VICTORIA JUNIOR COLLEGE
2022 JC2 PRELIMINARY EXAMINATIONS
Higher 2

Name : ________________________________ CT group : ___________

PHYSICS **9749 / 03**
Paper 3 Longer Structured Questions **0800 – 1000 h**
2 Hours

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

READ THESE INSTRUCTIONS FIRST

Write your name and CT group at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

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	
2	
3	
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6	
Section B	
7	
8	
Total (max. 80)	

This document consists of **20** printed pages.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $(1/(36\pi)) \times 10^{-9}$ 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 mol^{-1} K^{-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}

Formulae

uniformly accelerated motion,	$s = ut + (½)\, at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\dfrac{GM}{r}$
temperature	T/K=T/°C+273.15
pressure of an ideal gas	$p = \dfrac{1}{3}\dfrac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \dfrac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos\omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = Q/4\pi\varepsilon_0 r$
alternating current/voltage,	$x = x_o \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \dfrac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \dfrac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1. Figure 1.1 below shows a ball of mass 150 g, attached to an elastic cord, being thrown vertically upwards, with a velocity 5.7 m s^{-1}, from the ground. The cord has a spring constant of 45 N m^{-1}. Initially the cord is unstretched but after a while it becomes stretched. The cord obeys Hooke's law and air resistance is ignored.

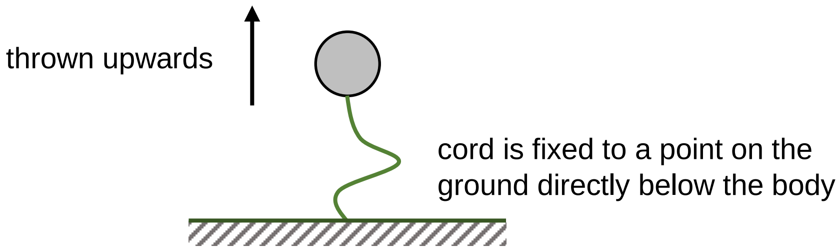


Figure 1.1

(a) Given that the maximum height reached by the ball is 1.12 m, calculate the extension of the elastic cord. Explain your working. [3]

(b) Hence, determine the length of the unstretched cord. [1]

(c) Sketch, on Figure 1.2, the variation with displacement of the kinetic energy *K*, gravitational potential energy *G* and the elastic potential energy *E* when the mass moves from the ground to maximum height. Label your graphs clearly and indicate on the scale with values from parts (a) and (b). [4]

Figure 1.2

(d) The ball, still attached with the elastic cord, is now being swirled into a vertical circle shown in Figure 1.3.

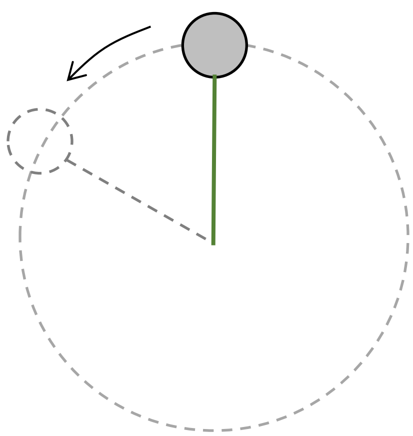


Figure 1.3

Discuss whether any work is done by the tension, in the cord, acting on the ball. [2]

2. A parallel sound beam is emitted from a source perpendicularly towards a wall 15 cm away.

(a) Explain why a stationary wave will be formed between the source and the wall. [2]

(b) The source can be considered to be a node. There are only two more nodes between the source and the wall.

Draw in the space below a diagram representing the stationary wave. Include the source and the wall in your diagram. [1]

(c) The speed of sound is 360 m s^{-1}. Calculate the frequency of the sound. [2]

(d) The location of the node nearest (but not at) the source is marked as ‘X’. The source is then replaced with a point source that emits sound uniformly in all directions.

(i) When the sound wave travels directly from the point source to location X, it has an amplitude of 3.0×10^{-5} m. Calculate the amplitude of the wave after it has been reflected by the wall and travels back to location X. Assume that no energy is lost when the wave is reflected by the wall. [3]

(ii) Calculate the amplitude of the resultant sound wave at location X due to the interference of the wave that comes directly from the point source, and the wave that is reflected by the wall. Explain your reasoning. [2]

3(a) State what is meant by electric field strength. [2]

(b) Two point charges A and B are situated a distance 15 cm apart in a vacuum, as illustrated in Fig. 3.1.

