6735 Unit Test PHY5

1. Equations

$\frac{GMm}{r^2}$ ✓

$m\omega^2 r$ or $mv\omega$ ✓ **2**

Show that T is independent of m

Since $\frac{GMm}{r^2} = m\omega^2 r$, eliminating m ✓

Using $\omega = \frac{2\pi}{T}$ to link ω with T [correct maths and physics required] ✓ **2**

4

[Just quoting for example $\frac{4\pi^2 r^3}{GM} = T^2$ is not sufficient]

2. Electric field

An area / space / volume / region	✓	
in which a charge experiences a force	✓	**2**
Defined direction of *E*		
Direction in which a (free) positive charge would tend to move	✓	**1**
Establishing equation and unit		
Use of $\frac{kQ}{r^2}$ eg $\frac{k3\times10^{-6}}{(L/2)^2}$	✓	
Attempt to add *E* values, eg $\frac{k3\times10^{-6}}{(L/2)^2} + \frac{k\times10^{-6}}{(L/2)^2}$	✓	
Working evident to show $E = \frac{16\times10^{-6}}{L^2}\mathrm{k}$	✓	**3**
Unit and direction of *E*		
$\mathrm{V\ m^{-1}}$, $\mathrm{N\ C^{-1}}$	✓	
Towards −1 μC / to the right or equivalent [not positive to negative]	✓	**2**
Explanation for neutral point		
$E_{3\mu C}$ acts to the right	✓	
$E_{-1\mu C}$ acts to the left	✓	
[Forces/fields act in opposite directions, one mark or 'Y' is a neutral point 1 mark – only award if above marks not scored]		
$\lvert E_{3\mu C}\rvert = \lvert E_{-1\mu C}\rvert$ at Y / fields are equal / fields balance	✓	**3**
		11

3. Estimate of charge stored

Attempt to measure area under graph, eg trapezium rule, mid-ordinate rule, counting squares, treat area as a trapezium ✓

Numerical value (1940 – 2000)/(1.94 – 2.00)/(1940 – 2000) × 10^{-6} ✓

Appropriate unit μC / mC / C [ie unit matched with value]
[can obtain this mark if $Q = It$ is used] ✓ **3**

Calculation of potential difference

Use of $V = \dfrac{Q}{C}$ ie $\dfrac{3300\ \mu\text{C}}{500\ \mu\text{F}}$ ✓

= 6.6 V ✓ **2**

Potential difference across R

(12 – 6.6) V = 5.4 V ✓ **1**

Resistance of R

Value of I read from graph / 53 – 54 μA ✓

Use of $R = \frac{V}{I}$ ie $\frac{5.4\ \text{V}}{53 - 54 \times (10^{-6})\ \text{A}}$ ✓

$= 1.00 - 1.02 \times 10^{5}\ \Omega$ ✓

OR

I at time 0 read from graph, ie 120 μA ✓

Use of $R = \frac{V}{I}$ ie $\frac{12\ \text{V}}{120 \times (10^{-6})\ \text{A}}$ ✓

= 100 000 Ω ✓

OR [though NOT part of PHY5 syllabus content, but some candidates may use this method]

Time constant read from graph, ie 50 s ✓

Time constant CR used, ie $500 \times 10^{-6}\ \text{F} \times R = 50$ s ✓

= 100 000 Ω ✓

OR

Half life read from graph, ie 35 s ✓

0.693 CR i.e. $\log_e 2 \times 2CR$ used ✓

= 100 000 Ω ✓ **3**

Sketch on graph

Starting at 120 μA and below drawn graph ✓ **1**

10

4 Direction of magnetic field lines

Upwards on diagram ✓ **1**

Minimum current

Use of *mg* ie $5 \times (10^{-4}) \times 9.81$ N/kg [Ignore conversion if not made] ✓

