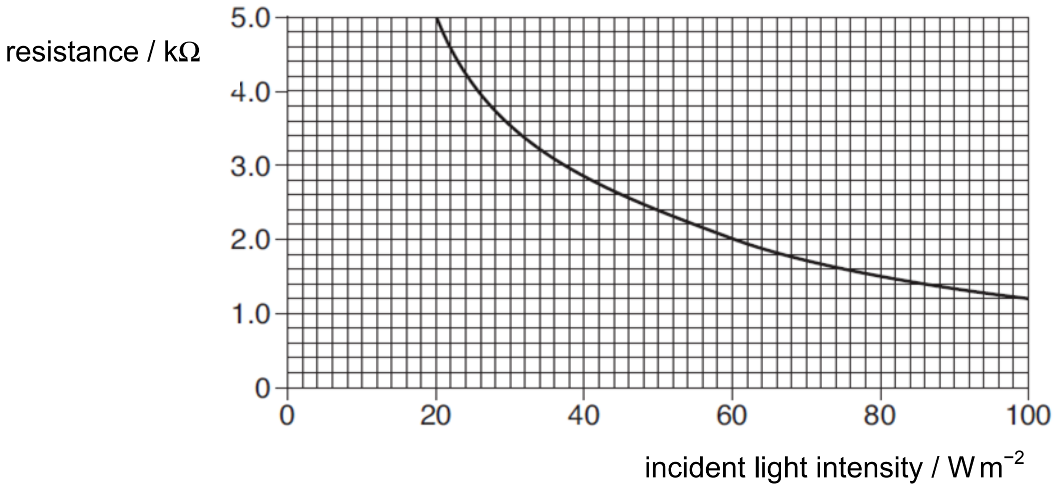

Fig. 3.1

Fig. 3.2 shows a light-sensing potential divider circuit used in a lamp where the potential difference across the LDR can be used to control the brightness of the lamp in a room.

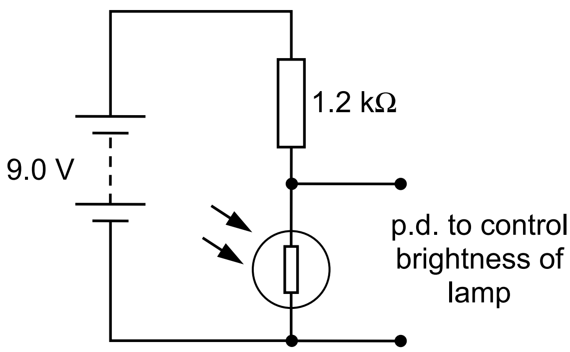

Fig. 3.2

The battery has an e.m.f. of 9.0 V and negligible internal resistance. The 1.2 kΩ resistor is made of carbon. When the room is in a low-light condition, the potential difference across the LDR reaches 7.0 V.

(a) State the potential difference across the 1.2 kΩ resistor, when the room is in a low-light condition.

potential difference = ... V [1]

(b) Hence, calculate the resistance R of the LDR.

R = ... kΩ [2]

(c) Use Fig. 3.1 to determine the light intensity when the p.d. across the LDR is 7.0 V.

light intensity = ... $W\,m^{-2}$ [1]

(d) Fig. 3.3 shows a close-up of the LDR device used in the circuit in Fig. 3.2. The LDR consists of a uniform strip of semiconductor whose resistance is dependent on the intensity of the light incident on it. The cross-sectional area of the strip is 5.0×10^{-7} m^2.

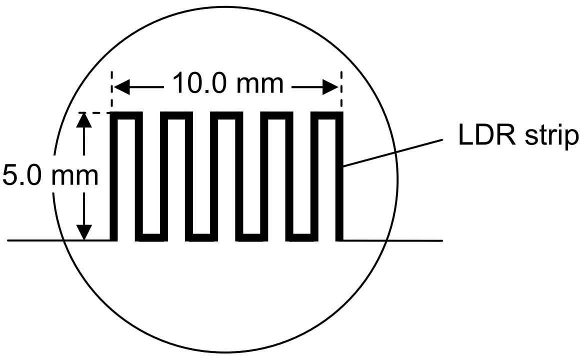

Fig. 3.3

Use your answer in **(b)** to determine the resistivity of the LDR.

resistivity = ... Ω m [2]

(e) Use the evidence provided by Fig. 3.1 to explain the sensitivity of this LDR for the light-sensing circuit used in controlling the brightness of the lamp.

....

....

....

.... [2]

4 A coil with 100 turns is placed in a uniform magnetic field of flux density 0.35 T. The area of the coil perpendicular to the field is 2.5×10^{-2} m^2, as shown in Fig. 4.1.

