H

NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS
Paper 2 Structured Questions
Candidate answers on the Question Paper.

No Additional Materials are required.

9749/02

26 August 2021
2 hours

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

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

Answers **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	**/ 6**
2	**/ 9**
3	**/ 9**
4	**/ 10**
5	**/ 9**
6	**/ 9**
7	**/ 8**
8	**/ 20**
Total (80m)	

This document consists of **24** printed pages and **no** blank 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	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
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** the questions in the spaces provided.

1 A beam is clamped at one end and an object X is attached to the other end of the beam, as shown in Fig. 1.1.

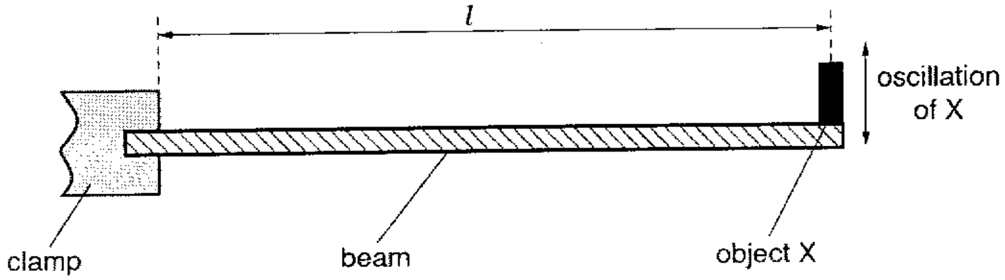


Fig. 1.1

The object X is made to oscillate vertically.

The time period T of the oscillations is given by

$$T = K\sqrt{\frac{Ml^3}{E}}$$

where M is the mass of X,
l is the length between the clamp and X,
E is the Young's modulus of the material of the beam and the unit is kg m^{-1} s^{-2}
and K is a constant.

(a) Determine the S.I. base units of K.

S.I. base units of K .... [2]

(b) Data in S.I. units for the oscillations of X are shown in Fig. 1.2.

quantity	value	uncertainty
T	0.45	± 2.0%
l	0.892	± 0.2%
M	0.2068	± 0.1%
K	1.48×10^5	± 1.5%

Fig. 1.2

Calculate E and its actual uncertainty.

E .... ± .... kg m^{-1} s^{-2} [4]

[Total :6]

2 **(a)** **(i)** Define *linear momentum*.

....

.... [1]

(ii) State the relation between force and momentum.

....

.... [1]

(b) A projectile of mass 300 g, initially at rest, is fired from a cylindrical barrel of cross-sectional area 2.8×10^{-4} m^2 by means of compressed gas. The variation with time t of the excess pressure p of the gas in the barrel above atmospheric pressure is shown in Fig. 2.1.

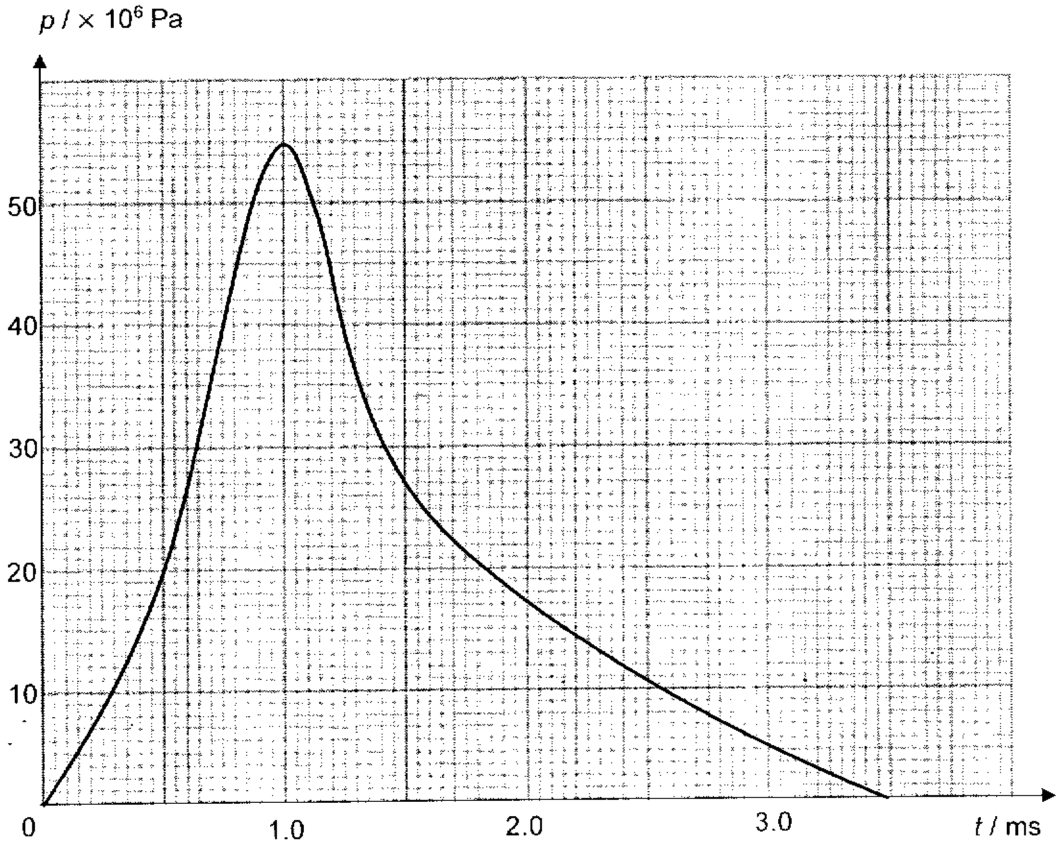


Fig. 2.1

(i) Calculate the maximum acceleration of the projectile due to the force exerted by the compressed gas on it.

maximum acceleration = ... $m\ s^{-2}$ [2]

(ii) Using Fig. 2.1, estimate the total change of momentum of the projectile due to the force exerted by the compressed gas on it.

change in momentum = ... $kg\ m\ s^{-1}$ [3]

(iii) The excess pressure exerted on the projectile is now higher than that shown in Fig. 2.1 from $t = 0$ ms to $t = 3.5$ ms. Explain how the final speed of the projectile will change.

