SECTION A: 1 mark for each unit / sig. fig problem (up to 5 marks each)

SECTION B: ½ mark each time (up to 2 marks each)

(Don't want to penalise for intermediate unit problems)

SIG FIG: between 2 and 4

Only "figuratively" - allow leniency.

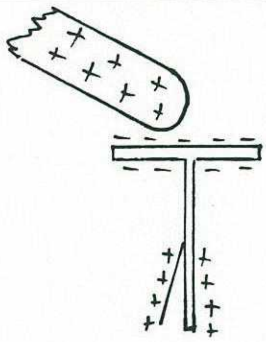
TEE PHYSICS 1991

LES STANNING
309 2948

DRAFT SOLUTIONS

SECTION A

1. a) Drawing of charges on the diagram (2 marks)



Can accept electric field set up inside electroscope will cause leaf to rise.

b) The positively charged rod attracts electrons to the pole, which causes a positive charge to appear on the leaves. The leaf diverges since the positive charges repel. (2 marks)

accept "like charges repel"

2. a) The power consumed by the toaster is given by $P = VI$ so

$$I = {}^{P}/_{V} = 2 \times 10^3 / 250 = 8.00 \text{ A} \quad (1) \quad (1)$$ (2 marks)

b) Now current is coulombs per sec. Thus the number of electrons per second is (1)
$8 / 1.6 \times 10^{-19} = 5 \times 10^{19}$.
In 120 seconds a total of $120 \times 5 \times 10^{19} = 6.00 \times 10^{21}$ electrons flow through the toaster. (1)

(2 marks)

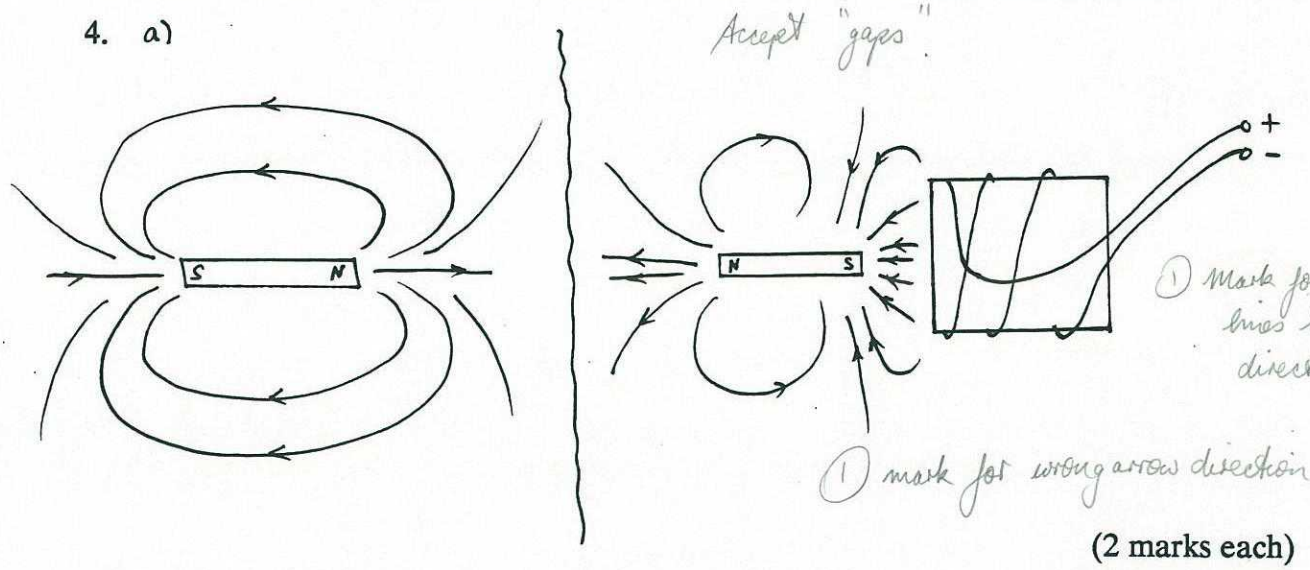
(1)

3. a) The power generated in the light bulb is $VI = 110 \times 0.37$ W. Thus the light energy generated is
$$P = 0.01 \times 110 \times 0.37 = 0.407 \text{ W} \quad (1)$$ (2 marks)

b) The remainder of the energy is dissipated as heat. / radiation (2 marks)

4. a)

Accept "gaps".



