EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2020
General Certificate of Education Advanced Level
Higher 3

CANDIDATE NAME	

CIVICS GROUP	1	9	-			REGISTRATION NUMBER			

PHYSICS 9814/01

Paper 1

21 September 2020

3 hours

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

READ THESE INSTRUCTIONS FIRST

Write your name, civics group and registration number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid.

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

Section A
Answer **all** questions.
You are advised to spend about 1 hour and 50 minutes on Section A.

Section B
Answer **two** questions only.
You are advised to spend about 35 minutes on each question in 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	
Section A	
1	7
2	11
3	9
4	4
5	10
6	19
Section B	
7	20
8	20
9	20
s.f.	
c.f.	
Total	100

This document consists of **37** printed pages and **3** blank page.

Data

speed of light in free space,	c	=	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o	=	8.85×10^{-12} F m^{-1}
			$(1/(36\,\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e	=	1.60×10^{-19} C
the Planck constant,	h	=	6.63×10^{-34} J s
unified atomic mass constant,	u	=	1.66×10^{-27} kg
rest mass of electron,	m_e	=	9.11×10^{-31} kg
rest mass of proton,	m_p	=	1.67×10^{-27} kg
molar gas constant,	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k	=	1.38×10^{-23} J K^{-1}
gravitational constant,	G	=	6.67×10^{-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	=	$u^2 + 2as$
moment of inertia of rod through one end	I	=	$\frac{1}{3}ML^2$
moment of inertia of hollow cylinder through axis	I	=	$\frac{1}{2}M(r_1^2 + r_2^2)$
moment of inertia of solid sphere through centre	I	=	$\frac{2}{5}MR^2$
moment of inertia of hollow sphere through centre	I	=	$\frac{2}{3}MR^2$
work done on/by a gas,	W	=	$p\,\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-\frac{Gm}{r}$
Kepler's third law of planetary motion	T^2	=	$\frac{4\pi^2 a^3}{GM}$
temperature,	T/K	=	$T/°C + 273.15$
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	=	$x_o \sin \omega t$
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,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
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	$= \frac{1}{2}CV^2$
electric potential,	V	$= \frac{Q}{4\pi\varepsilon_o r}$
electric field strength due to a long straight wire	E	$= \frac{\lambda}{2\pi\varepsilon_o r}$
electric field strength due to a large sheet	E	$= \frac{\sigma}{2\varepsilon_o}$
alternating current/voltage,	x	$= x_o \sin \omega t$
magnetic flux density due to a long straight wire	B	$= \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	$= \frac{\mu_o N I}{2r}$
magnetic flux density due to a long solenoid	B	$= \mu_o n I$
energy in an inductor	U	$= \frac{1}{2}LI^2$
RL series circuits	τ	$= \frac{L}{R}$
RLC series circuits (underdamped)	ω	$= \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$
radioactive decay,	x	$= x_o \exp(-\lambda t)$
decay constant	λ	$= \frac{\ln 2}{t_{\frac{1}{2}}}$

Please turn over for Question 1

Section A

Answer **all** questions in this section.

You are advised to spend about 1 hour 50 minutes on this section.

1 Fig. 1.1 shows the radar screen on battleship A. Battleship A is always at the origin of the radar screen and the concentric rings represent distances of 10 km, 20 km and 30 km from the battleship A. At 12 p.m., another battleship B is detected on the screen at position B_1 with a bearing of 060° from battleship A. At 1 p.m., battleship B is found to be at B_2 with a bearing of 100° from battleship A.

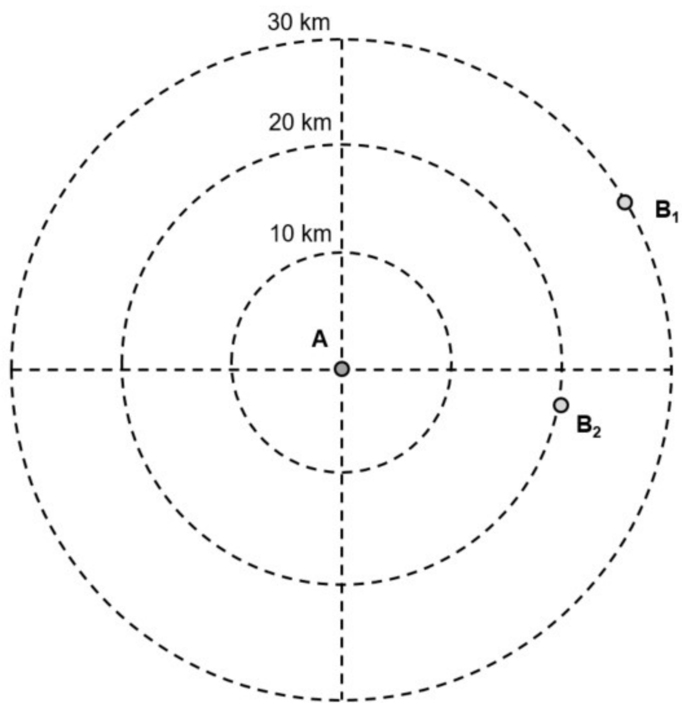


Fig. 1.1

Assuming that both ships are travelling with the constant velocities, determine

(a) the speed of battleship B relative to the battleship A.

