Name: ______________________________ Class: ______________

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2021

PHYSICS **9749/02**

Higher 2 **14 September 2021**

Paper 2 Structured Questions **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.

Answer **all** questions.

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	/ 12
2	/ 10
3	/ 10
4	/ 12
5	/ 8
6	/ 8
7	/ 20
Total	/ 80

Data

speed of light in free space	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ 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 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}

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	$\phi = -\frac{GM}{r}$
temperature	$T\ /\ \text{K} = T\ /\ {}^\circ\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$
	$= \pm\omega\sqrt{x_0{}^2 - x^2}$
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	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a 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	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** questions in the spaces provided

1 An object of mass 350 g is released from rest at a height of 50 cm on a frictionless incline as shown in Fig. 1.1. The incline makes an angle of 30° to the horizontal. It is placed on a table of height 2.0 m above the smooth ground. The table is fixed to the ground.

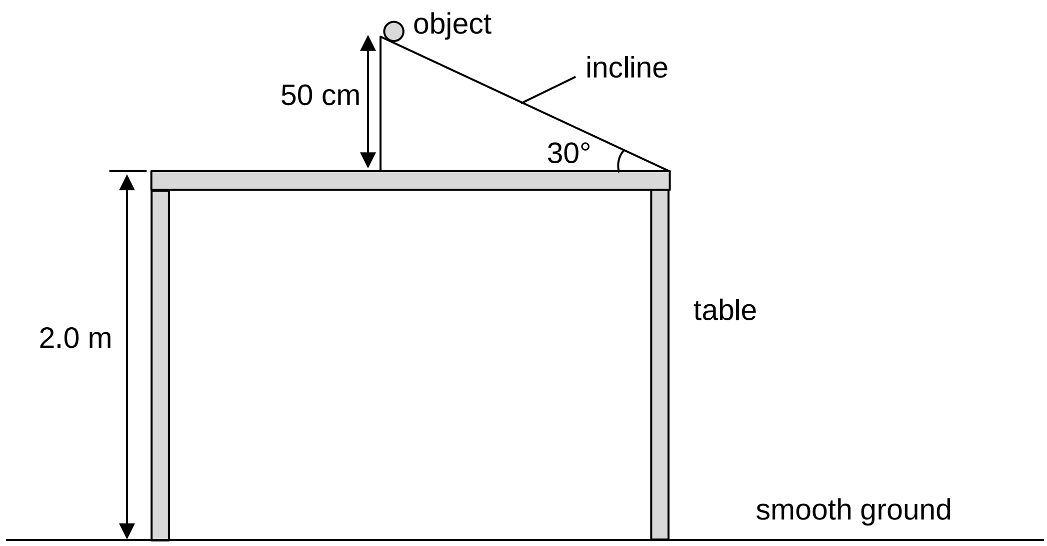

Fig. 1.1

(a) Show that the acceleration of the object is 4.9 m s^{-2} as it slides down the incline.

[1]

(b) Determine the speed of the object as it leaves the incline.

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

(c) The object lands on the ground after falling off the incline.

Calculate the horizontal distance of the object from the edge of the table.

distance = ... m [3]

(d) A small trolley of mass 1.2 kg is moving to the left at a speed of 4.0 m s^{-1} along the smooth ground. The object is released again from the same height on the incline. It lands in the trolley and they move off together horizontally.

(i) Explain whether momentum of the system of object and trolley is conserved in the horizontal direction.

....

....

....

.... [2]

(ii) Hence, calculate the final velocity of the trolley and object.

magnitude of velocity = ... m s^{-1}

direction = ... [3]

2 **(a)** The pressure p of an ideal gas of density ρ is related to the mean square speed $< c^2 >$ of its molecules by the expression

$$p = \frac{1}{3}\rho < c^2 > .$$

Show that the average kinetic energy of a molecule of an ideal gas is proportional to the thermodynamic temperature T.

[3]

(b) A scuba tank for a diver has a volume of 9.4×10^3 cm^3 and when the tank is filled, the air has a pressure of 2.32×10^7 Pa at a temperature of 24 °C. The diver is swimming in water of density 1.03×10^3 kg m^{-3} and temperature 24 °C at a depth of 15 m. When the diver breathes in, the pressure of the air delivered from the tank to the diver is always equal to the pressure of the surrounding water.