Set equal to *BIL* [ie 2×10^{-2} T $\times I \times 0.4$ m] ✓

= 0.61 A ✓ **3**

Explanation for factor of 4

Volume is increased by factor of 4 from $\pi \frac{d^2}{4}$ if $d \times 2$ ✓

Therefore mass / weight of wire is increased by factor of 4 ✓

Electromagnetic force must ∴ be increased by same factor which means $I \times 4$ because *B* and *L* unchanged ✓ **3**

[reference to $B = \mu_0 I / 2\pi a$;electrical resistance; *I*=*nAve* 0/3]

7

5. Direction of induced current

Must be such that it appears to have an anticlockwise direction at end facing magnet	✓	**1**
Conservation of Energy Principle		
The pole induced at the end of the coil facing the magnet opposes its motion / is a north pole which repels / induced B field opposes motion	✓	
	✓	
Work is required to move the magnet / decreases ke of magnet / slows down magnet	✓	**3**
This is transferred to an equivalent amount of electrical energy / ke converted to electrical energy		

[Also **reverse** argument to above – up to 3 marks:
- If south/opposite pole is induced the magnet would be attracted and gain E_k
- No (external) work/no (external) energy would have been supplied to produce this gain in E_k (and therefore electrical energy)
- This contradicts conservation of energy principle so polarity must oppose motion/be north/opposite pole]

Why current is not constant		
Quality of written communication	✓	
Magnetic field of magnet is not uniform / description of field	✓	
Hence rate of change magnetic flux linkage between coil and magnet is not constant / increases	✓	
Induced emf is not constant / increases (and therefore the current is not constant / increases)	✓	**4**
[If a description involving the magnet entering and then leaving the coil, leading to a change of current direction is given, 1/3]		**8**

6735/2A Practical Test PHY 5

Question A

(a)	(i)	$\sum nT_v \geq 30$ for both 200 g and 300 g	✓	
		$\sum nT_r \geq 20$ for both 200 g and 300 g	✓	
		All four repeated	✓	
		[Unit penalty [-1] (once only) if units not seen somewhere for each set of timings] [-1 if 1 s precision]		
		Both ratios calculated correctly, no unit and 3 significant figures [allow 2 decimal places if < 1]	✓	
		Values within 0.1 of each other	✓✓	**6**
		[within 0.2 → (1)]		
		[calculate if necessary]		
		[Only if sensible values]		
	(ii)	Percentage difference calculated correctly using average as denominator	✓	
		Compared with 8% (e.c.f.)	✓	
		OR		
		Values ± 4% calculated and checked for overlap [e.c.f. if ± 2%]	✓✓	**2**

(b) (i) [Polarity of capacitor (-1) polarity of meter – no penalty]

Circuit set up correctly without help ✓✓ **2**

(ii) t_1 and t_2 found to 0.1 s or better, with unit and t_1 in range 10 – 25 s ✓

Both repeated ✓

t_2/t_1 between 1.8 and 2.2 ✓ **3**

(iii) "Exponential" curve sketched ✓

Must have finite I value at $t = 0$

Values shown (approximately) correctly ✓

t_2/t_1 calculated and compared with '2' ✓ **3**

[or similar quantitative argument] **16**

Allow $t_2 \approx t_1$ if obvious

Sample results

(a) (i) 20 T_v / s: 12.74, 12.78

$T_v = 0.638$ s

10 T_r / s: 14.70, 14.66

$T_r = 1.47$ s

$T_r / T_v = 1.47/0.638$

$= \underline{2.30}$

20 T_v / s: 15.48, 15.52

$T_v = 0.775$ s

10 T_r / s: 18.26, 18.24

$T_r = 1.83$ s

$T_r/T_v = 1.83/0.775$

$= \underline{2.36}$

(ii) Percentage difference $= \dfrac{2.36 - 2.30}{2.33} \times 100$

$= 2.6\%$

This is well within the experimental uncertainty of $4 \times 2\% = 8\%$ and so the results support the suggestion