....

....

.... [2]

[Total: 9]

3 **(a)** A body moving with uniform speed v in a circle of radius r experience an acceleration a.

(i) Explain why the acceleration is directed towards the centre of the circle.

....

....

....

.... [2]

(ii) Write the expression of the acceleration a in terms of v and r.

.... [1]

(b) The Mars helicopter, Ingenuity, completed its first flight outside Earth on 19 April 2021.

To understand the difficulty of this flight, we will consider a simple model of Ingenuity comprising of a pair of rotating blades and a body, as shown in Fig. 3.1.

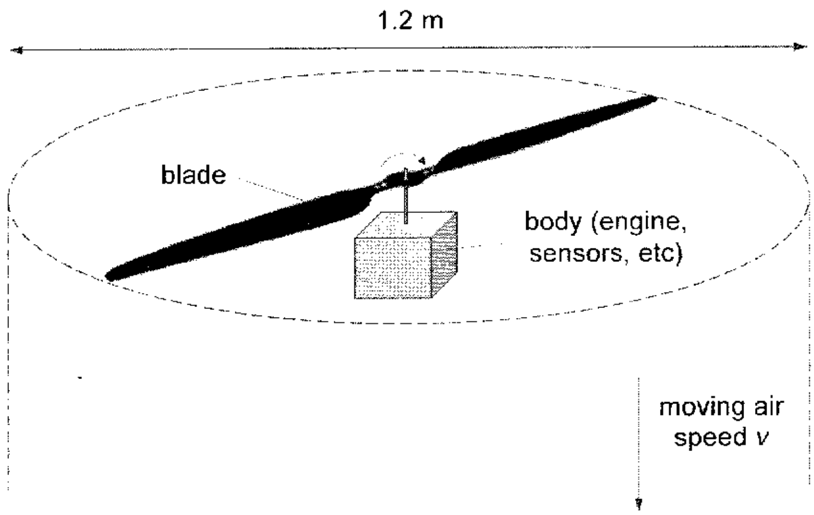


Fig. 3.1

The mass of the model is 1.8 kg.

When the motor is switched on, the air moves with a speed v in a uniform cylinder of diameter 1.2 m.

(i) The density of air on Earth is 1.2 kg m^{-3}.
Determine the speed v of the air when the model is hovering at a constant height from the surface of the Earth.

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

(ii) The density of air on Mars is 0.020 kg m^{-3} and the gravitational field strength near the surface of Mars is 38% that of Earth.

When the model operates on Mars, the same blades will need to rotate at a much higher angular velocity than in **(b)(i)**. The blades are therefore subjected to a larger amount of stress.

Explain why the blades

1. need to rotate at a higher angular velocity,

....

.... [1]

2. experience a larger stress by referring to your answer in **(a)**.

....

....

....

.... [2]

[Total: 9]

4 A ripple tank is used to demonstrate the interference of water waves.
Two dippers D1 and D2 produce coherent waves that have circular wavefronts, as illustrated in Fig. 4.1.

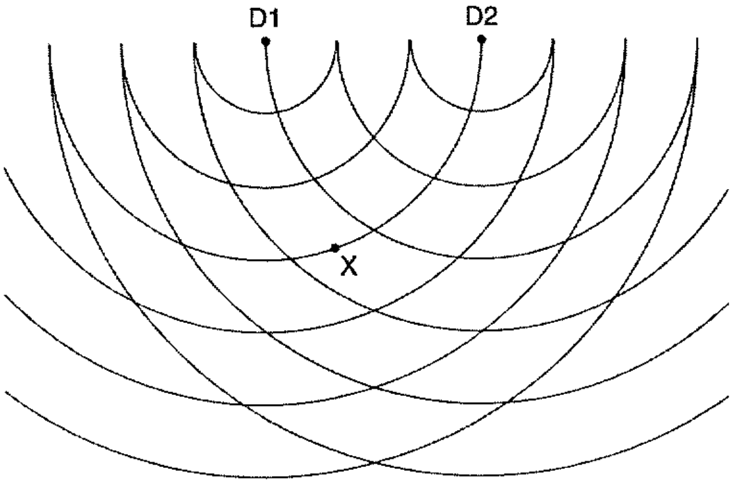


Fig. 4.1 (not to scale)

The lines in the Fig. 4.1 represent crests.

(a) (i) **1.** Explain what is meant by *coherent waves* produced by the dippers.

....

.... [1]

2. Describe how the apparatus can be arranged to ensure that the waves from the dippers are coherent.

....

.... [1]

(ii) State one other condition that must be satisfied by the waves in order for the interference pattern to be observable.

....

.... [1]

(b) Light from a lamp above the ripple tank shines through the water onto a screen below the tank. Describe one way of seeing the illuminated pattern more clearly.

....

.... [1]

(c) Fig. 4.2 shows the water level at one of the dippers.