Atmospheric pressure is 1.01×10^5 Pa. Air may be considered as an ideal gas.

Calculate, for the depth of 15 m,

(i) the total pressure on the diver,

total pressure = ... Pa [2]

(ii) the volume of air available at this pressure from the tank.

volume = ... cm^3 [2]

(c) The supply of air in **(b)** is sufficient for the diver to remain at a depth of 15 m for 45 minutes.

Assuming that the diver always breathes at the same rate regardless of the pressure, determine how long the air in the tank will last for the diver at a depth of 35 m and a water temperature of 19 °C.

time = ... min [3]

3 Fig. 3.1 shows a pair of identical loudspeakers A and B placed 2.0 m apart and emitting coherent sound waves of frequency 470 Hz. An observer walks from X to Y. The perpendicular distance between the sources and XY is 12 m. As he walks, he hears a sound of maximum intensity at P, followed by minimum intensity at Q and the next maximum intensity at R. P is equidistant from A and B. R is 4.5 m away from P.

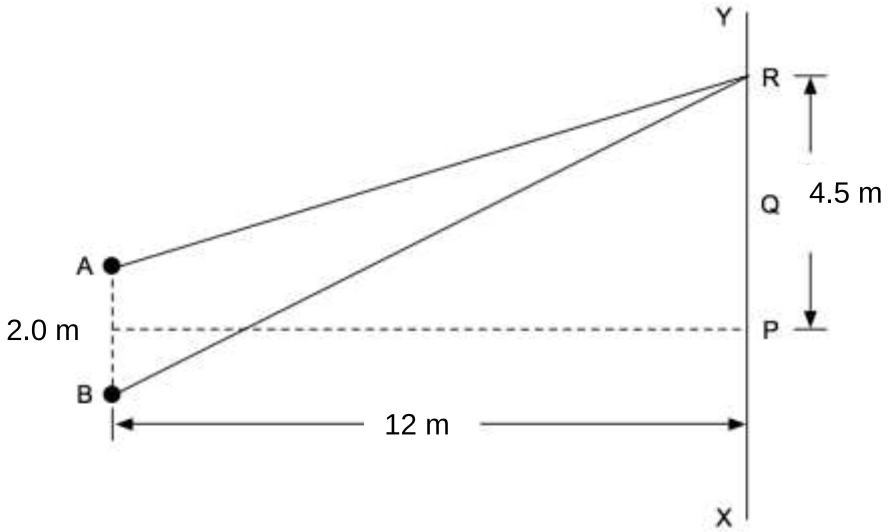

Fig. 3.1

(a) Explain how minimum intensity of sound is formed along the line XY.

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

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

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

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

(b) **(i)** Show that BR is 13.2 m.

[1]

(ii) AR is 12.5 m.

Determine the wavelength of the sound.

wavelength = ... m [2]

(iii) Determine the speed of the sound.

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

(c) The sound reaching Q from A alone has intensity I and that from B alone has intensity $\frac{I}{3}$.

Determine the intensity at Q in terms of I.

intensity = ... I [3]

4 (a) A car headlamp is marked 12 V, 36 W. It is switched on for a 20 minute journey.

Calculate

(i) the current in the lamp,

current = ... A [2]

(ii) the charge which passes through the lamp during the journey,

charge = ... C [2]

(iii) the energy dissipated by the lamp during the journey ,

energy dissipated = ... J [1]

(iv) the resistance of the lamp.

resistance = ... Ω [1]

(b) Three of the headlamps in **(a)** are connected to a battery of e.m.f. 12 V and negligible internal resistance as shown in Fig. 4.1.

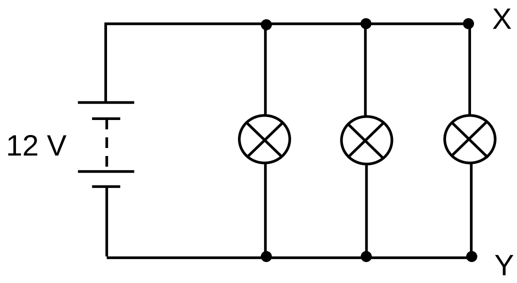

Fig. 4.1

(i) Determine the current provided by the battery.

current = ... A [2]

(ii) Another identical headlamp is connected across points X and Y in the circuit.