speed = ……………………… m s^{-1} [2]

(b) the time (to nearest minutes) when both battleships are closest to one another.

time = ..……… : ………. p.m. [3]

(c) The bearings and the speed in which a torpedo should be fired relative to battleship A at 1 pm for it to hit battleship B at the time in **(b)**.

bearing = ………………… ° [1]

speed = ………………… m s^{-1} [1]

[Total: 7]

2 **(a)** **(i)** Show from first principles, that the moment of inertia of a uniform solid sphere with radius R through its centre is given by

$$I_{CM} = \frac{2}{5}MR^2$$

[3]

(ii) A solid sphere of mass *M* and radius *R* is being attached to a massless string of length *L* and hung at a pivot P as shown in Fig. 2.1.

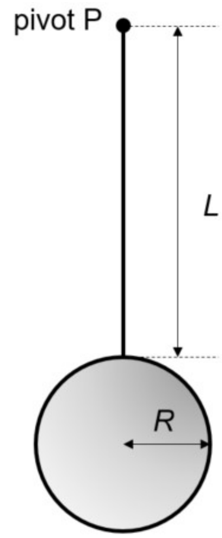


Fig. 2.1

Using your answer in **(a)(i)**, determine the moment of inertia of the solid sphere about the pivot, I.

[2]

A physical pendulum is any real pendulum, using a body of finite size, as contrasted to the idealized model of the simple pendulum with all the mass concentrated at a single point. An example of a physical pendulum is shown in Fig. 2.1.

In the equilibrium position, the centre of mass of the sphere is directly below the pivot.

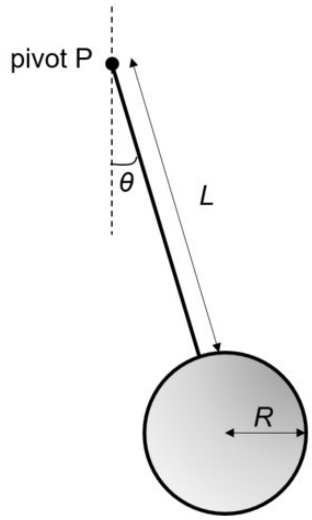


Fig. 2.2

When the physical pendulum is being displaced from the equilibrium by a small angle θ as shown in Fig. 2.2,

(b) **(i)** Write down an expression of the torque produced by the weight of the pendulum. Taking clockwise direction as negative.

[1]

(ii) Using Newton's second law for rotation, show that the angular acceleration, α of the physical pendulum can be expressed as

$$\alpha = -\frac{g(L+R)}{\left(\frac{7}{5}R^2 + L^2 + 2LR\right)}\sin\theta$$

[2]

(iii) State the condition for the oscillation to be approximately simple harmonic, hence determine the period of the oscillation if L = 1 m and R = 30 cm.

T = ………………………… s [3]

[Total: 11]

3 A very long solid insulating cylinder has a volume charge density ρ. Let r be the distance from the centre axis of the cylinder to a general point P within the cylinder.

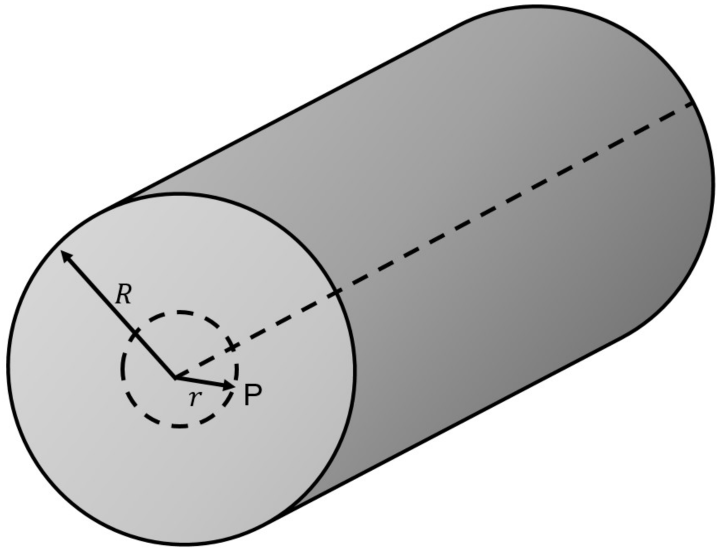


Fig. 3.1

(a) Show that, the magnitude of electric field at P is given by

$$E = \frac{\rho r}{2\varepsilon_0}$$

[1]

(b) Derive an expression for E when $r > R$ where R is the radius of the cylinder.

[2]

(c) Sketch the graph of E against r for r = 0 to $r \rightarrow \infty$. Label your graph clearly.