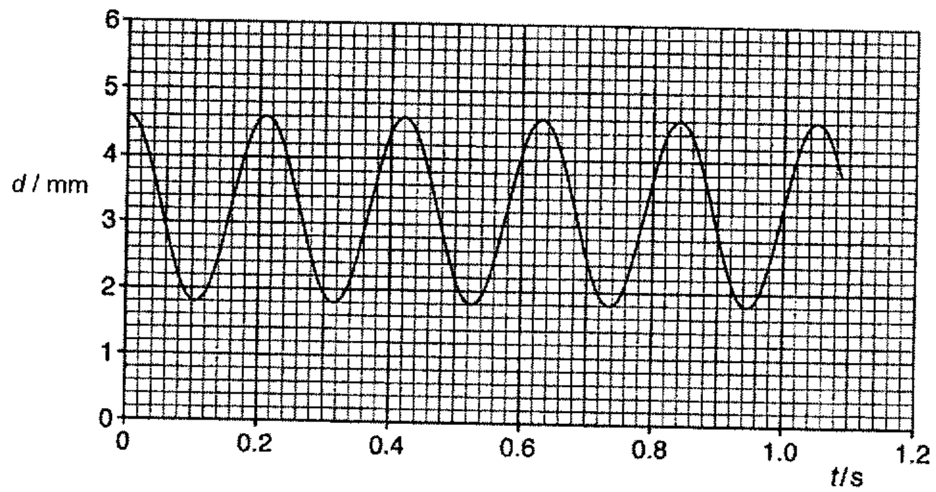


Fig. 4.2

The speed of waves is 0.40 m s^{-1}.
Show that the waves have a wavelength of 8.4 cm.

[2]

(d) Fig. 4.1 shows a point X that lies on a crest of the wave from D1 and midway between two adjacent crests of the wave from D2.

For the waves at point X,

(i) determine the path difference,

path difference = ... cm [2]

(ii) state the phase difference.

phase difference = ... ° [1]

(e) On Fig. 4.1, draw **one** line, at least 4 cm long, which joins points of the interference pattern where only maxima of path difference equal to two wavelengths are observed. [1]

[Total: 10]

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

....

....

.... [1]

(b) Two charged metal spheres A and B are situated in a vacuum, as illustrated in Fig. 5.1.

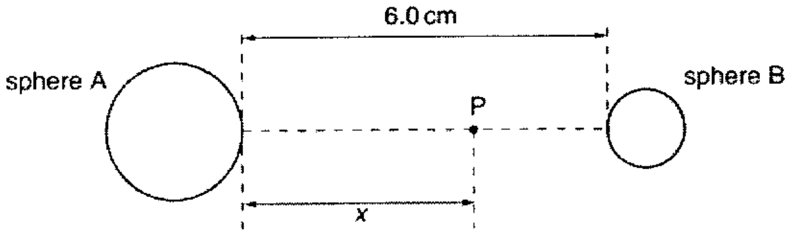


Fig. 5.1

The shortest distance between the surfaces of the spheres is 6.0 cm.

A movable point P lies along the line joining the centres of the two spheres, a distance x from the surface of sphere A.

The variation with distance x of the electric field E at point P is shown in Fig. 5.2.

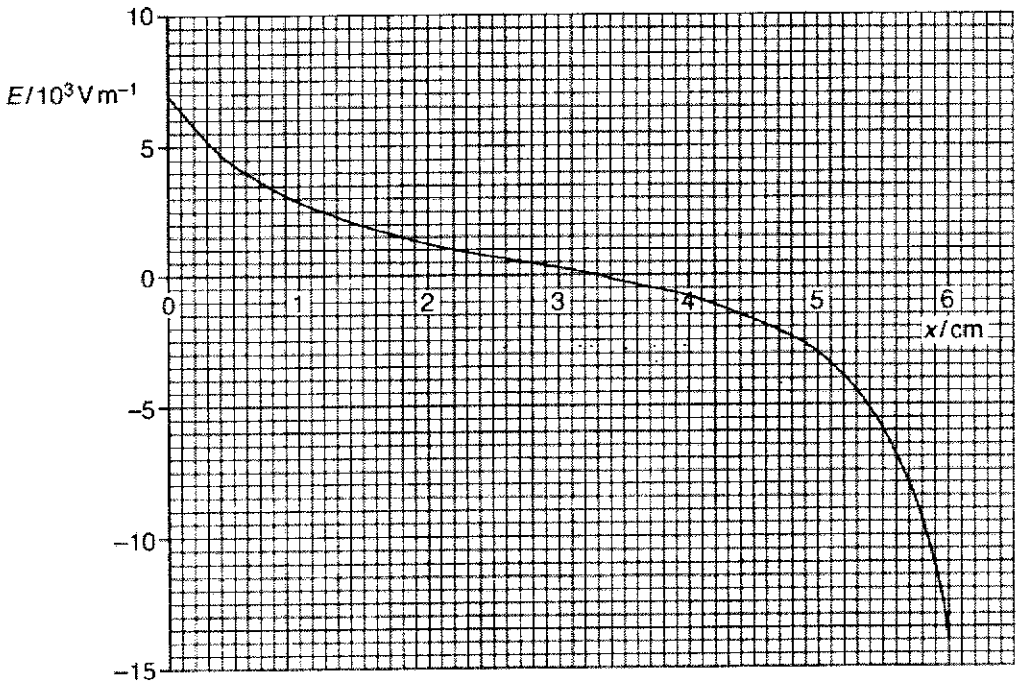


Fig. 5.2

(i) Use Fig. 5.2 to explain whether the two spheres have charges of the same, or opposite sign.

....

....

....

.... [2]

(ii) A proton is at rest at point P where $x = 5.0$ cm.

1. Use data from Fig. 5.2 to determine the magnitude of the acceleration of the proton.

acceleration = ... m s^{-2} [3]

2. Use data from Fig. 5.2 to estimate the speed of the proton at $x = 3.3$ cm.

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

[Total: 9]

6 (a) Fig. 6.1 shows a battery of negligible internal resistance connected with a thermistor in parallel with an ohmic resistor of resistance 1200 Ω.

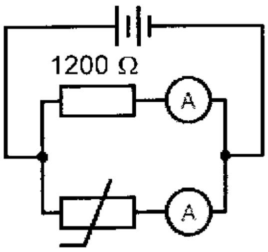


Fig. 6.1

The current in the 1200 Ω resistor is measured to be 5.0 mA.