1. Describe and explain any change to the brightness of the three headlamps in Fig. 4.1.

....

....

....

.... [2]

2. The battery is replaced by another of the same e.m.f. but with an internal resistance of 1.0 Ω.

State and explain any change to your answer in **part 1**.

....

....

....

.... [2]

5 Fig. 5.1 shows a 1.6 m long solenoid with 400 turns and a cross-sectional diameter of 0.040 m. A coil Y, with 80 turns, is wound tightly around the centre region of the solenoid.

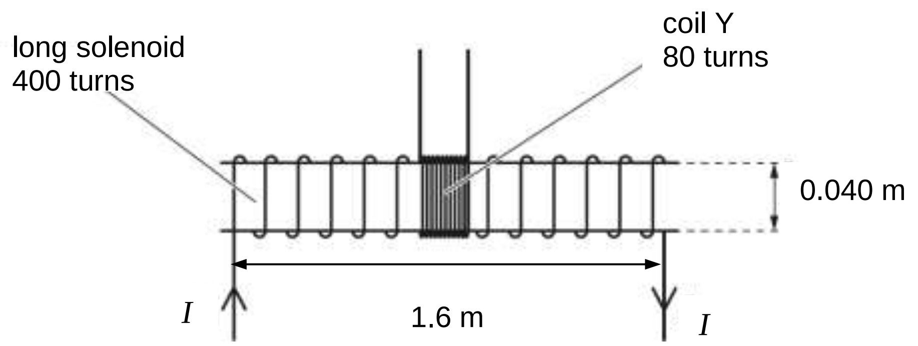

Fig. 5.1

(a) Show that, for a current I of 3.8 A in the solenoid, the magnetic flux linkage of coil Y is 1.2×10^{-4} Wb.

[2]

(b) The current I in the solenoid in **(a)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil Y.

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

(c) The current I in the solenoid varies with time t as shown in Fig. 5.2.

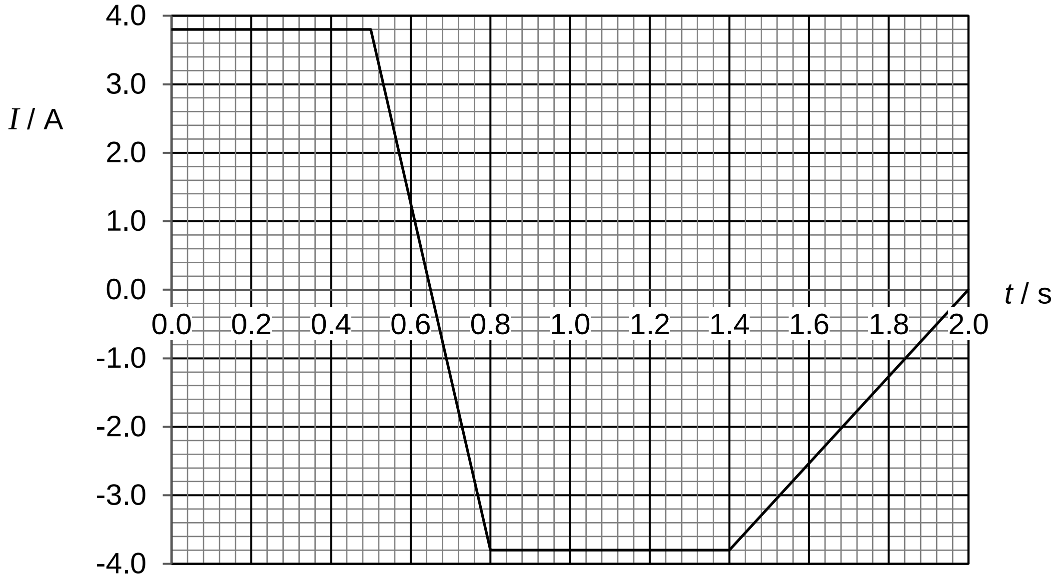

Fig. 5.2

Use your answer to **(b)** to sketch, on Fig. 5.3, the variation with time t of the e.m.f. E induced in coil Y for time t = 0 to time t = 2.0 s.