(b) (i) Circuit set up correctly without help

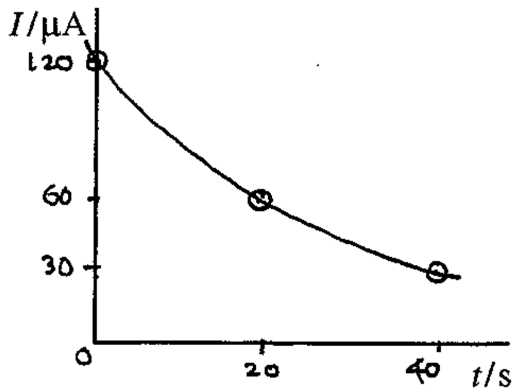
(ii) t_1/s: 19.59, 19.68

$\bar{t}_1 = 19.6$ s

t_2/s: 40.09, 40.08

$\bar{t}_2 = 40.1$ s

(iii)



$t_2/t_1 = 40.1/19.6 = 2.05$

If the discharge is exponential this should be 2.00. As it differs by only 2.5%, which is acceptable experimental error, it suggests the discharge <u>is</u> exponential.

Question B

(a)	(No mark)		
	$\ln a = -\lambda N + \ln a_o$	✓	**1**
	$y = mx + C$ (not necessary)		
	Do not allow $\ln (a/a_o) = -\lambda N$ as this doesn't contain $\ln a_o$ value		
(b)	Table with units (including ln)	✓	
	Scale readings shown	✓	
	Repeats shown	✓	
	Correct ln to ≥ 2 decimal places	✓	
	Range up to $N_{1/2}$	✓	
	6 values 0.02 in ln (a/cm) [± 0.02 if ln (a/mm)	✓✓	
	[4 values → ✓]		
	[If $N_{1/2} = 10$ then 5 values = 2 marks]		**7**
(c)	<u>Sensible scale</u> (occupying at least ½ the grid in each direction, avoiding 3's etc.) with axes labelled (ignore units)	✓	
	<u>Plots:</u> Accurate to at least ½ square	✓	
	<u>Line:</u> Sensible line of best fit	✓	
(d)	Should be <u>straight line</u> with <u>negative gradient</u>	✓	
	Description of their line	✓	
	<u>hence</u>		
	sensible interpretation [must indicate if scatter or non-linear region]	✓	**3**
	Max 2/3 if straight line 'fixed'		
(e)	Large Δ ($\Delta x \Delta y \geq 80$ cm^3)	✓	
	Correct calculation with <u>no unit</u>, <u>not</u> negative and <u>2</u> significant figures	✓	**2**
			16

Sample results

(a) $N_{1/2} = 8$

$$a = a_o e^{-\lambda N}$$

$$\ln a = -\lambda N + \ln a_o$$

$$y = mx + C$$

(b)

N	Scale readings at max. displacement/cm		a/cm	ln (a/cm)
0	20.0	20.0	10.0	2.30
1	19.3	19.1	9.2	2.22
2	18.7	18.5	8.6	2.15
3	18.1	17.9	8.0	2.08
4	17.4	17.6	7.5	2.01
5				

17.1
16.9
7.0
1.95

6
16.7
16.5
6.6
1.89

7
16.1
16.3
6.2
1.82

8
15.8
16.0
5.9
1.77

(c) See graph

(d) Should be straight line with negative gradient.