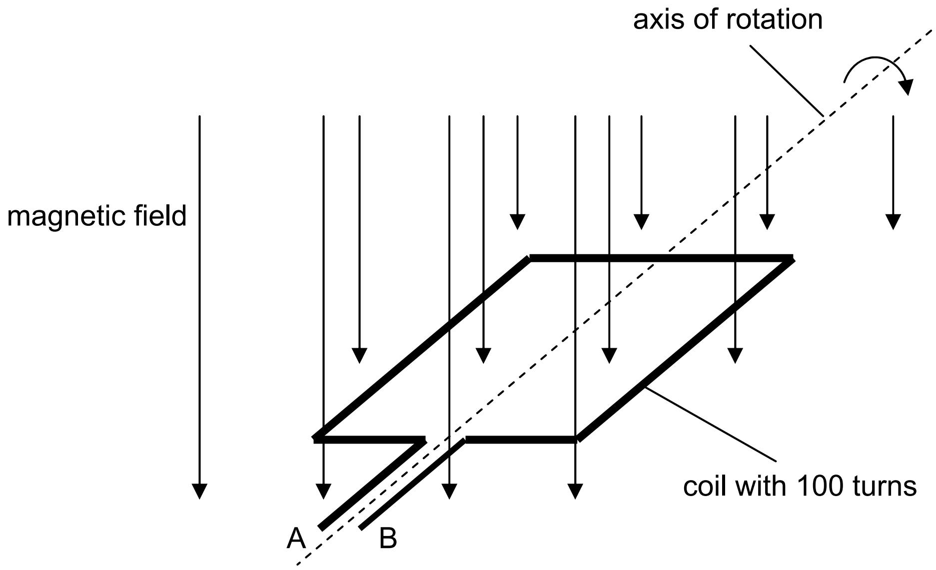

Fig. 4.1

The coil is rotated at 50 revolutions per second, starting from the position shown in Fig. 4.1, where $t = 0$ s.

(a) On Fig. 4.2, sketch a graph to show the variation with time of the e.m.f. induced in the coil. Label the values on the time axis clearly.

Fig. 4.2

[2]

(b) For the coil rotating through the first quarter of a revolution,

(i) calculate the average e.m.f. induced across the coil AB,

average e.m.f. induced = ... V [2]

(ii) explain clearly which point, A or B, is at a higher potential.

....

....

....

.... [2]

(c) The maximum current flowing through the coil is 1.2 A. Hence, calculate the maximum torque experienced by the coil due to the current.

torque = ... N m [2]

5 **(a)** What is meant by the term *threshold frequency* as applied to the photoelectric effect?

....

.... [1]

(b) In a typical set-up of the photoelectric experiment, a metal surface is illuminated with radiation of wavelength 450 nm, causing the emission of photoelectrons which are collected at an adjacent electrode.

(i) Calculate the energy of a photon incident on the surface.

energy = ... J [2]

(ii) The intensity of the incident radiation is $2.7 \times 10^{3}\ \text{W m}^{-2}$ and the area of the metal surface is 3.0 cm^2. Calculate the number of photons incident per second on the surface.

number per second = ... [2]

(iii) Fig. 5.1 shows a graph of how the photoelectric current, I varies with the potential difference, V between the electrodes.

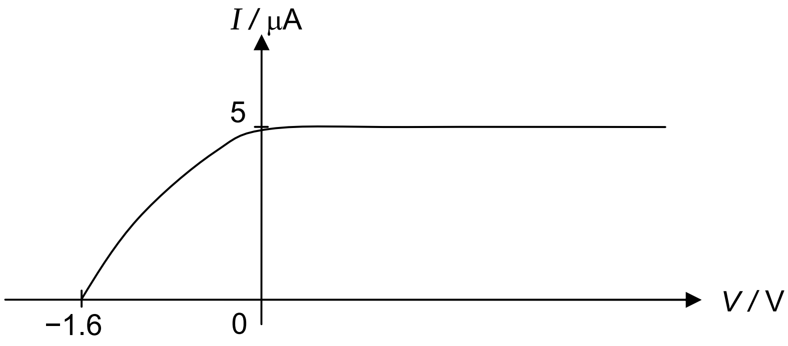

Fig. 5.1

Calculate the threshold wavelength of the metal.

wavelength = ... m [3]

Section B

Answer **two** questions from this section.

6 (a) Define the term *gravitational field strength*.

....

.... [1]

(b) The acceleration of free fall g on the surface of the Earth at the North Pole is slightly higher than that at the Equator. The Earth is assumed to be a uniform sphere. Account for the difference in the value of g at the North Pole and the Equator.

....

....

....

.... [2]

(c) A geostationary satellite, of mass 1500 kg, orbits the Earth in a circle of radius r with period T. It is known that the two quantities are related by the equation $T = Ar^n$. The Earth has a mass of 6.0×10^{24} kg and a radius of 6.4×10^{6} m.

(i) Determine the values of n and A. Include appropriate units, if any, with your values.

n = ... [2]

A = ... [2]

(ii) Calculate the distance of the orbit from the surface of the Earth.

distance = ... m [2]

(iii) Calculate the total energy of the satellite in orbit.

total energy = ... J [2]

(iv) Hence, or otherwise, determine the energy required to put this satellite into orbit.

energy = ... J [2]

(v) Explain why the satellite's orbit must lie in the plane of the equator.