(1) mark for correct lines but wrong direction.

(1) mark for wrong arrow direction

(2 marks each)

5. a) Synthetic shirts tend to acquire a static charge. (1 mark)

This charge induces an opposite charge on your body and the shirt is attracted to it. Must mention attraction!
(1 mark)

b) The crackling noise is caused by sparks (electric discharge) jumping between the shirt and your body.
(2 marks)

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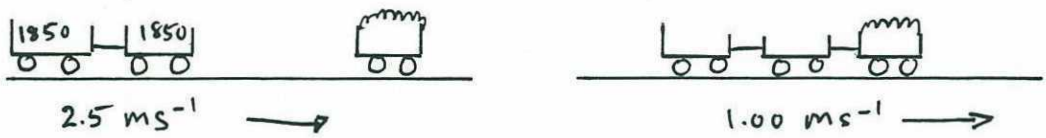
6. Taking the upwards direction as positive, the change in momentum is

$= m v_2 - m v_1$ (1 mark)
$= 0.055 \{ 4.5 - (-5.5) \}$
$= 0.55 \text{ kgms}^{-1}$ (2 marks)

The direction of the change in momentum is upwards. (1 mark)

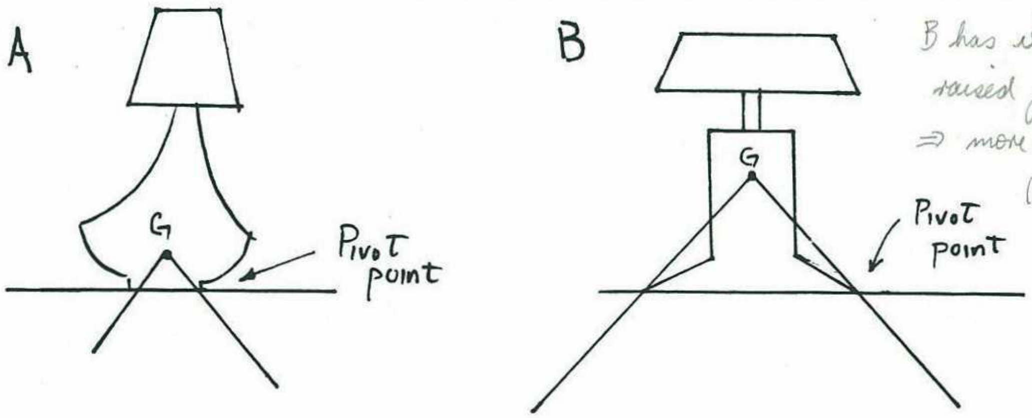
7.



initial momentum = final momentum (1 mark)
$2 \times 1850 \times 2.5 = (3 \times 1850 + m) \times 1.00$ — ① for each statement 2 (~~1~~ mark)

$m = 2 \times 1850 \times 2.5 - 3 \times 1850 = (5 - 3) \times 1850$
$= 3700 \text{ kg}$ (~~2~~ 1 marks)

8.



B has its C. of G. raised further. ⇒ more stable (FULL MARKS)

a) Lamp B is more stable. (1 mark)

b) Construction lines. + labels. (1 mark)

From the construction lines, it can be seen that lamp B has to be tipped further before it will fall over. When the vertical line passing through the centre of mass passes through a pivot point, the lamp is on the verge of falling over. It can be seen from the diagrams that lamp B has to be tipped further before this will happen.
(2 marks)

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9. If the frequency for (i) is f, the frequency for (ii) is $3f$ and the frequency for (iii) is $5f$.

2 (~~1~~ mark)

Thus the frequency for (i) is 170 Hz and for (iii) is 850 Hz.