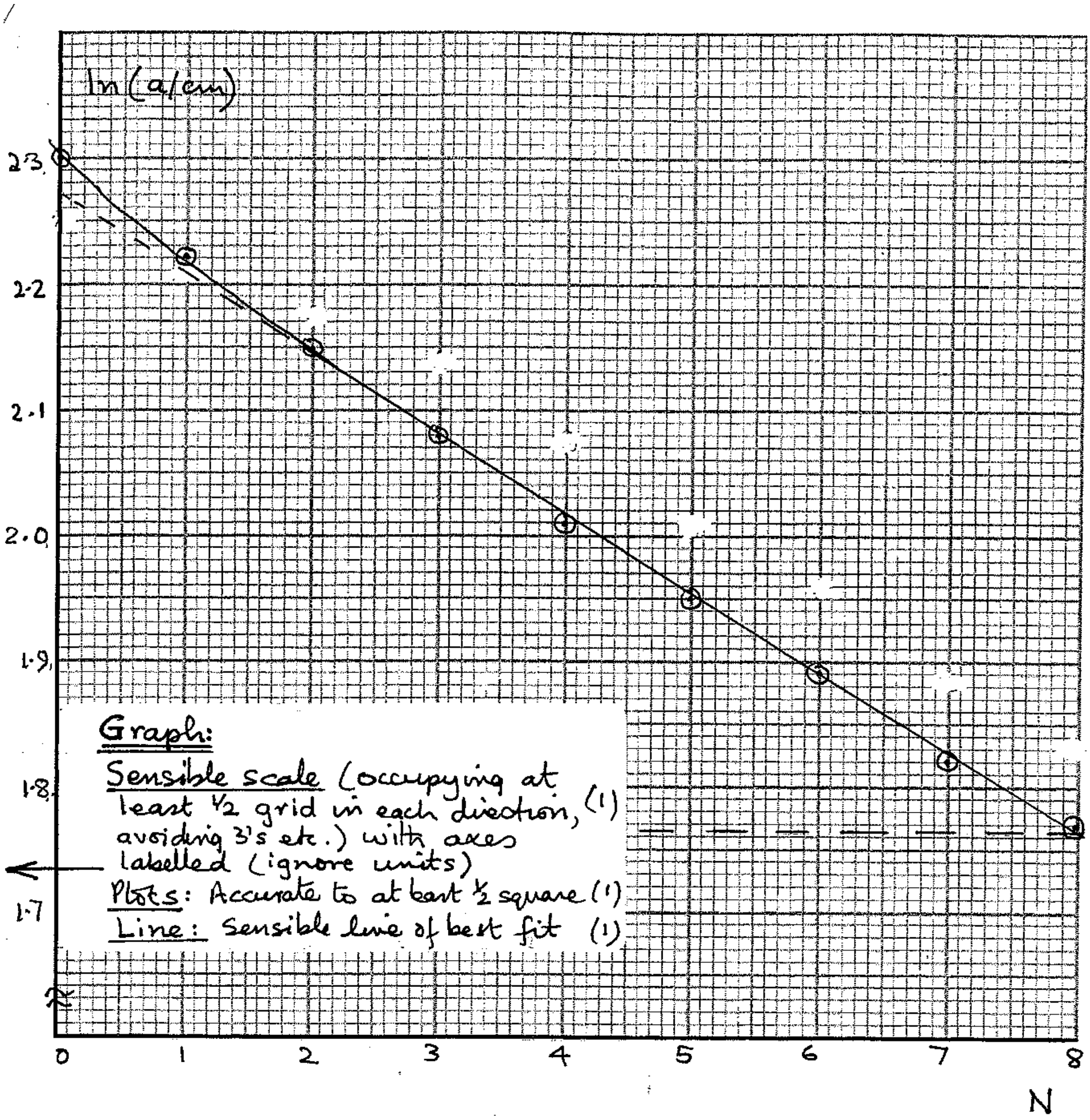
This is not entirely the case, but would seem to support the assumption for larger values of N.

(e)

$$\text{Gradient of linear part} = \frac{2.270 - 1.765}{0.00 - 8.00}$$

$\lambda = 0.063$

Question (iii)