[2]

(d) A cylindrical hole with radius a is bored along the entire length of the cylinder. The axis of the hole is a distance b from the axis of the cylinder, where $a < b < R$ as shown in Fig. 3.2.

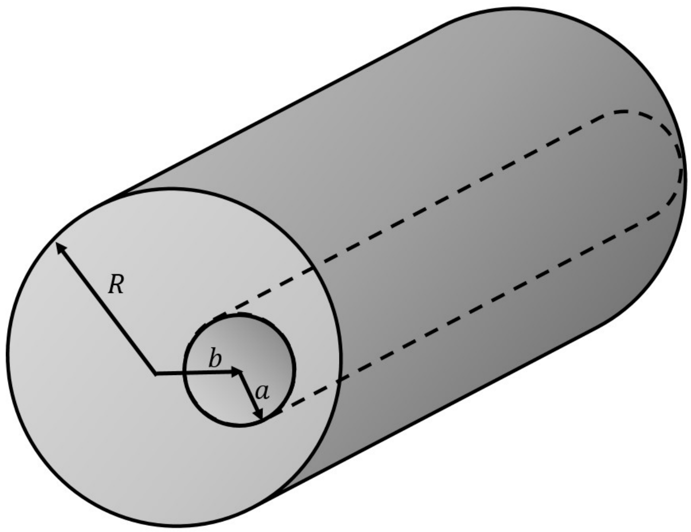


Fig. 3.2

Determine the magnitude and direction of the electric field $\vec{E}$ inside the hole.

[2]

(e) Describe and explain the value of the electric field if the hole is coaxial with the cylinder.

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

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

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

[Total: 9]

4 An inductor of inductance L is connected to a variable d.c. supply as shown in fig. 4.1.

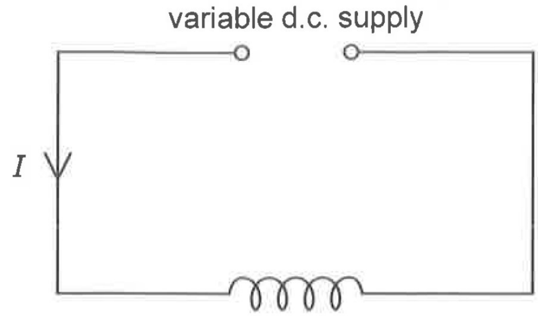


Fig. 4.1

At time $t = 0$ the current I is zero. The current is increased, for $t > 0$, until it reaches a final steady state when $I = I_f$.

By considering the change in current and the energy required to increase the current to its final value I_f, determine an expression for the total energy E_T stored in the inductor.

[4]

[Total: 4]

Please turn over for Question 5

5 **(a)** An orbiting satellite of mass *m* under the influence of the gravitational field due to the Earth of mass *M*, is at a distance *r* from the centre of Earth.

Assuming that the system consists of Earth and a satellite and the mass of Earth is many times larger than that of satellite, show that the total energy *E* of the system is given by

$$E = \frac{1}{2}mv_r^2 + \frac{L^2}{2mr^2} - \frac{GMm}{r}$$

where *L* is the angular momentum of the satellite,
v_r is the radial velocity of the satellite.

[2]

(b) Fig 5.1 is a typical elliptical orbit of a satellite of mass *m* around the Earth of mass *M*. Assume the mass of Earth is many times larger than that of satellite.

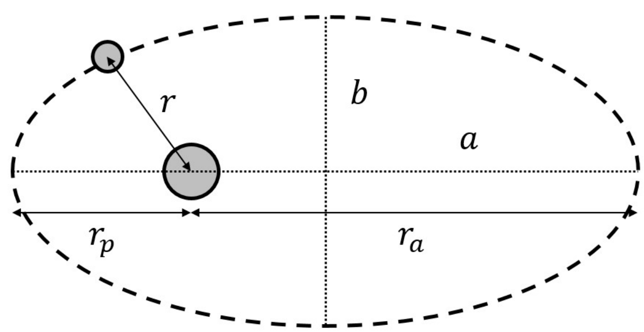


Fig 5.1

The turning points r_p and r_a are the distances of closest approach and furthest recession from the centre of Earth.

(i) State *Kepler's First Law*

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

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

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

(ii) When the satellite is at either turning points r_p and r_a , the equation in **(a)** can be written in the form as $r^2 + Ar + B = 0$.

Express the constants *A* and *B* in terms of *G*, *r* , *M*, *m*, *E* and *L*.

where *M* is the mass of Earth,
m is the mass of the satellite,
G is the universal gravitational constant,
r is the distance between the satellite and the centre of Earth,
E is the total energy of the satellite and Earth system,
and *L* is the angular momentum of the satellite.

[3]

(iii) Hence, calculate the total energy E of the system.

where mass of satellite = 10.0 kg,
mass of Earth = 5.97×10^{24} kg,
distances of closest approach $r_p = 25.0 \times 10^6$ m,
distances of furthest recession $r_a = 35.0 \times 10^6$ m.

total energy E = ………………………….. J [4]

[Total: 10]

Please turn over for Question 6

6 Bats emit high frequency sound waves and receive reflected echoes. They use the echoes to locate their position. This process is called echolocation.