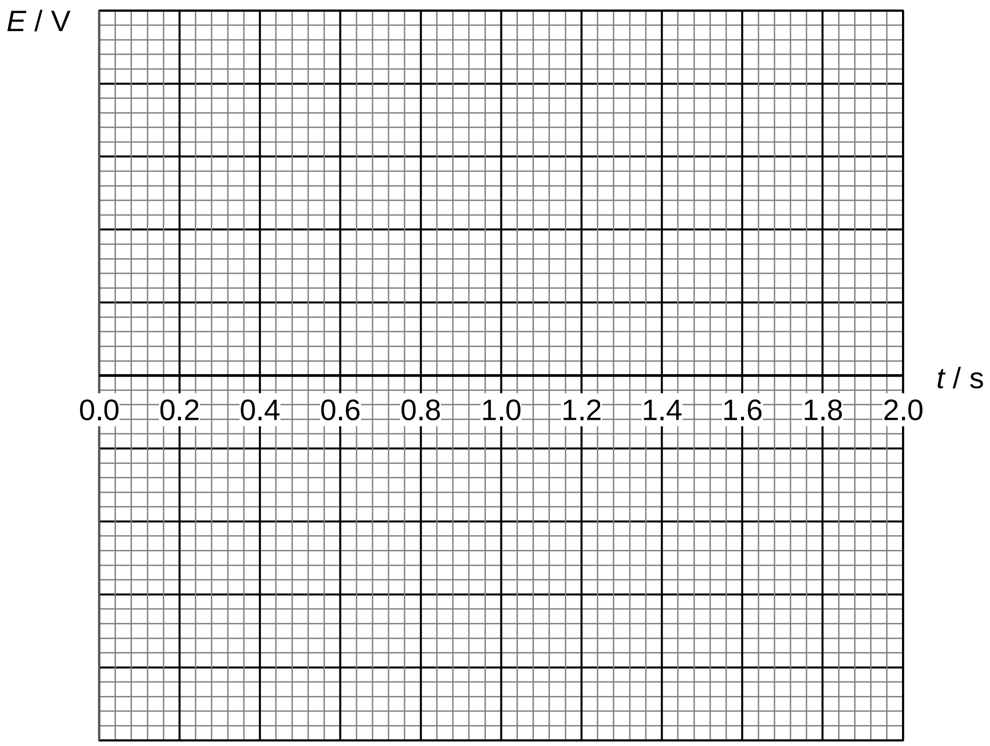

Fig. 5.3

[3]

(d) State and explain the effect on your answer in **(b)** if there is now an iron core placed in the solenoid.

....

....

.... [1]

6 **(a)** By reference to the photoelectric effect, explain

(i) why the existence of a very short emission time provide evidence for the particulate nature of electromagnetic radiation, as opposed to wave theory,

....

....

....

....

.... [2]

(ii) what is meant by the *work function* of a surface,

....

.... [1]

(iii) why, even when the incident light is monochromatic, the emitted electrons have a range of kinetic energy up to a maximum value.

....

....

....

....

.... [2]

(b) Two beams of monochromatic light have similar intensities. The light in one beam has wavelength 350 nm and the light in the other beam has wavelength 700 nm.

The two beams are incident separately on three different metal surfaces. The work function of each of these surfaces is shown in Fig. 6.1.

metal	work function/ eV
tungsten	4.5
magnesium	3.8
potassium	2.3

Fig. 6.1

State which combination, if any, of monochromatic light and metal surface could give rise to photoelectric emission. Give a quantitative explanation of your answer.

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

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

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

7 Read the passage below and answer the questions that follow.

Solar Power in Singapore

Singapore has set a target for solar energy which aims to produce enough power by 2030 to meet the annual needs of 350 000 households. The present total installed capacity is 400 MWp (mega-watt-peak is the power output of a solar power system which would be achieved under ideal conditions). This is a tiny fraction of the country's total power output of 12 600 MW produced by power stations with an overall efficiency of 27%. The power stations use natural gas as a fuel that has an energy density of 56 MJ kg^{-1}.