(i) The thermistor has a resistance of 4700 Ω at room temperature.

Determine the current in the thermistor.

current = ... mA [2]

(ii) The temperature increases.
State how the currents in the resistor and the thermistor change.

resistor: ....

thermistor: .... [1]

(b) Fig. 6.2 shows an illumination level sensor circuit used to send a voltage signal V_{out} to another processing circuit.

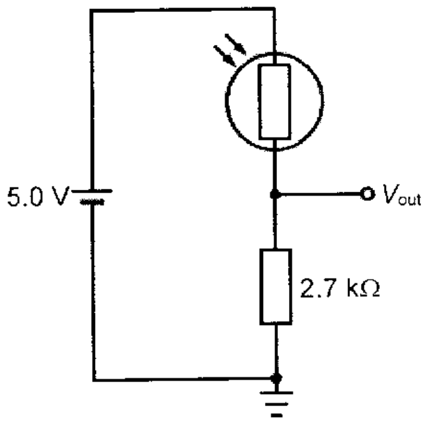


Fig. 6.2

The minimum and maximum resistances of the light-dependent resistor is 0.7 kΩ and 4.5 kΩ over the range of illumination level it is expected to operate in.

(i) Determine the minimum and maximum V_{out} the processing circuit is expected to receive.

minimum V_{out} = ... V

maximum V_{out} = ... V [3]

(ii) The processing circuit processes the V_{out} signal to calculate the relative illumination levels measured by the illumination level sensor circuit.

It is recommended that the resistance of the resistor be comparable to the range of resistances of the light-dependent resistor.

Explain the limitation if the resistance of the resistor is very small compared to the range of resistances of the light-dependent resistor.

....

....

....

....

.... [3]

[Total: 9]

7 An electron having charge $-q$ and mass m is accelerated from rest in a vacuum through a potential difference V.

The electron then enters a region of uniform magnetic field of magnetic flux density B, as shown in Fig. 7.1.

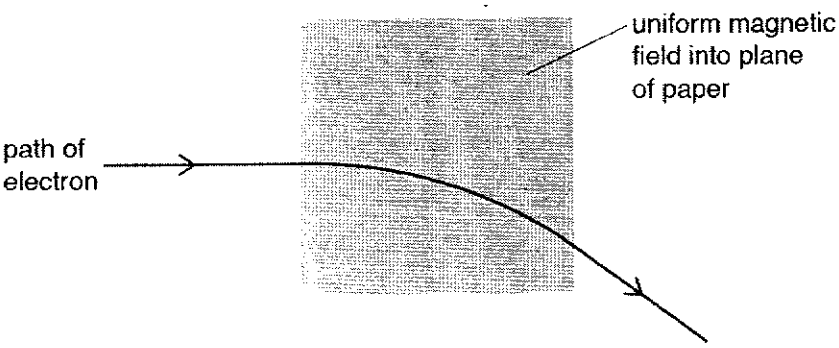


Fig. 7.1

The direction of the uniform magnetic field is into the plane of the paper.
The velocity of the electron as it enters the magnetic field is normal to the magnetic field.
The radius of the circular path of the electron in the magnetic field is r.

(a) Explain why the path of the electron in the magnetic field is the arc of a circle.

....

....

....

....

.... [3]

(b) Show that the magnitude p of the momentum of the electron as it enters the magnetic field is given by

$$p = \sqrt{2mqV}$$

[2]

(c) The potential difference V is 120 V. The radius r of the circular arc is 7.4 cm. Determine the magnitude of the magnetic flux density B.

B = ... T [3]

[Total: 8]

8 Read the following article on the Millikan Oil Drop experiment then answer the questions that follow.

In 1909, Millikan and Fletcher performed the oil drop experiment to measure the elementary electric charge – the charge of the electron. Millikan received the Nobel prize in Physics due to the results of this experiment.

Fig. 8.1 shows the important features of the apparatus used by Millikan to measure the electron charge by observations on charged oil droplets.

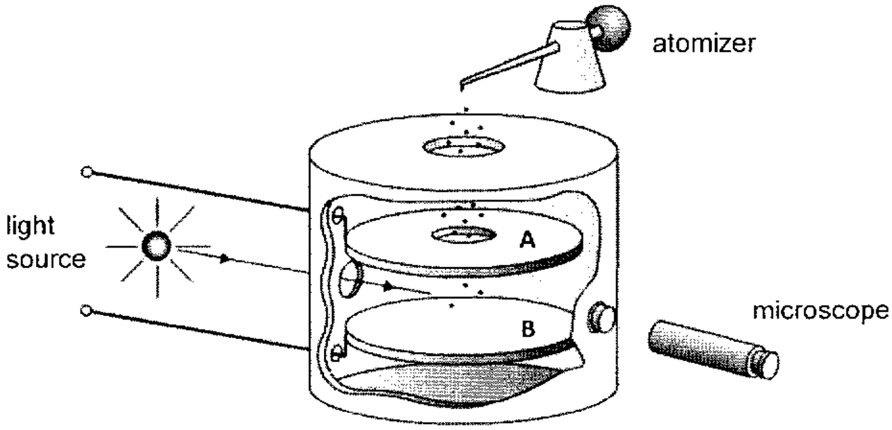


Fig. 8.1

The apparatus consists of a pair of horizontal metal plates A and B separated by a distance d.

The microscope is focused on the illuminated space under the hole through which oil droplets can enter.

The atomizer introduces a mist of oil droplets through the hole in the top plate that is ionized by X-rays, making them negatively charged.

When electric field is applied across plates A and B, the potential difference between the plates can be adjusted until a particular oil droplet is suspended. The value V that suspends that specific oil droplet can then be measured.