Fig. 6.1 illustrates this process.

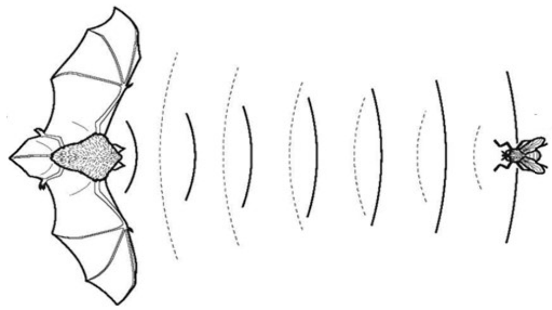


Fig. 6.1

(a) Sound waves emitted by the bat travels at 340 m s^{-1}. Their typical frequency range is 20 kHz to 80 kHz.

Calculate the range of wavelengths for this frequency range.

range of wavelength = ……………………… mm [2]

(b) Bats emit two waveforms, wave B and wave P, which superpose to form wave E.

- Wave B (shown in Fig. 6.2) gives information about the surrounding background.
- Wave P (not shown in Fig. 6.2) enables the bat to detect insect prey.
- Wave E (shown in Fig. 6.2) is the superposition of wave B and wave P.

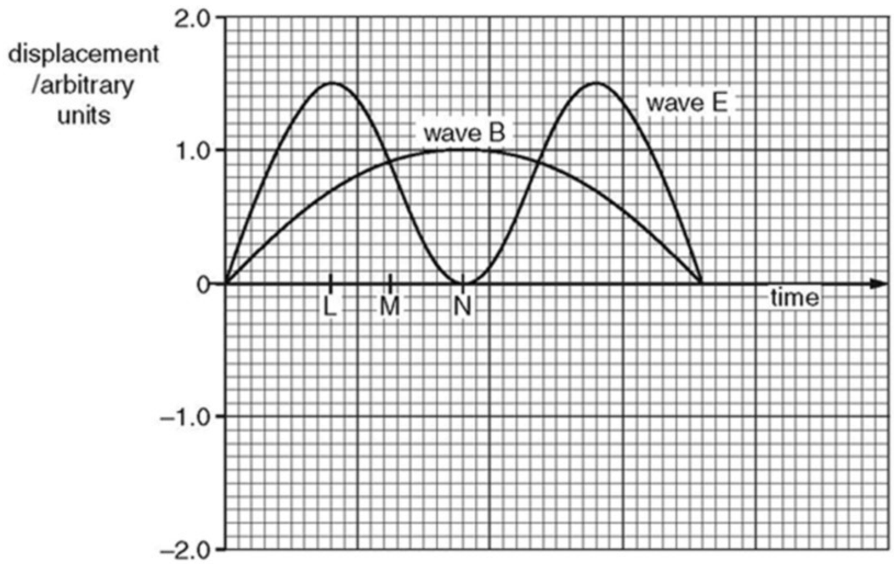


Fig. 6.2

(i) Using the principle of superposition to determine the displacement of wave P at times corresponding to points L, M and N on the time axis.

Write the displacement values in the spaces provided.

displacement of wave P at L = ... units

displacement of wave P at M = ... units

displacement of wave P at N = ... units

[2]

(ii) Hence draw the waveform for wave P on Fig. 6.2. [2]

(c) An effect known as the Doppler effect uses changes in frequency to determine speeds. The change in frequency, Δf, shown by wave P when it is reflected by an insect travelling with speed v is given approximately by the formula

$$\frac{\Delta f}{f} = \frac{2v}{c}$$

where c represents the speed, 340 m s^{-1}, of sound waves emitted by the bat and f represents the original transmitted frequency emitted by the bat.

(i) Wave P has a frequency of 50.80 kHz. Its apparent frequency after reflection is 51.25 kHz.

Calculate the speed of the insect.

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

(ii) State and explain the direction of travel of the insect relative to the bat.

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

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

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

(iii) Even though bats have evolved to account for Doppler effect, suggest an environmental factor that can make echolocation difficult for a bat.

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

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

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

(iv) Research has also shown that certain species of bats that uses higher frequencies of sound for echolocation are able to catch smaller size insects.

Explain why this is possible.

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

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

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

(d) The bat's high frequency waves are strongly attenuated in air. Fig. 6.3 shows the variation of intensity I with range in air x for the high frequency waves.