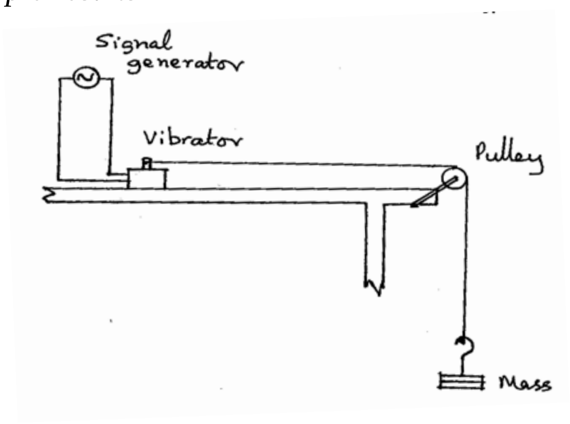
Question C

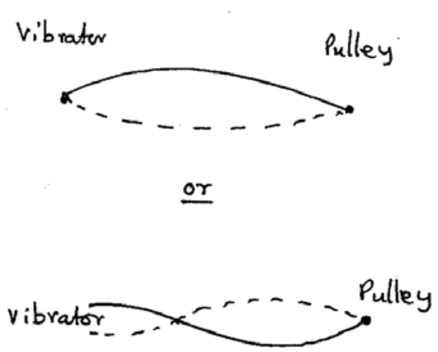
(a)		Signal generator connected to vibrator	✓	
		Correctly orientated string connected to vibrator and passing over pulley with suspended mass at other end	✓	
		[A vertical arrangement is acceptable provided the vibrator is horizontal]		
		Correct shape	✓	
		Vibrator and pulley marked and labelled correctly	✓	
		Keep length of string between vibrator and pulley constant	✓	
		Vary mass on mass hanger	✓	
		Vary frequency until max. amplitude of oscillation is observed	✓	
		Record frequency at resonance	✓	
		Approach resonance from both directions	✓ **[max]**	
				8
(b)	(i)	Correct T values with unit (2/3 decimal places / 3 significant figures)	✓	
		Correct $\sqrt{T}$ values with unit (here, or on graph)	✓	
		Graph: axes reversed (−1) or wrong graph plotted (−1)		
		Scale: at least ½ grid in both directions, avoiding 3's etc.	✓	
		Axes: labelled with units ; e.c.f. from table for $\sqrt{T}$	✓	
		Plots: accurate to at least ½ square	✓	
		Line: good straight line of best fit	✓	**6**
	(ii)	The graph is a straight line but it does not go through the origin.	✓	
		Discussion of systematic error **or** constant term in equation	✓	**2**
		Max. ½ if line fixed through origin		

‘False’ origin 0/2 **16**

Sample results

(a)