By repeating the experiment multiple times with differently sized oil droplets and recording the potential difference used, the charge of each oil droplet can be determined as small integer multiples of a certain base value of electronic charge. It is proposed that this base value is the elementary electric charge q.

$$\text{Charge of oil droplet, } Q = N q$$

where N is an integer
and q is the base value of electronic charge

(a) **(i)** A particular oil droplet suspended at rest with potential difference V, has a weight W and carries a charge Q. Assuming the upthrust of the air is negligible, show that

$$Q = W\left(\frac{d}{V}\right)$$

[1]

(ii) State and explain which plate, A or B, is at higher potential.

....

....

.... [2]

(iii) Explain why it is reasonable to neglect the upthrust.

....

.... [1]

(b) When the electric field is removed, the suspended oil droplet will start to fall. The oil droplets quickly reaches terminal velocity. The terminal velocity of the falling droplet can be measured.

The weight of an oil droplet is found by timing its fall at terminal speed over a standard distance, when the potential difference across the plates is zero.

Fig. 8.2 shows the relationship between the weight W of oil droplets and the time T taken by the oil droplets to fall 1.00 mm in air.

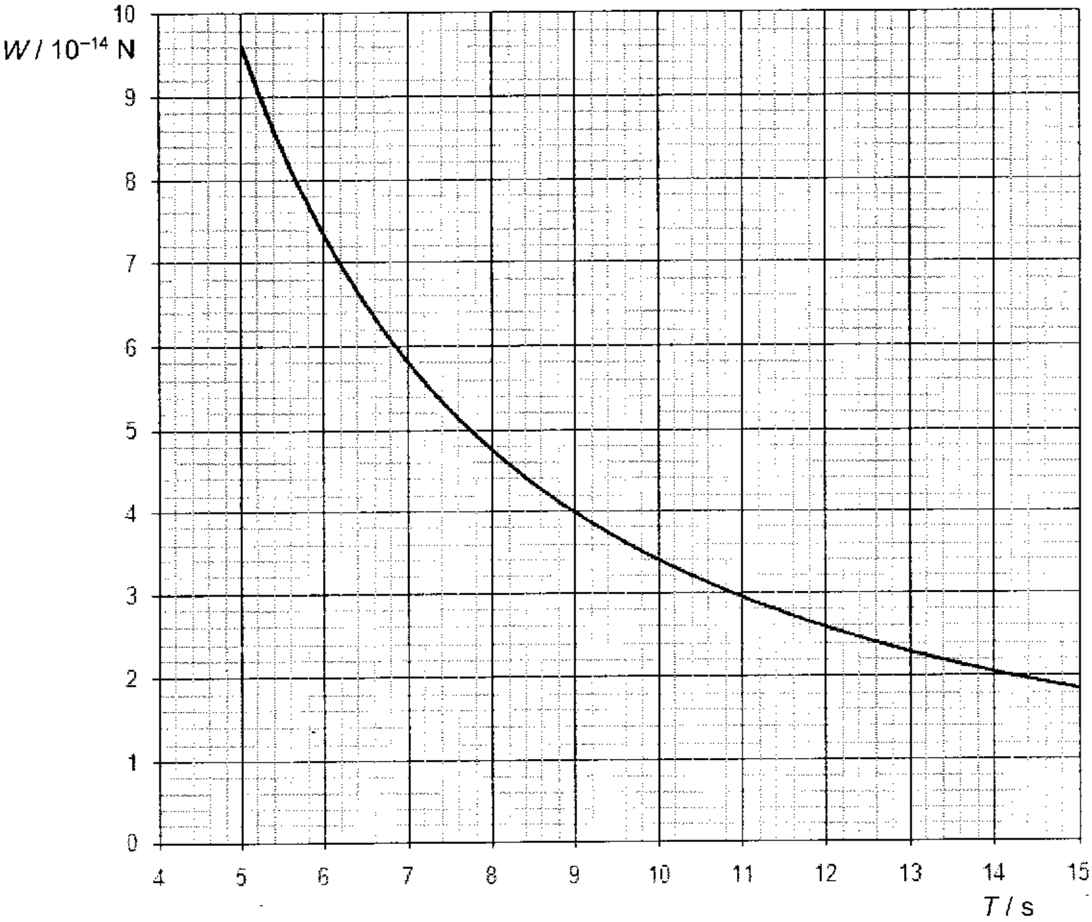


Fig. 8.2

The results shown in Fig. 8.3 were obtained with a Millikan apparatus.

For each oil droplet, the experimenter measured V across the plates at which the droplet was observed to be stationary. The distance between the plates was 4.42 mm.

The experimenter also measured the time T for the droplet to fall 1.00 mm in air at terminal speed after switching off the potential difference across the plates.

V / V	T / s	W / 10^{-14} N	Q / 10^{-19} C
770	11.2	2.9	1.66
230	10.0	3.4	6.53
1030	9.4	3.7	1.59
470	7.6		
820	6.9	5.9	3.18
395	6.2	7.0	7.83

Fig. 8.3

Complete Fig. 8.3. [2]

(c) It is suggested that the drag force F_D on a small sphere of radius r moving with speed v through a viscous fluid is given by

$$F_D = 6\pi\eta rv$$

where η is the coefficient of viscosity of the fluid.

If the coefficient of viscosity of air at room temperature is 1.8×10^{-5} kg m^{-1} s^{-1}, estimate the radius of the oil droplet for the first row of Fig. 8.3.