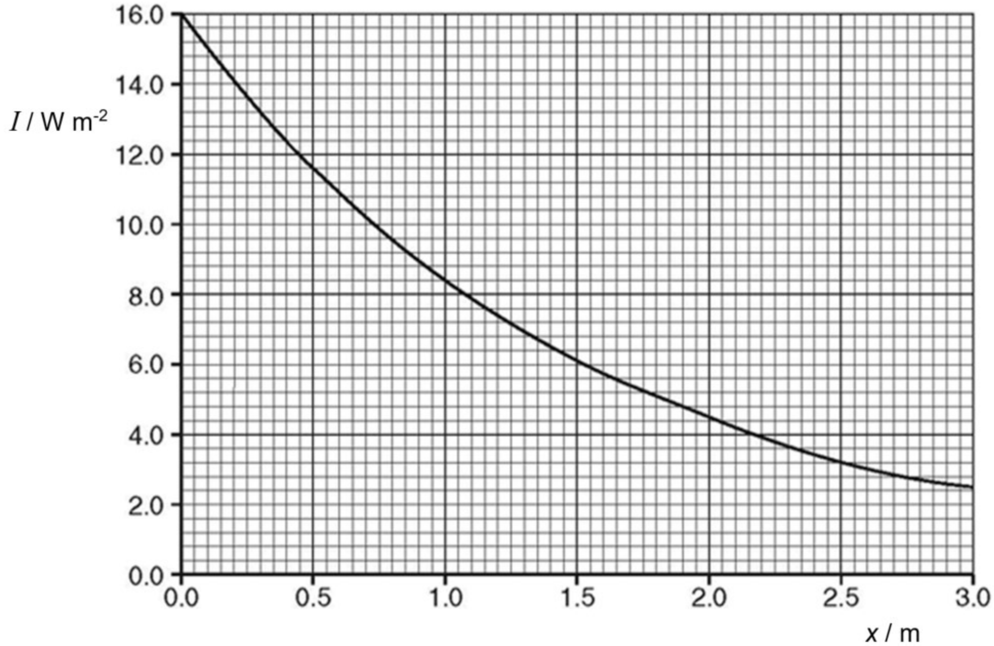


Fig. 6.3

The shape of the curve in Fig. 6.3 suggests that the decrease of the intensity I with range in air x could be exponential. In order to test this suggestion, a graph of ln I against x is plotted as shown in Fig. 6.4.

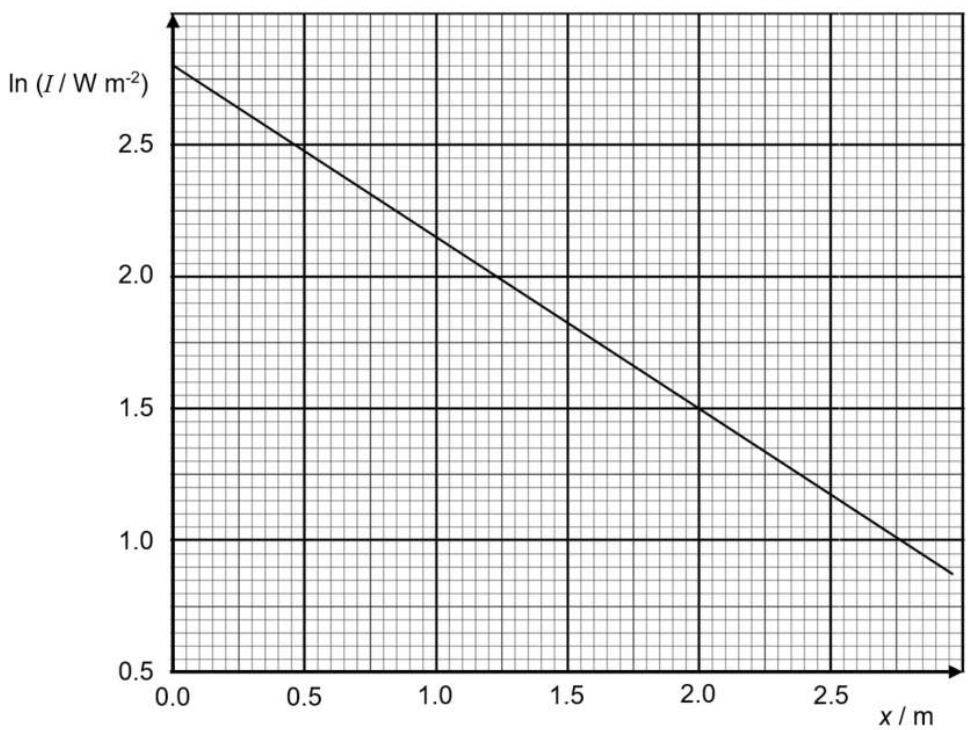


Fig. 6.4

(i) Show that Fig. 6.4 indicates a relationship of the form

$$I = I_o e^{-\alpha x}$$

where α is a constant.

[3]

(ii) The constant α is known as the attenuation coefficient.

Using Fig. 6.4, show that the value of α is about 0.7 m^{-1}. [1]

(iii) State one factor that can affect the value of α and explain how the factor mentioned affects α.

....

....