Keep length of string between vibrator and pulley constant

Vary mass on mass hanger

Vary frequency until max. amplitude of oscillation is observed

Record frequency at resonance

Approach resonance from both directions

(i) *M* / g 1.96
1.40
f / Hz 250
T / N 11.8
2.45
$\sqrt{T}$ / $N^{1/2}$ 1.57

50
4.9

0.4
9
0.7
0

10
0
7.2
0.9
8
0.9
9

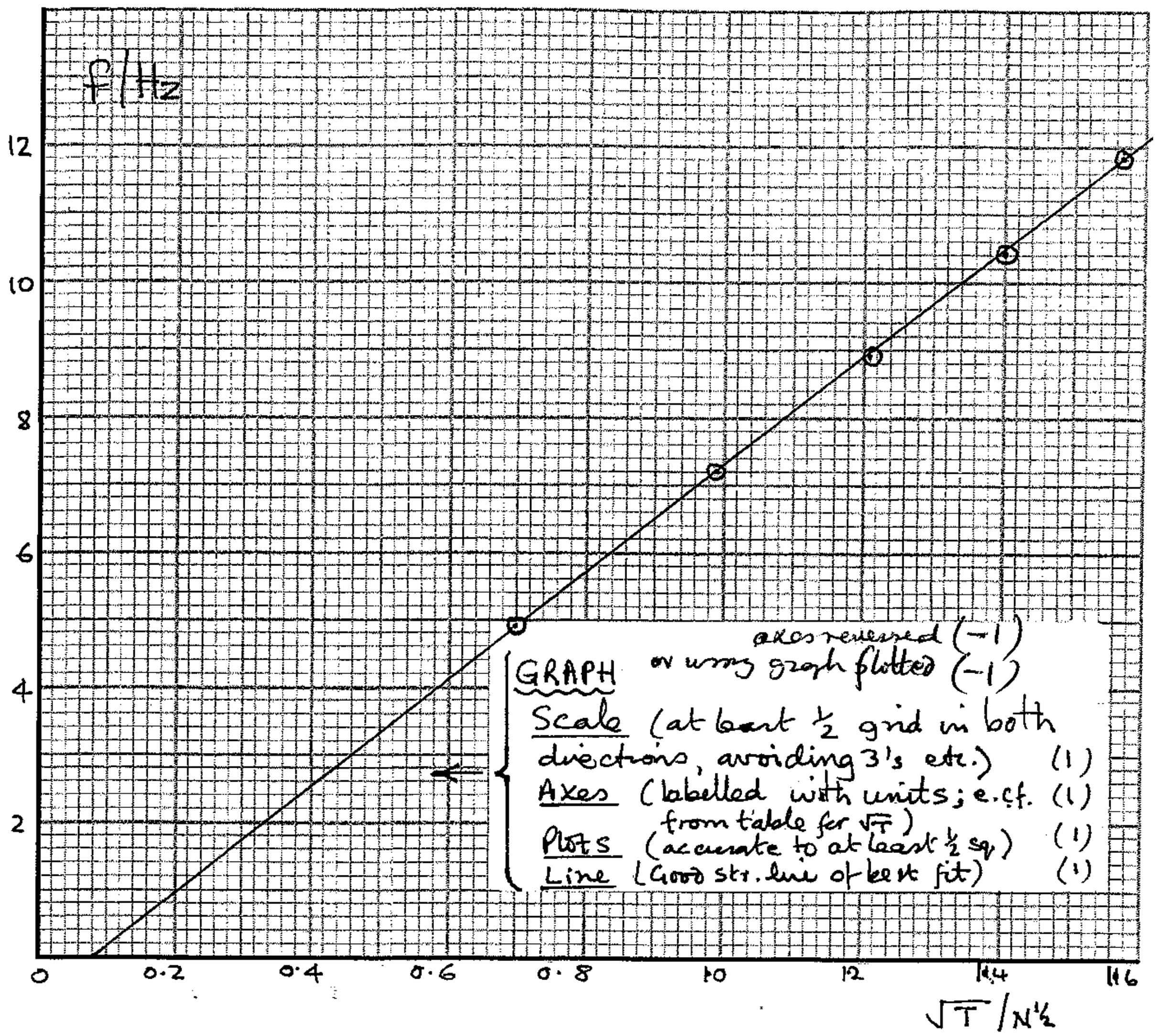
15
0
8.9
1.4
7
1.2
1

20
0
10.
4

See graph

(ii) The graph is a straight line but it does not go through the origin. If this is due to systematic error, the graph could support the suggested equation, or else there is a constant term in the expression.

Question (i)

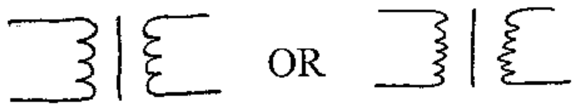

f/Hz
12
10
8
6
4
2
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
√T /N½
axes reversed (−1)
GRAPH or wrong graph plotted (−1)
Scale (at least ½ grid in both directions, avoiding 3's etc.) (1)
Axes (labelled with units; e.c.f. from table for √T) (1)
Plots (accurate to at least ½ sq) (1)
Line (Good str. line of best fit) (1)

6736 Unit Test PHY6

1.	(a)	(i)	Betatron is a circular/ring accelerator, Van de Graaff is a linear accelerator	✓	
		(ii)	Electrons move (in circles of) constant radius	✓	
			Magnetic field is varied	✓	
			Electrons given energy all the way round/by a tangential force	✓	
			OR		
			Electrons spiral outwards/radius increases	✓	
			Magnetic field is constant	✓	
			Electrons given energy (only) as they cross gap	✓	**4**
	(b)	(i)	Fleming/left hand rule/$Be\upsilon$/ $Bq\upsilon$/ magnetic field	✓	
		(ii)	$m\upsilon^2 / r_0 = Be\upsilon$	✓✓	
			$\Rightarrow r_0 = m\upsilon/Be$ [No mark]		
			To keep r_0 constant B must increase with $m\upsilon$ / $B \propto m\upsilon$ / B up as $m\upsilon$ up	✓	**4**
	(c)	(i)	Magnetic flux/ϕ = BA/magnetic flux density perpendicular to area times area	✓	
			$\phi = \pi r_0^2 B_{av}$	✓	
		(ii)	$eBr_0 = e\phi/2\pi r_0$	✓	
			$\Rightarrow \phi = 2\pi r_0^2 B_0$	✓	
			Therefore $B_{av} = 2B_0$ the magnetic field at the orbit	✓	**5**