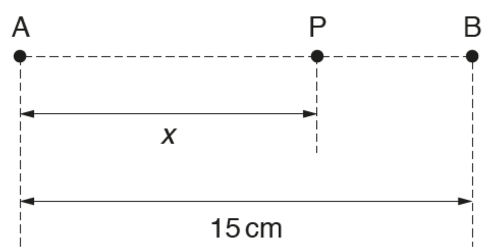


Fig. 3.1

Point P lies on the line joining the charges and is a distance x from charge A. The variation with distance x of the electric field strength E at point P is shown in Fig. 3.2.

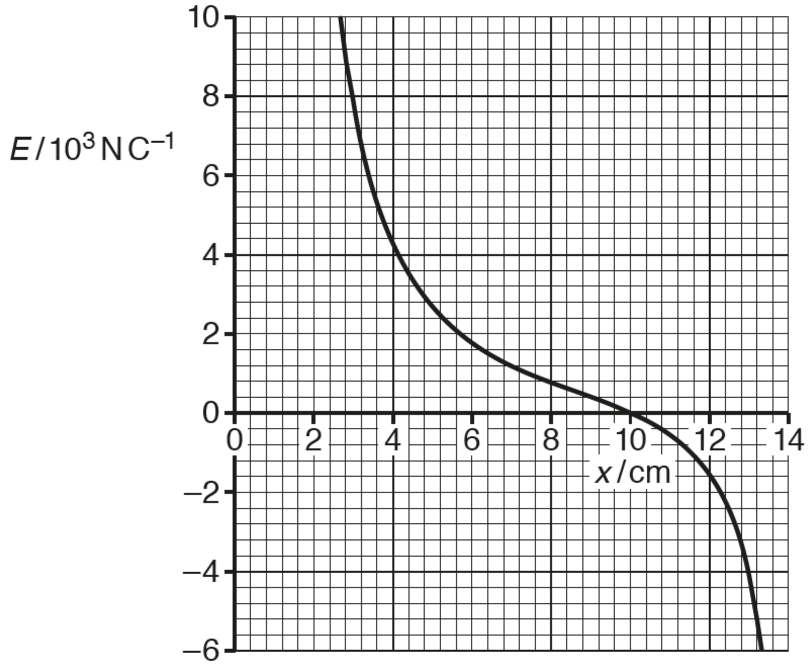


Fig. 3.2

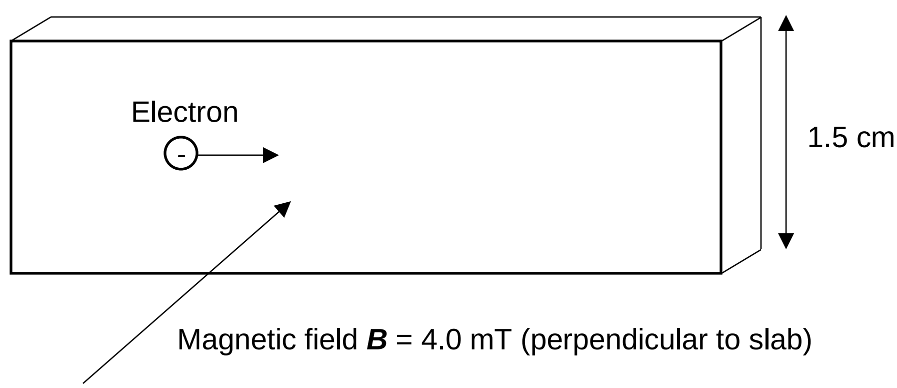
(i) By reference to the direction of the electric field, state and explain whether the charges A and B have the same, or opposite, signs. [2]

(ii) State why, although charge A is a point charge, the electric field strength between x = 3.0 cm and x = 7.0 cm does not obey an inverse-square law. [1]

(iii) A proton is at point P where x = 6.0 cm. Use data from Fig. 3.2 to determine the magnitude of the acceleration of the proton. [3]

(iv) Use Fig. 3.2 to determine the ratio of the magnitude of charge A to the magnitude of charge B. [3]

4. An electric current consisting of electrons flowing horizontally from left to right through a thin slab of conductor of width 1.5 cm. The slab of conductor is immersed in a uniform magnetic field ***B*** of 4.0 mT, which is applied perpendicularly to the slab of conductor, as shown in the diagram below:



(a) The speed of the electrons is 0.60 mm s^{-1}. Calculate the magnetic force acting on each electron. [2]

(b) Because of the magnetic force, the electrons accumulate on one side of the conductor. Indicate on the diagram above, where the electrons will accumulate. [1]

(c) A vertical electric field is created across the slab as a result of the accumulation of electrons.