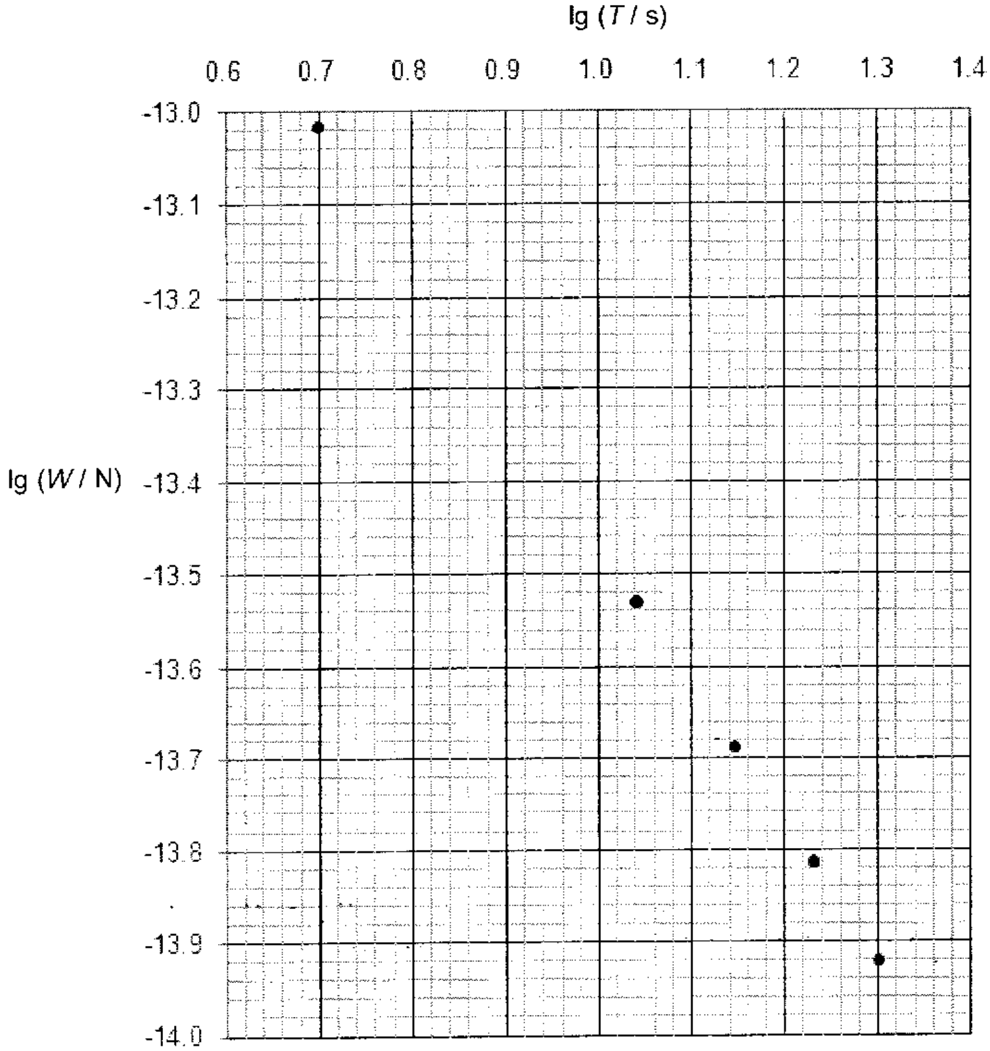
radius = ... m [3]

(d) It is thought that, when the potential difference between the plates is zero, the weight W of an oil droplet varies with time T of its fall (at terminal speed over a standard distance) according to the equation

$$W = aT^b \text{ ------ } (1)$$

where a and b are constants.

Some data from Fig. 8.2 are used to plot the graph of Fig. 8.4



(i) Use Fig. 8.2 to determine lg (W / N) for a time T of 8.0 s.

lg (W / N) = ... m [1]

(ii) On Fig. 8.4,

1. plot the point corresponding to $T = 8.0$ s [1]

2. draw the line of best fit for the points. [1]

(iii) Use the line drawn in **(d)(ii)** to determine the constant b in equation (1).

b = ... [2]

(iv) Deduce, from your value of b in **(d)(iii)**, how the weight W of oil drop would depend on its terminal speed v.

[2]

(e) The Millikan experiment is said to provide experimental evidence for the *quantisation of charge*. Suggest what is meant by *quantisation of charge*.

....

.... [1]

(f) An early experimenter, working in non S.I. units, obtained the following six values for the magnitudes of the charges on small oil drops.

$Q/10^{-9}$ units	6.86	4.44	8.37	5.39	1.97	2.96

Use these results to find the magnitude of the largest possible basic electronic charge as measured in these units.

basic electronic charge = ...units [3]

[Total: 20]