.... [2]

[Total: 19]

Section B

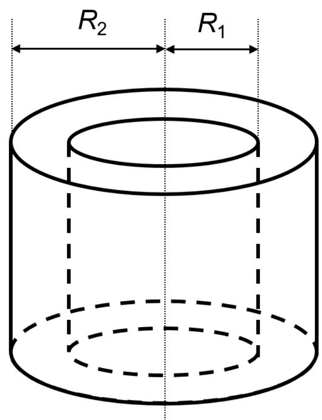
Answer **two** questions from this section.

You are advised to spend about 35 minutes on each question.

7 (a) (i) Show, from first principles, that the moment of inertia of a hollow cylinder about the central axis as shown in Fig. 7.1 is given by:

$$I = \frac{1}{2}M(R_1^2 + R_2^2)$$

where R_1 is the inner radius and R_2 is the outer radius.



central axis

Fig. 7.1

[3]

(ii) Using your result for **(a)(i)**, or otherwise, determine the moment of inertia of a solid cylinder of mass M and radius R about its central axis.

I_{solid} = ………………………………………..[1]

(b) A uniform, solid cylinder with mass M and radius $2R$ rests on a horizontal tabletop. A string is attached by a yoke to a frictionless axle through the center of the cylinder so that the cylinder can rotate about the axle. The string runs over a disk-shaped pulley with mass M and radius R that is mounted on a frictionless axle through its center. A block of mass M is suspended from the free end of the string shown in Fig. 7.2.

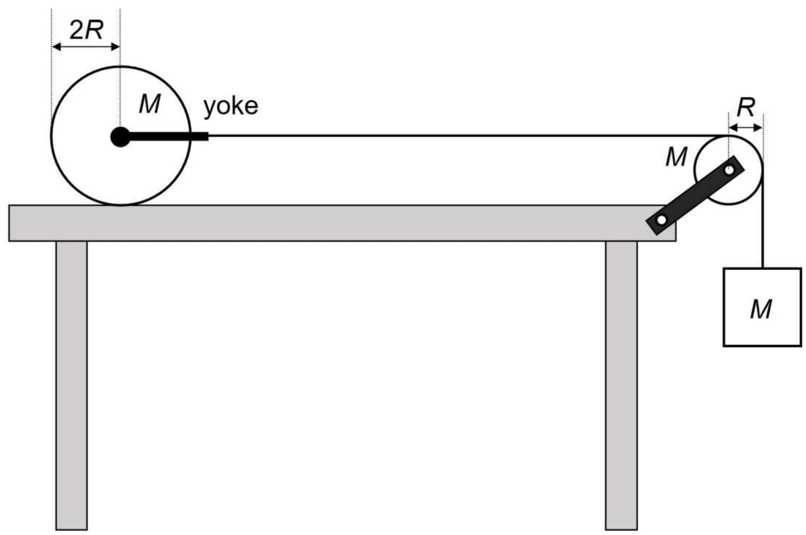


Fig. 7.2

The string does not slip over the pulley surface, and the cylinder rolls without slipping on the table top.

(i) On the diagram in Fig. 7.3, add force arrows and labels to show clearly the torque exerted on the block, cylinder and the pulley as they are set into motion. Distinguish clearly the tension in the section of the string parallel to the table top using T_1 and the tension along the vertical section suspending the block as T_2.

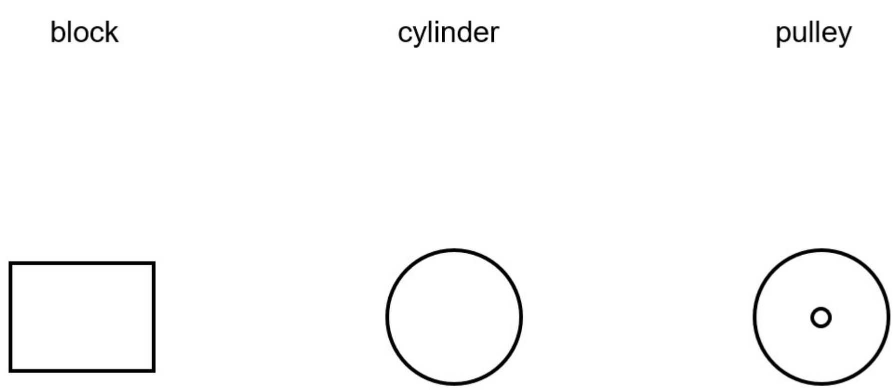


Fig. 7.3

[4]

(ii) Explain why the magnitude of the tension in the section of the string parallel to the table top, T_1 is not the same as that in the vertical section suspending the block, T_2.

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

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

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

(iii) Using the free body diagram drawn in **(b)(i)**, determine the magnitude of the acceleration of the block after the system is released from rest.

acceleration = ……………………… m s^{-2} [4]

(iv) Using conservation of energy arguments, as an alternative method, show that the acceleration of the block can be given by

$$a = \frac{g}{3}$$

[4]

(d) Predict and explain what will be the acceleration of the block if the pulley is massless and the cylinder slid without rolling. (no further calculation is expected)

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

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

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

[Total: 20]

8 A series circuit consists of a battery of negligible internal resistance and e.m.f. E, a resistor of resistance R, a capacitor of capacitance C and a switch, as shown in Fig. 8.1.