(i) Draw on the diagram above an arrow to represent the electric field. Label it as ***E***. [1]

(ii) As more and more electrons accumulate, the electric field gets stronger and stronger. The rate of electron accumulation decreases. Eventually, further electrons do not accumulate anymore, but continue to travel horizontally.

1. Explain why the rate of accumulation of electrons decreases, and why eventually further electrons do not accumulate anymore. [3]

2. Calculate the potential difference across the horizontall sides of the slab of conductor when the accumulation of electrons stops. [3]

5. When light illuminates a clean surface of potassium, electrons can be emitted. This is the photoelectric effect. Fig 5.1 shows a section of the surface at a microscopic scale.

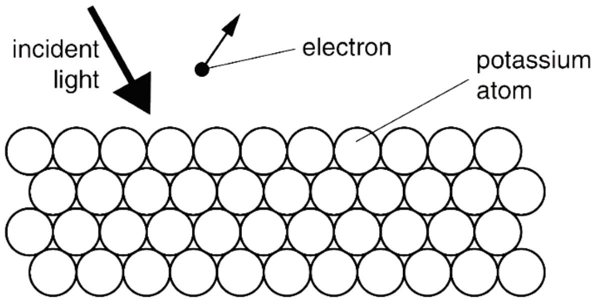


Fig 5.1

(a) Electrons are emitted when the incident light is violet, but not when the incident light is red. Increasing the intensity of violet light causes more electrons to be emitted. Increasing the intensity of red light has no effect.

Use the quantum theory of light to explain these observations. [4]

(b) Einstein explained the photoelectric effect by suggesting that there is a minimum energy ϕ, the work function, which must be supplied to remove an electron from the surface of a metal.

The work function for potassium is 4.5×10^{-19} J.

Show that photons of frequency less than 6.8×10^{14} Hz cannot remove electrons from a potassium surface. [2]

(c) The variation with frequency f of the maximum kinetic energy E_k of the emitted electrons is shown in Fig. 5.2