- END OF PAPER -

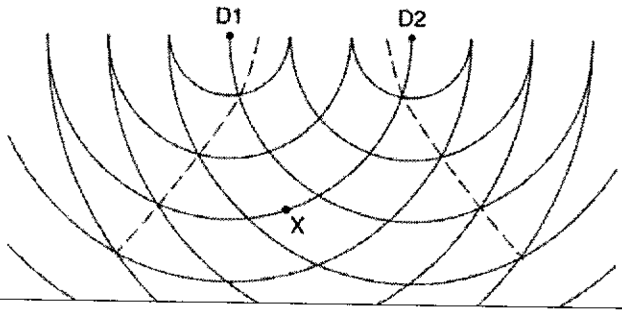
Paper 2 Solutions

1			
	(a)	units of T: s, l: m and M: kg $K^2 = T^2E / M l^3$ hence units: $s^2 kg\ m^{-1}s^{-2} / kg^3$ (= m^{-4}) C1 (for correct substitution of units of T, l and M, allow omission of square/square root but do not allow e.g. s^{-1}) units of K: m^{-2} A1	[2]
	(b)	E = [(1.48 × 10^5)2 × 0.2068 × (0.892)3] / (0.45)2 = 1.588 × 10^{10} B1 % uncertainty in E = 4% + 0.6% + 0.1% + 3% = 7.7% C1 7.7% of E = 1.22 × 10^9 (allow ecf) A1 OR E_{max} = [(1.48 × 10^5) (1.015)]^2 [0.2068 (1.001)] [0.892 (1.002)]^3 / [0.45 (0.980)]^2 = (150220)^2 (0.2070068) (0.893784)^3 / (0.441)^2 = 1.715 × 10^{10} E_{min} = [(1.48 × 10^5) (0.985)]^2 [0.2068 (0.999)] [0.892 (0.998)]^3 / [0.45 (1.020)]^2 = (145780)^2 (0.2065932) (0.890216)^3 / (0.459)^2 = 1.470 × 10^{10} C1 (E_{max} or E_{min} correct) ΔE = ½ (Emax – Emin) or Emax – E or E – Emin A1 (= 1.22 × 10^9) E = (1.6 ± 0.1) × 10^{10} kg $m^{-1}s^{-2}$ (allow ecf) B1 (award this mark if absolute uncertainty is in 1 sf and actual value follows the dp of the uncertainty)	[4]

2	(a)	(i)	product of mass and (linear) velocity	B1
		(ii)	force equal rate of change of momentum **or** change in momentum per unit time	B1
	(b)	(i)	maximum pressure = 55 × 10^6 Pa maximum force = 55 × 10^6 × 2.8 × 10^{-4} = 15400 N maximum acceleration = 15400 / 0.300 = 5.13 x 10^4 m s^{-2}	C1 A1
		(ii)	momentum change = area under graph × cross-sectional area of barrel evidence of correct estimation of area under p–t graph 18 kg m s^{-1} ≤ Δp ≤ 20 kg m s^{-1}	M1 M1 A1
		(iii)	*either* excess pressure or force > original, so larger momentum change or impulse *or* excess pressure or force > original, so larger (average) acceleration *or* force > original, larger work done so larger increase in kinetic energy	M1

				final speed of projectile > original	A1
3	(a)	(i)		(constant speed, so) acceleration (is always) normal / perpendicular to velocity velocity tangent to circle (at any point), so acceleration is directed towards centre	B1 B1
		(ii)		$a = \frac{v^2}{r}$	B1
	(b)	(i)		force on rotating blades $= \frac{\Delta m}{\Delta t} \times v$ $\frac{\Delta m}{\Delta t} = \rho(\pi r^2)v = 1.2 \times \pi \times 0.6^2 \times v$ force on blades equal weight when hovering $1.2 \times \pi \times 0.6^2 \times v \times v = 1.8 \times 9.81$ $v = 3.61$ m s^{-1}	C1 M1 A1
		(ii)	1.	provide sufficient upward force in lower air density by having a higher air speed, so as to move larger mass (or volume) of air per unit time	B1
			2.	higher angular velocity so higher linear speed, centripetal acceleration higher (at every point on blades) centripetal acceleration (or force) provided by tension / tensional force in blades so, larger stress in the blades	B1 B1

4	(a)	(i)	1.	constant phase difference (and does not vary with time) between the waves (produced by the dippers)	B1
			2.	connect dippers to same vibrator/motor	B1

		(ii)	overlapping waves have <u>similar / same amplitude</u>	B1
	(b)		any means of 'freezing' the pattern e.g. use of a stroboscope, video	B1
	(c)		evidence of using ≥ 2 cycles to calculate period (T = 0.21 s) or frequency $\lambda = \frac{v}{f} = vT = 0.40 \times 0.21$ so, $\lambda = 0.084$ m or 8.4 cm	B1 B1
	(d)	(i)	Evidence to deduce distances of X from source (e.g. X is 3λ and 3.5λ from D1 and D2, X on 3rd wavefront from D1 and between 3rd and 4th wavefronts from D1) path difference = $3.5\lambda - 3.0\lambda = 0.5\lambda$ = 4.2 cm	 M1 A1
		(ii)	180°	B1
	(e)		draw either lines 	B1
5	(a)		(electrostatic) force between two <u>point</u> charges <u>proportional</u> to <u>product of charges</u> and <u>inversely proportional</u> to the <u>square</u> of the distance (or separation)	B1
	(b)	(i)	field strengths (between spheres) are <u>opposite directions</u> because *either* <u>positive</u> (before 3.3 cm) and <u>negative</u> (after 3.3 cm) on graph *or* <u>E = 0 at a point</u> between spheres so, <u>same</u> sign	 M1 A1
		(ii) 1.	$E = 3.0 \times 10^3$ V m^{-1} $a = qE / m = (1.60 \times 10^{-19} \times 3.0 \times 10^3) / (1.67 \times 10^{-27})$ $a = 2.9$ (or 2.87) $\times 10^{11}$ m s^{-2}	C1 C1 A1
		2.	evidence of correct estimation of ΔV by area under graph between 3.3 to 5 cm $(1.60 \times 10^{-19}) \times \Delta V = \frac{1}{2}(1.67 \times 10^{-27}) v^2$ 6.03×10^4 m s^{-1} < v < 6.64×10^4 m s^{-1}	M1 M1 A1
6	(a)			
		(i)	$V = 5.0 \times 10^{-3} \times 1200 = 6.0$ V C1 $I = 6.0 \div 4700 = 0.00128$ A ≈ 1.3 mA or 1.28 mA A1	[2]

		(ii)	resistor: (same pd same resistance hence) no change thermistor: (same pd lower resistance hence) increases B1	[1]
	(b)			
		(i)	Minimum $V_{out} = \frac{2.7}{4.5+2.7}(5.0)$ or Maximum $V_{out} = \frac{2.7}{0.7+2.7}(5.0)$ C1 – An attempt (with substitution) to use the Potential Divider Rule or $V = IR$ Minimum V_{out} = 1.9 or 1.88 V A1 Maximum V_{out} = 4.0 or 3.97 V A1 (minus 1 mark if wrong min/max)	[3]
		(ii)	(according to the potential divider rule,) potential difference across the resistor very small fraction of 5.0 V **or** pd across LDR ≈ 5 V B1 Very low range of V_{out} received **or** $V_{out} \approx 0$ at all illumination level or very small difference in V_{out} B1 Therefore very low precision of illumination level calculated or high relative (fractional/percentage) uncertainty of illumination level calculated or processing instrument/circuit not sensitive enough to detect small changes in V_{out} B1 (accept V_{out} too small to be detected but max 2 marks, cannot score for 2nd mark)	[3]