2 (~~3~~ marks)

Answers + no working ⇒ FULL MARKS.

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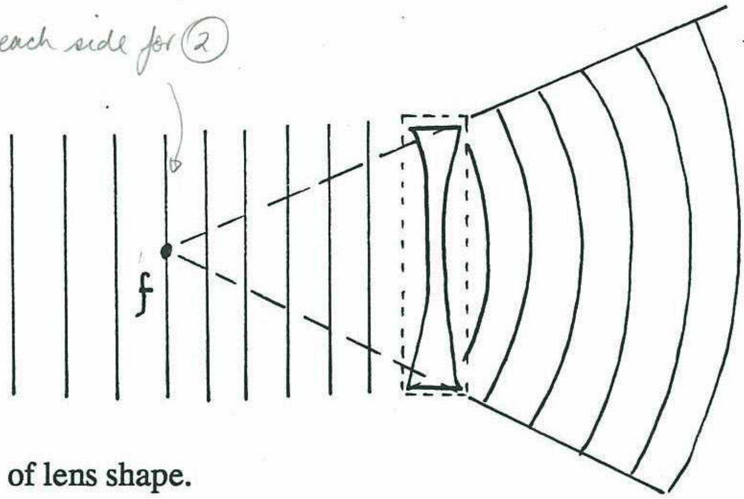
10. Allow 1λ each side for (2)

Construction lines are not necessary.



Other focal point is also correct.

a) i) Sketch of lens shape. (1 mark)

ii) Approximate position of focal point. (2 marks)

b) These lenses are called <u>diverging</u> or <u>concave</u>. (1 mark)

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11. a) The force exerted on a current-carrying wire by a magnetic field is

$$F = i \ell B \quad \text{(1 mark)}$$
$$= 0.5 \times 0.1 \times 0.45 \times 10^{-6}$$
$$= 2.25 \times 10^{-8}\ \text{N} \quad \text{(1 mark)}$$

b) The orientation is important; the maximum force is obtained when the wire is perpendicular to the magnetic field. (Bare minimum)

(2 marks)

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12. **Conclusion 1 :** There is no electric field and no magnetic field in the region. (1 mark)

Conclusion 2 : There is no electric field in the region and the electron is moving parallel to the magnetic field. (1 mark)

Conclusion 3 : The electron is moving ~~parallel~~ perpendicular to the electric field and perpendicular to the magnetic field such that the forces exerted by the two fields are equal and opposite and they cancel. (2 marks)

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13. Since the activity has decreased by a factor of 8, it has halved three times. — can be 1 sig fig. ⇒ 9 is OK as answer.

(2 marks)

Thus the half life is one-third of 27 hours, i.e., 9.00 hours.

Doesn't have to show working. (2 marks)

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14. a) The energy of the photons is

$$E = h\nu = \frac{6.63 \times 10^{-34} \times 7.2 \times 10^{14}}{1.6 \times 10^{-19}} = 2.98 \text{ eV}$$

Since this energy is greater than the work function of the material, each photon can generate a photoelectron. Thus the maximum rate for the emission of photoelectrons is $1.00 \times 10^{8}\ s^{-1}$. (2 marks)

b) The energy of the photons is

$$E = h\nu = \frac{6.63 \times 10^{-34} \times 1.3 \times 10^{14}}{1.6 \times 10^{-19}} = 0.53 \text{ eV}$$

Since this energy is less than the work function, it is not possible to generate photoelectrons, and none can be emitted. (2 marks)

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15. a) $_{92}U^{235} + {_0n^1} \dashrightarrow {_{56}Ba^{141}} + {_{36}Kr^{92}} + \boxed{3\ {_0n^1}} + 200 \text{ MeV}$ (2 marks)

b) This is a **fission** reaction (spelling important) $_0^3x$ - 1 (1 mark)

c) The missing particles are **neutrons.** (1 mark)

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16. For an electron going from the n = 5 energy level to the n = 1 energy level, the change in energy is