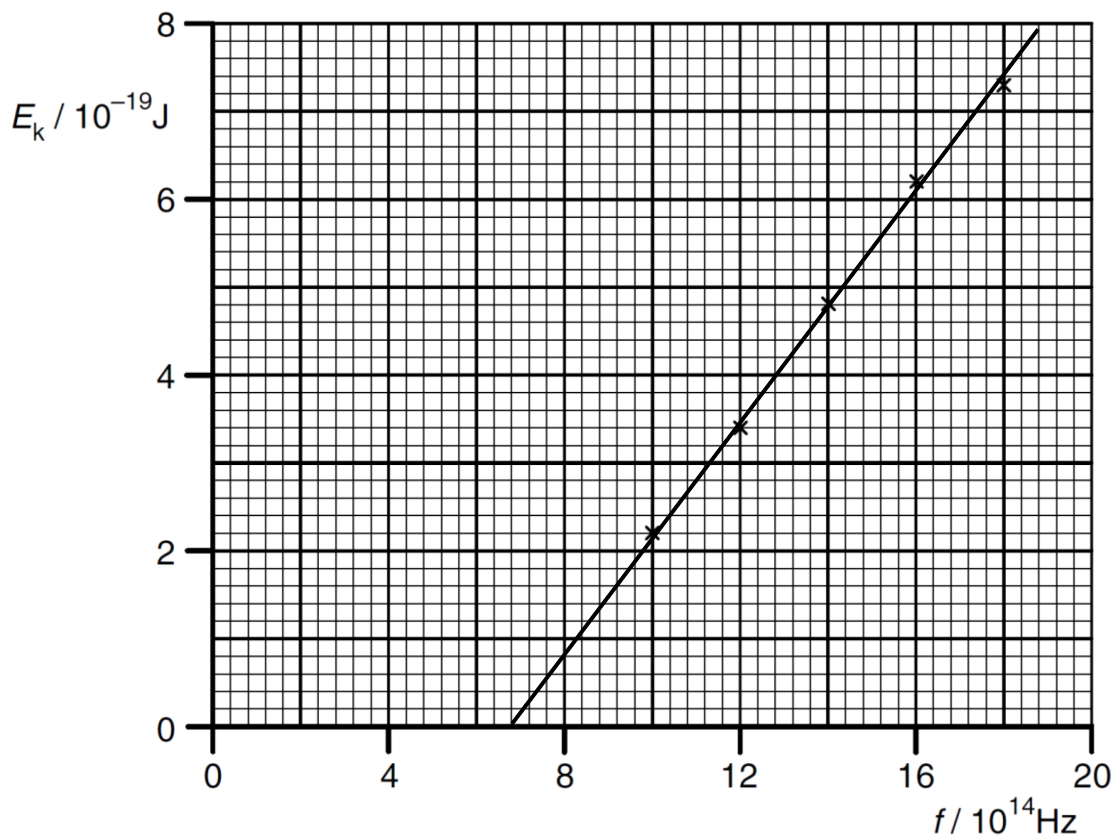


Fig. 5.2

(i) Explain the shape of the graph in Fig.5.2. [2]

(ii) Use Fig. 5.2 to determine a value for the Planck constant. [2]

6(a) Define binding energy. [1]

(b) A minimum energy *Q* is required to remove a neutron from a helium-4 nuclide to form a helium-3 nuclide. The following data is given:

Binding energy per nucleon of helium-4 nuclide = 6.8465 MeV
Binding energy per nucleon of helium-3 nuclide = 2.2666 MeV
Mass of neutron = 1.0097 u
1u = 931.494 MeV

(i) Write the nuclear equation for this reaction. [1]

(ii) Calculate *Q*. [3]

(iii) Hence, calculate the difference in mass between the helium-3 and helium-4 nuclides. [3]

(iv) With reference to the above process, explain why the mass difference is less than the mass of a neutron. [1]

Section B

Answer **one** question from this section in the spaces provided.

7(a) State *Newton's law of gravitation*. [2]

(b) A satellite of mass m is to be placed into orbit round the Earth at a vertical distance of 350 km above the Earth's surface.
(mass of Earth = 6.0×10^{24} kg, radius of Earth = 6.4×10^{6} m)

(i) Calculate the magnitude of the gravitational field strength at a point P, 350 km above the Earth's surface and state its direction. [3]

(ii) Calculate, using the answer in (b)(i), the time taken for the satellite to complete one orbit round the Earth. [2]

(c)(i) Define gravitational potential at a point in a gravitational field. [1]

(ii) Explain why gravitational potential is always negative. [2]

(iii) Fig. 7 below shows the variation of potential between the surface of the Moon and the surface of Earth along the line joining their centres.