Solar photovoltaic (PV) panels consist of a number of cells composed of semiconducting materials that convert sunlight into electricity through what is known as the photovoltaic effect. The constraints to Singapore's ability to host a substantial solar photovoltaic capacity arise from limited availability of two natural resources - sunlight and space.

Although Singapore's climate is relatively hot and the weather is usually sunny, the average intensity of solar radiation across a full year is significantly less than that in northern China, and in the deserts of North Africa, the Middle East and Australia. The average solar intensity in Singapore is 780 W m^{-2}. The average monthly sunshine hours in Singapore in 2020 is shown in Fig. 7.1.

month	total sunshine hours / h
January	170
February	185
March	195
April	175
May	180
June	180
July	190
August	180
September	155
October	155
November	130
December	135

Fig. 7.1 (Source: Meteorological Service Singapore)

Space is the second key constraint. Singapore lacks vast open spaces to build solar arrays. Today, about one third of the country's solar energy capacity sits on the rooves of residential buildings. A detailed analysis produced by a consortium led by the Solar Energy Research Institute of Singapore (SERIS) concluded that the total usable space for solar PV panels amounted to just 37 km^2, out of the total land area of 728 km^2 in Singapore.

The maximum efficiency of commercially available PV cells currently is 20 %. The life span of well-maintained solar panels is 25 years. This compares to 40 years for a gas-fired power station. The panels will then need to be replaced and the materials recycled.

(a) **(i)** Use the unit MJ kg^{-1} to deduce what is meant by *energy density*.

....

.... [1]

(ii) Determine the rate of consumption of natural gas in the power stations.

rate = ... kg s^{-1} [2]

(b) The radiant power of the Sun is 3.90×10^{26} W. The average radius of the Earth's orbit about the Sun is 1.50×10^{11} m.

(i) Calculate the solar intensity incident on Earth.

intensity = ... W m^{-2} [2]

(ii) State an assumption you have made in **(b)(i)**.

....

.... [1]

(iii) Suggest two reasons for the difference between the average solar intensity in Singapore and your answer in **(b)(i)**.

1. ....

....

2. ....

.... [2]

(c) The symbol for a PV cell is shown in Fig. 7.2.

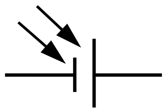

Fig. 7.2

To provide a useful supply, many identical PV cells are connected in a series and parallel array, as shown in Fig. 7.3.

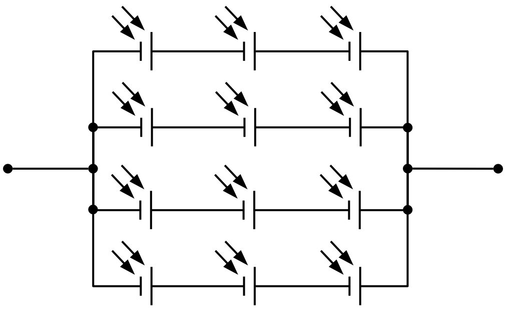

Fig. 7.3

Explain

(i) one advantage of connecting the cells in series,

....

.... [1]

(ii) two advantages of connecting the cells in parallel.

1. ....

....

2. ....

.... [2]

(d) Use appropriate values from the passage to determine the ratio

$$\frac{\text{solar power output from 37 km}^2\text{ of PV panels}}{\text{total power output from power stations}}$$

ratio = ... [2]

(e) A PV panel of area 1.50 m^2 is installed to produce solar power for a household in Singapore. The average monthly household electricity consumption is 480 kWh.

The electricity tariff is $0.23 per kWh.

(i) Calculate

1. the solar power produced by the PV panel,

power = ... W [2]

2. the electrical energy produced by the PV panel in 2020.

energy = ... kWh [2]

(ii) The cost of installing a PV panel is $750.

Using appropriate values from the passage and your answer in **(e)(i)**, write an argument for or against the use of solar power. You should show calculations with clear working in support of your argument.

....

....

....

....

.... [3]

End of paper