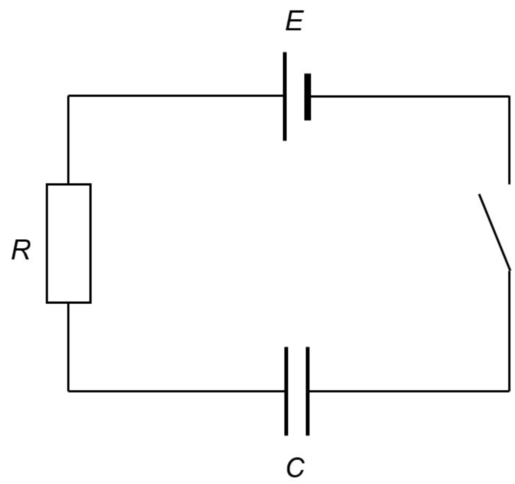


Fig. 8.1

The capacitor is initially uncharged and the switch is closed at time t = 0.

(a) (i) State an expression for the maximum charge on the capacitor using appropriate terms specified above.

.... [1]

(ii) On the sets of axes of Fig. 8.2, draw two sketch graphs.

On the first graph, show how the charge *q* on the capacitor varies with time. Mark the value of maximum charge.

On the second graph, show how the current I in the circuit varies with time. Mark the value of maximum current with I_{max}.

Use the same scale for the time axis on each graph. [2]

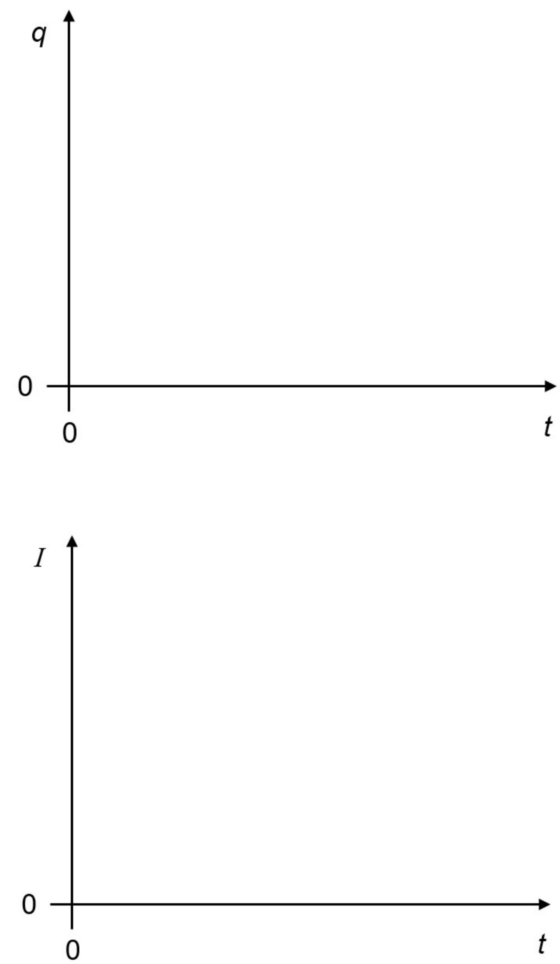


Fig. 8.2

(b) **(i)** State an expression for how much energy is stored on the capacitor when the capacitor is fully charged using appropriate terms specified in part **(a)**.

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

(ii) State an expression for how much work is done by the battery in fully-charging the capacitor using appropriate terms specified in part **(a)**.

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

(iii) Show that the equation for the charge q on the capacitor after the switch is closed is given by:

$$R\frac{dq}{dt}+\frac{q}{C}=E$$

[1]

(iv) Show, by direct substitution or otherwise, that the solution **to the equation in (b)(iii)** is given by:

$$q=A+Be^{-\frac{t}{\tau}}$$

where A, B and τ are constants.

Determine A, B and τ .

[4]

(v) Using the equation and your answer in **(b)(iv),** find an expression for the current I in the circuit.

[1]

(vi) Use your expression for I from **(b)(v)** to determine the instantaneous power dissipated in the resistor.

Hence, determine an expression for the total energy dissipated in the resistor while fully charging the capacitor.

[2]

(vii) Explain whether this result is in agreement with your answer in **(b)(i)**.

....

.... [1]

(c) In the circuit shown in Fig. 8.3, the switch S_0 is closed to fully charge the two capacitors C_1 and C_2 from the cell. The switch S_0 is then re-opened.