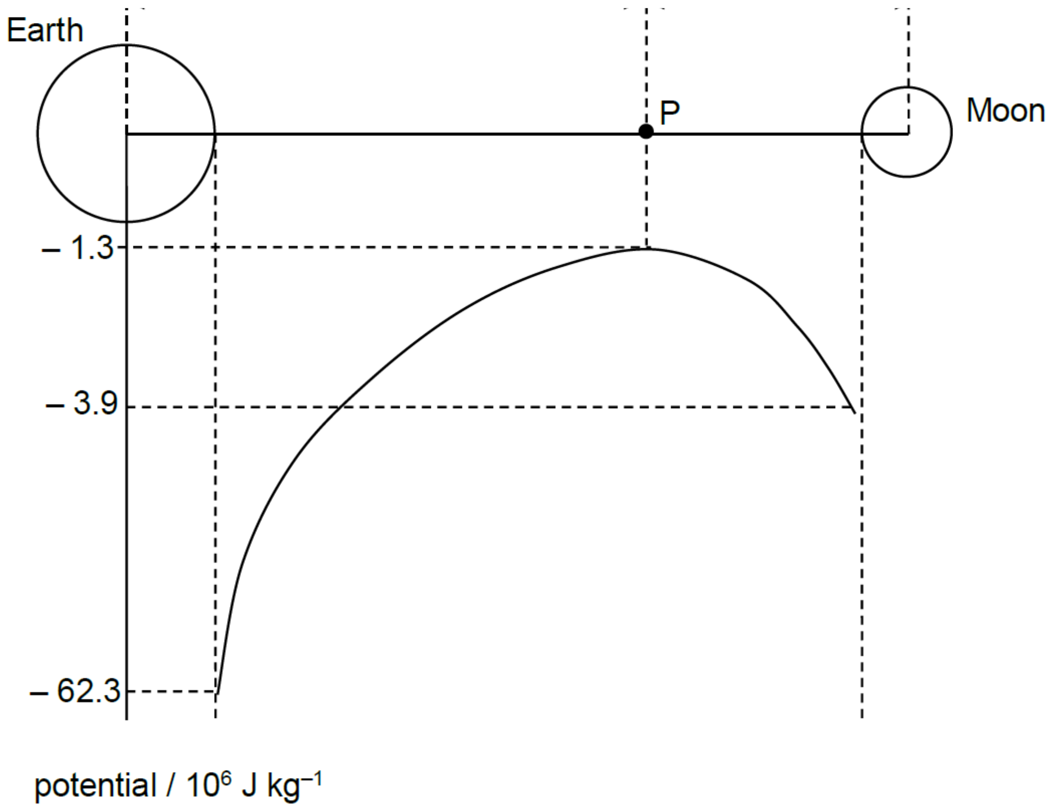


Fig. 7

Explain why the gradient of the potential graph near the surface of the Earth and that near the surface of the Moon have *opposite* signs. [3]

(iv) Using the values in Fig. 7, determine the *minimum* speed that a spacecraft of mass *m* needs to be propelled from the surface of the Moon if it is to reach the surface of the Earth. [3]

(d)(i) Data for a certain planet are given below:

Mass of planet = 1.20×10^{24} kg
Diameter of planet = 7.50×10^{6} m

Calculate the escape velocity of a mass on this planet. Explain your working. [3]

(ii) An atmosphere is formed when gases such as nitrogen is allowed to orbit around the planet. Given that the average speed of a molecule of nitrogen at the surface of the planet is 3.9×10^{4} m s^{-1}, explain whether this planet has an atmosphere. [1]

8(a) The filament of a 230 V light bulb is 0.72 m long and has a radius of 6.0×10^{-2} mm. The resistivity of the filament metal is $1.2 \times 10^{-5}\ \Omega$ m.

(i) Calculate the resistance of the filament of the light bulb. [2]

(ii) Calculate the power supplied by the 230 V supply. [2]

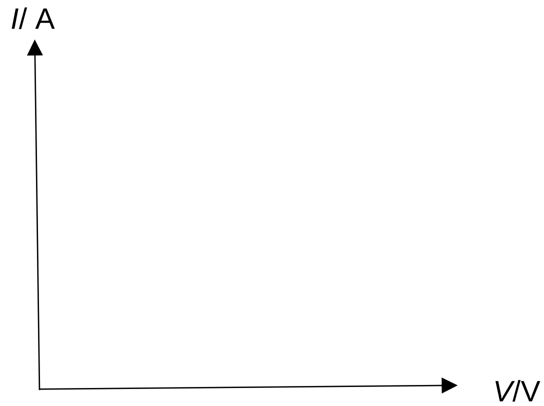
(iii) The filament of the bulb becomes thinner over time. Suggest why this happens. [1]

(iv) Explain the effect the thinning of the filament wire will have on:

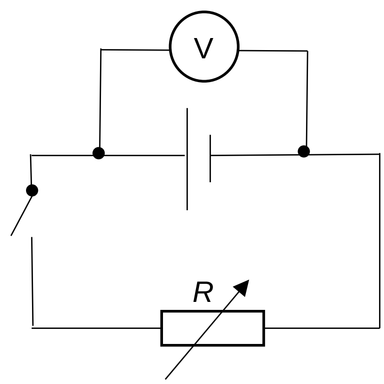
1. the resistance of the filament, [2]

2. its power output. [1]

(v) On the same graph, sketch the current-voltage characteristics for a filament lamp and an ohmic device. [2]



(b) The following circuit is set up, with an ideal voltmeter connected across the terminals of a dry-cell battery. The battery is connected to a variable resistor *R*.



(i) Initially the switch is open and the voltmeter reads 2.10 V.

1. Determine the e.m.f. of the battery. [1]

2. State the energy supplied by the battery for every coulomb of charge delivered by the battery. [1]

3. With the switch open, explain whether any energy is being generated in the battery if the voltmeter is ideal. [2]

(ii) The variable resistance R is set to 10 Ω. When the switch is closed, the voltmeter reading drops to 2.00 V. Deduce a value for the internal resistance of the battery. [3]

(iii) The efficiency of the dry-cell battery is defined as the ratio of energy dissipated in variable resistor R over the energy dissipated in the complete circuit. Explain how the efficiency of cell will change when R increases. [3]

End of paper