(d)		$m\upsilon = e\phi/2\pi r_0 \Rightarrow \phi = 2\pi r_0 m\upsilon/e$	✓	
		Units for ϕ are m kg m s^{-1} C^{-1}	✓	
		Use of C = A s	✓	
		Unit for B is unit of $\phi \div A$ = kg s^{-2} A^{-1}	✓	
		Use of N = kg m s^{-2}	✓	**Max 4**
(e)	(i)	S above, N below	✓	
		Use of FLHR or equivalent	✓	
		Electrons are negatively charged/ref electron and conventional current	✓	
	(ii)	Right hand grip rule produces B-field down/Lenz's law	✓	
		so trying to reduce/oppose electromagnet	✓	**5**
(f)	(i)	20×10^6 eV ÷ 180 eV i.e. correct ratio	✓	
		$= 1.1 \times 10^5$		
		1.1×10^5 [ecf] $\times 2\pi$ 0.85 m	✓	
		= 590 km/5.9×10^5 m		**2**
	(ii)	Use of $\Delta E = c^2 \Delta m$ e.g.		
		$\Delta m = 3.2 \times 10^{-12}$ J ÷ $(3.0 \times 10^8 \text{ m s}^{-1})^2$	✓	
		= 3.6 / 3.55×10^{-29} kg	✓	
		aware mass = rest mass/$m_e + \Delta m$	✓	
		Use of $m_e = 9.1 \times 10^{-31}$ kg	✓	
		$\Rightarrow \Delta m/m_e \approx 39/40$	✓	**5**

(g)

 ✓

(not a drawing of a transformer)

[not needed]

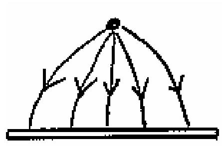
P is the coil of the electromagnet ✓

S is the circle/loop/orbit of the electrons ✓ **3**

32

2. (a) (i) Curved lines ✓

Arrows correct ✓



(ii) Average *E*-field is 3.2×10^6 V m^{-1}/calculation of *E* shown ✓

but field is stronger where lines are closer ✓ **4**

(iii) α-particle ionises air molecules ✓

ions/electrons move towards wire/plate ✓

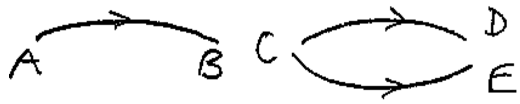
gaining energy/accelerating ✓

causing more ionisation/an avalanche ✓

leading to a spark [No mark] **Max 3**

(b) (i) CD and CE oppositely curved ✓

All correct ✓



B-field:

to learn charges (of particles) ✓

to deduce momentum (of particles) ✓

(ii) Any neutral particle [eg n ^1_0n γ π^0 etc] ✓

as they do not produce ionisation ✓ **6**

(c) Advantages:

Can record many times per second ✓

Data is fed to computer/no need for processing photos/no need to control T or p etc ✓

Speed of particle can be deduced ✓ **Max 2**

15

3. (a) (i) (gas consists of) lots of tiny particles/atoms/molecules ✓

in (rapid) random motion ✓

Particles occupy no volume ✓

do not attract each other ✓

time in collisions is negligible ✓

collide elastically ✓ **Max 4**

(ii) $p = \frac{1}{3}\rho \bar{c}^2$ and $\upsilon = \sqrt{(\gamma p / \rho)}$

Substitute for p, ρ or p / ρ ✓

$\Rightarrow \upsilon^2 = \frac{\gamma}{3}\bar{c}^2$ ✓

$\upsilon = \sqrt{(1.4 \div 3)}\ \sqrt{\bar{c}^2} = 0.68\ \sqrt{\bar{c}^2}$ ✓

υ could not be greater than $\sqrt{\bar{c}^2}$ as sound travels by the passing on of compression/rarefaction waves ✓ **4**