7			
	(a)	(magnetic) force (always) normal to velocity/direction of motion B1 so provides the centripetal force or a force towards the centre of a circle B1 magnitude of (magnetic) force constant (accept omission of magnitude if direction of force mentioned above) or speed is constant/kinetic energy is constant B1	[3]

	(b)	increase in KE = loss in PE **or** ½ $mv^2 = qV$ KE = $p^2/2m$ or $p = mv$ with algebra leading to $p = \sqrt{(2mqV)}$	M1 A1	[2]
	(c)	Magnetic force provides the centripetal force $Bqv = mv^2 / r$ $mv = Bqr$ **or** $p = Bqr$ $(2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2} = B \times 1.60 \times 10^{-19} \times 0.074$ $B = 5.0 \times 10^{-4}$ T	M1 C1 A1	[3]

8	**(a)**	**(i)**	To remain at rest, net force = 0. $W = QE$ or at minimum $W = Q\left(\frac{V}{d}\right)$ leading to $Q = W\left(\frac{d}{V}\right)$	B1	[1]
		(ii)	electric force upwards (to balance downward weight or to suspend oil droplets) hence A is at a higher potential (for downward electric field or to attract negative charges)	M1 A1	[2]

		(iii)	density of air << density of oil	B1	[1]
	(b)		Correct W: 5.1 or 5.2 (read off from graph in Fig. 7.2 at T = 7.6 s) B1 Correct Q (allow ecf): 4.80 (for W = 5.1) or 4.89 (for W = 5.2) B1 or $Q = W(d/V)$ calculated correctly for wrong values of W stated		[2]
	(c)		At terminal speed, net force = 0 Substitution of F_D (= W) = 2.9 × 10^{-14} N C1 (accept substitution of $W = Q(V/d)$ = 1.66 × 10^{-19} (770 / 4.42×10^{-3}) even though it is not necessary) Substitution of v (= D/T) = 1.00 × 10^{-3} / 11.2 C1 (allow this mark for erroneous substitution of D e.g. 1.00, 4.42 or 4.42 × 10^{-3}) (do not allow for any substitution of v using any equation of motion where $a \neq 0$) r = 9.57 × 10^{-7} m (accept 9.58 × 10^{-7} due to early round-off) A1		[3]
	(d)	(i)	From Fig. 7.2, When T = 8.0 s, W = 4.7 or 4.8 x 10^{-14} N, => lg W = −13.33 or −13.32 (2dp)	B1	[1]
		(ii)	correct point plotted within half a square B1 best fit line drawn	B1	[2]
		(iii)	$W = aT^b \Rightarrow \lg W = b\lg T + \lg a$ b = gradient e.g. $= \frac{(-13.14)-(-13.86)}{0.78-1.26} = \frac{0.72}{-0.48} = -1.5$ an attempt to calculate gradient or clear working that b = gradient C1 gradient calculated correctly with points chosen on best fit line at least half the length of the drawn best fit line apart A1		[2]
		(iv)	$W = aT^{-1.5} = a\left(\frac{1}{T}\right)^{1.5}$ Terminal speed $v = \frac{d}{T}$ => $W = a\left(\frac{v}{d}\right)^{1.5} \propto v^{1.5}$ since a and d are constants Substitution of the value of b into $W = aT^b$ or lg W = b lg T + lg a or $v = D/T$ C1 leading to $W = \frac{a}{D^{1.5}}v^{1.5}$ or $W \propto v^{1.5}$ A1		[2]
	(e)		any electric charge is always an integer multiple of a basic charge or there is a certain basic charge beyond which the charge is no longer divisible into smaller units	B1	[1]

	(f)	at least one value of Q divided by another value of Q or at least one difference between the values of Q determined C1 at least 5 values of Q or differences between values of Q divided by the smallest value of Q or smallest difference between values of Q or divide 5 other values of Q by $Q_5/4$ C1	[3]

e.g. $Q_1 = N_1q$ $Q_2 = N_2q$ $Q_3 = N_3q$
$Q_4 = N_4q$ $Q_5 = N_5q$ $Q_6 = N_6q$

largest possible q corresponds to smallest possible N_N

(choose to check Q_5 and N_5 since smallest N should be easiest to work with)

$Q_1/Q_5 = N_1/N_5 = 7/2$

Since N_1 must be a positive integer, $N_5 = 2n$ where n is a positive integer

$Q_2/Q_5 = N_2/N_5 = 9/4$ $N_5 = 4n$

$Q_3/Q_5 = N_3/N_5 = 17/4$ $N_5 = 4n$

$Q_4/Q_5 = N_4/N_5 = 11/4$ $N_5 = 4n$

$Q_6/Q_5 = N_6/N_5 = 11/4$ $N_5 = 2n$

smallest possible $N_5 = 4$

OR

	Q / 10^{-9} units					
	6.86	4.44	8.37	5.39	1.97	2.96
÷1.97	3.48	2.25	4.25	2.74	1.00	1.50
÷(1.97/2)	6.96	4.51	8.50	5.47	2.00	3.01
÷(1.97/3)	10.45	6.76	12.75	8.21	3.00	4.51
÷(1.97/4)	13.93	9.02	16.99	10.94	4.00	6.01 ← all are close to whole number

therefore largest possible $q = Q_5 / 4 = 1.97 \times 10^{-9} \div 4 = 4.93 \times 10^{-10}$ units A1