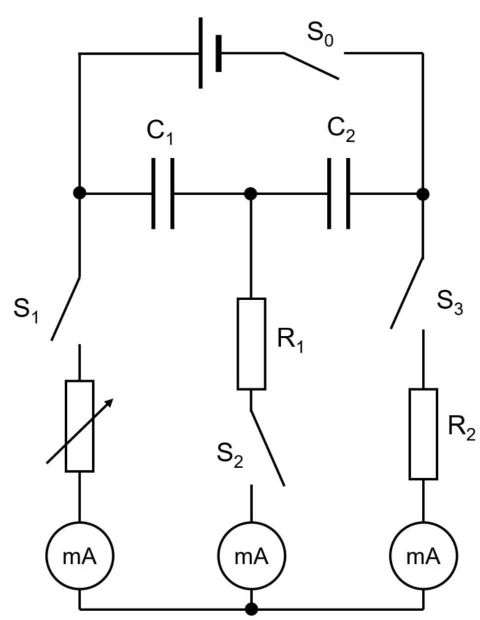


Fig. 8.3

The potential difference across the cell is 9.0 V.

The capacitance of C_1 is 2.5 μF and the capacitance of C_2 is 1.1 μF.

(i) Determine the charge on each capacitor.

charge on capacitor C_1 = …………………….. C

charge on capacitor C_2 = …………………….. C

[2]

(ii) Determine the p.d. across each capacitor.

p.d. across capacitor C_1 = …………………….. V

p.d. across capacitor C_2 = …………………….. V

[1]

(iii) The three switches S_1, S_2 and S_3, are closed simultaneously. The fixed resistors, R_1 and R_2, have resistances of 42 Ω and 58 Ω respectively. There is no current in R_1.

Calculate the resistance of the variable resistor.

resistance = …………………….. Ω [3]

[Total: 20]

9 **(a)** **(i)** State the principle of superposition of waves.

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(ii) Distinguish between phase difference and path difference.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

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

(b) A parallel beam of coherent, monochromatic light of wavelength λ is incident on a diffraction grating of spacing *d* at an angle α to the normal, as shown in Fig. 9.1.

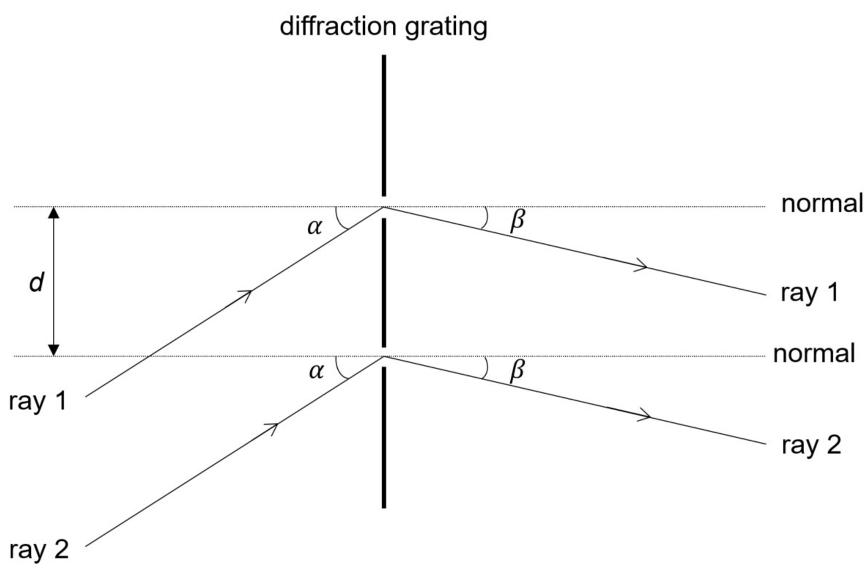


Fig. 9.1

On passing through the grating, the light is strongly diffracted at certain values of the angle β to the normal.

Each of these values defines a different order of diffraction.

(i) **1** Write down an expression for the path difference between ray 1 and ray 2 as the rays, incident at angle α, arrive at the grating.

[1]

2 Hence obtain an expression of the **total** path difference between ray 1 and ray 2 for rays incident at angle α, passing through the grating, and diffracted at angle β, as shown in Fig. 9.1.

[2]

3 Use the expression in **2** to derive an equation for strong diffraction to occur.

[1]

(ii) The expressions in **(b)(i)** is derived using 2 slits only. In practice, a diffraction grating is made up of a lot of slits.

State 2 practical disadvantages of using a two-slit grating to determine the wavelength of light.

1 ....

....

....

2 ....

....

.... [2]

(c) A parallel beam of coherent, monochromatic light is incident on a diffraction grating at an angle α to the normal. The first-order diffraction is observed in the transmitted light at an angle of 12.5° to the normal on one side of the normal and 49.7° to the normal on the other side of the normal.

(i) Draw a labelled diagram showing the grating, the direction of the incident light and 2 first-order diffraction.

[1]

(ii) Calculate the angle α.

α = ……………………..° [3]

(iii) The wavelength of the light used is 633 nm.

Determine the grating spacing *d*.

d = ………………… m [1]

(iv) Identify any higher order diffraction directions.

Draw and label any such directions on your diagram in **(c)(i)**.

Show your workings clearly on how you identify the higher order diffraction directions.

[5]

[Total: 20]

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