(b) (i) Ideal gas:

Energy = 3/2 (1.4 × 10^{-23} J K^{-1})(293 K)

Any value of T from 273 K – 313 K ✓

= 5.7 to 6.6 × 10^{-21} J ✓

<u>Either</u> visible photon energy: use of $E = hc/\lambda$ ✓

Any value of λ from 3 × 10^{-7} m – 8 × 10^{-7} m ✓

<u>Or</u> visible photon energy: use of $E = hf$ ✓

Any value of f from 4 ×10^{14} Hz – 1 × 10^{15} Hz ✓

$\Rightarrow$ 6.6 to 2.5 × 10^{-19} J ✓ **Max 4**

(ii)	Quality of written communication	✓	
	Neither gas molecule nor visible photon has enough energy to ionise air (molecules)	✓	
	Quantitative support i.e. 10 eV = 1.6×10^{-18} J	✓	
	Ions could be formed from flames/very hot surfaces/sparks	✓	
	Ions could be formed by radioactive materials / X-rays / UV light	✓	**Max 4**
			16

4. (a) (i) $F = kx \Rightarrow k = \dfrac{(0.40\text{ kg})(9.8\text{ N kg}^{-1})}{0.25\text{ m}}$ ✓

$= 16\text{ N m}^{-1}/\text{ kg s}^{-2}$ [15.7/16] ✓

(ii) $T = 2\pi\sqrt{\dfrac{m}{k}} = 2\pi\sqrt{\dfrac{0.40\text{ kg}}{16\text{ N m}^{-1}}}$ = 0.99 s / 1.00 s / 1.0 s / 1 s ✓

(iii) Mention of force/acceleration proportional to displacement ✓

Big oscillations mean high velocities/speeds ✓

so large distance covered same time as for small ✓ **6**

[Accept inverse argument]
[*T* independent is a general property of s.h.m. ⇒ 1/3]

(b) (i) Mention of magnetic flux/field ✓

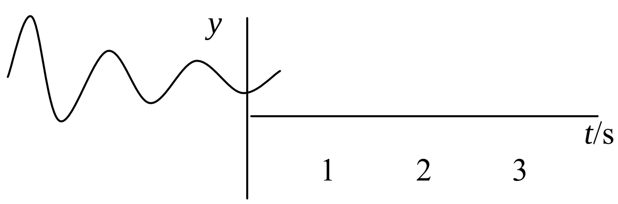
Induced e.m.f./current/p.d. or eddy current/induced N pole in cylinder ✓

I^2R OR equivalent heating ✓ **3**

(ii) *y*-*t*(s) up to 3 s/ 3*T* ✓

Reducing y_0 ✓

Approximately constant *T* ✓ **3**



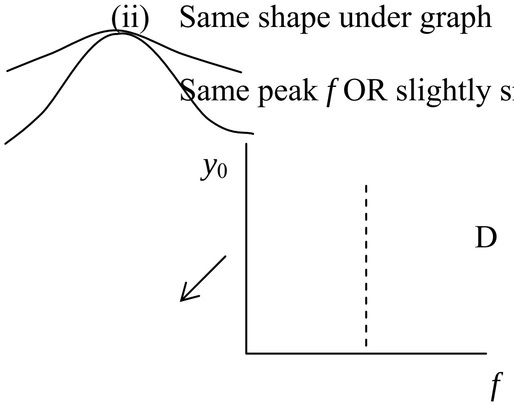
(c) (i) Mention of resonance ✓

Maximum energy transfer OR natural frequency equal to driving frequency ✓

$f_r = 1/T = 1.0$ Hz/1 Hz [e.c.f. T in (a)(ii)] ✓

(ii) Same shape under graph ✓

Same peak f OR slightly smaller [independent] ✓ **5**



17