....

....

....

.... [2]

(vi) The satellite carries rechargeable batteries and solar cells for the reception and transmission of data. Explain why both are necessary.

....

....

....

.... [2]

(vii) As the satellite orbits the Earth, it gradually loses energy because of air resistance.

1. State whether the total energy of the satellite becomes more or less negative.

.... [1]

2. Hence, state and explain the effect of this change on the radius of the orbit.

....

....

.... [2]

7 (a) In a continuous flow experiment to measure specific heat capacity, water flows at a rate of 0.150 kg min^{-1} through a tube and is heated by a 25.2 W heater. The steady inflow and outflow temperatures are 15.2 °C and 17.4 °C respectively. The rate of flow is then increased to 0.232 kg min^{-1} and the rate of heating to 37.8 W with the steady inflow and outflow temperatures unchanged.

(i) State what is meant by *specific heat capacity*.

....

....

.... [2]

(ii) Explain why it is essential to repeat the experiment with different flow rate and heater power but maintaining the same steady state of inflow and outflow temperatures of water.

....

....

.... [1]

(iii) Determine the specific heat capacity of water.

specific heat capacity of water = ... J kg^{-1} K^{-1} [3]

(b) By considering the expansion of an ideal gas contained in a cylinder and enclosed by a piston, show that the work done in a small expansion is equal to the product of pressure and volume change.

[2]

(c) A cylinder of nitrogen gas, at a temperature of 20.0 °C and pressure of 1.01×10^5 Pa, occupies a volume of 1000 cm^3. It then undergoes a two-stage change.

(i) In stage A, the gas expands at constant pressure to a volume of 1500 cm^3. Assuming that the nitrogen gas is ideal and given that the specific heat capacity at constant pressure of nitrogen is 1.03 $kJ\,kg^{-1}\,K^{-1}$ and mass of 1 mole of nitrogen gas is 28.0 g, calculate

1. the final temperature of the gas,

final temperature = ... K [2]

2. the work done by the gas in expanding,

work done = ... J [1]

3. the number of moles of gas,

number of moles = ... [1]

4. the quantity of heat supplied.

heat supplied = ... J [2]

(ii) In stage B, the gas is compressed isothermally to its original volume.

1. State and explain the change in internal energy in stage B.

....

....

.... [2]

2. Sketch a labelled p –V diagram showing stages A and B.

[2]

(iii) Determine the change in internal energy of the gas at the end of its two-stage change.

change in internal energy = ... J [2]

8 **(a)** Slow moving neutrons bombard stationary Uranium-235 nuclei to produce energy in a nuclear reactor. One possible nuclear fission reaction is

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{139}_{57}\text{La} + X + 2^{1}_{0}\text{n}$$

(i) Explain what is meant by *nuclear fission*.

....

....

....

.... [2]

(ii) State the number of protons and the number of neutrons in nucleus X .

number of protons = ... [1]

number of neutrons = ... [1]

(b) Energy released in the reaction in **(a)** is 200 MeV. Part of this energy is carried away as kinetic energy of the fission products.

(i) Suggest one other mechanism by which energy is released in the fission reaction.

.... [1]

(ii) Suggest one reason why a slow moving neutron is used instead of a fast moving neutron in bombarding the Uranium nucleus.

....

.... [1]

(iii) Express 200 MeV in joules.

200 MeV = ... J [1]

(iv) The reaction in **(a)** is used by a nuclear plant to generate thermal power of 3065 MW.

1. Calculate the number of fission processes taking place each second in the plant.

number of fission processes = ... [2]

2. The nuclear plant has an overall efficiency of 30%. Calculate the waste heat produced in each second.

waste heat produced in each second = ... J [1]

(v) 97% of the waste heat is removed using water pumped from a river and the rest is ejected into the atmosphere. A safety regulation mandates that the water which is used to cool the nuclear plant cannot be heated by more than 3.5 °C when it is discharged back into the river. Determine the minimum mass of water needed in each second to cool the nuclear plant if the regulation is to be met. The specific heat capacity of water is $4.2 \times 10^3\ \mathrm{J\,kg^{-1}\,K^{-1}}$.

minimum mass of water = ... kg [3]

(c) In Star Trek, the Enterprise is a super long range exploratory spacecraft designed to fly to far fringes of the Solar system. A radioisotope thermoelectric generator (RTG) is used to provide electrical power to Enterprise. The RTG is an electrical generator which obtains its power from the radioactive decay of Plutonium-238. Plutonium-238 has a half-life of 87.7 years.

(i) Define *decay constant* of a radioactive nuclide.

....

.... [1]

(ii) Calculate the decay constant of Plutonium-238.

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

(iii) When the RTG was manufactured, it contained 1.74×10^{25} atoms of Plutonium-238. Show that the activity of the Plutonium-238 in the RTG when it was first manufactured was 4.36×10^{15} Bq.

[2]

(iv) Calculate the activity of Plutonium-238 in the RTG 10 years after manufacture.

activity = ... Bq [2]

End of paper