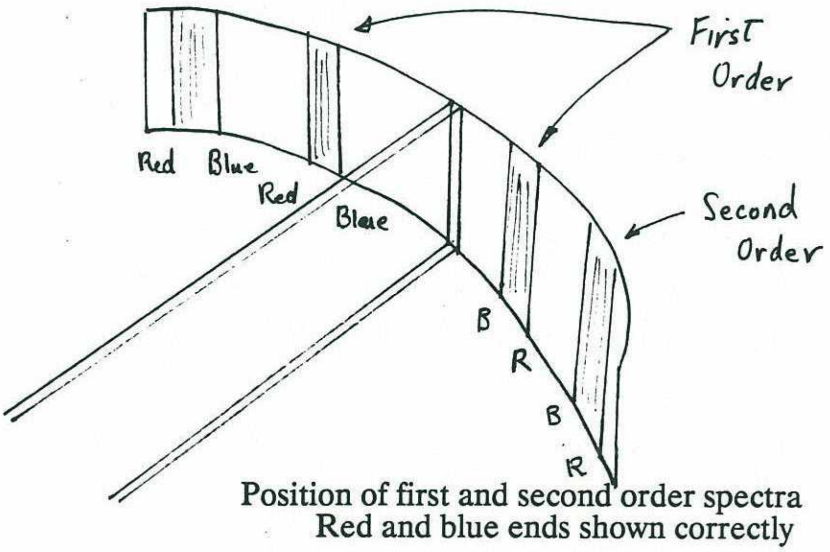
1 $-0.54 - (-13.58) = 13.04$ eV (1 mark)

$\lambda = {}^{hc}/_{E} = 6.63 \times 10^{-34} \times 3 \times 10^{8} / \{13.04 \times 1.6 \times 10^{-19}\}$

$= 95.3$ nm - 1 9.53×10^{-9} m (2 marks)

This photon is in the ultraviolet region. (1 mark)

17.



a) Position of first and second order spectra (2 marks)
b) Red and blue ends shown correctly (2 marks)

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18. Diagram (2 marks)

Grid reference value is (9,9) ← Full marks with no construction lines. (2 marks)

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units not important

19. a) Slope = $(2.9 - 0) / (5 - 0)$ Ns^{-2} = 0.58 (± 0.2?) (1 mark)

b) The centripetal force required to keep the stopper rotating in a circle is

$$F = m v^2 / r$$

$$v = 2\pi r / T \text{ so } F = 4\pi^2 m r / T^2$$ — 1

Thus the slope of the graph is $4\pi^2 mr$. From this we can work out the mass of the rubber stopper as 1

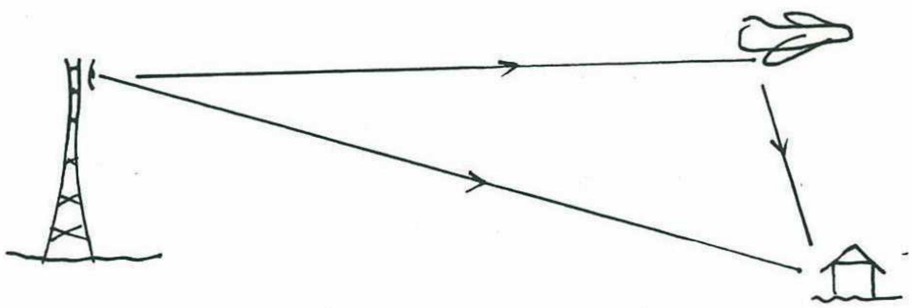
$$m = \text{slope} / 4\pi^2 r = 0.58 / 4\pi^2 \times 0.3$$
$$= 49.0 \text{ g}$$ — 1

(3 marks)

(Accept answers within a range of ±5 g)

20.

Interference — 1



Be lenient. Personal judgement.

Lines on diagram showing paths of TV waves. (2 marks)

Some radiation travels directly to the house and some is reflected off the aircraft. The radiation reflected from the aircraft travels further than the waves going directly from the transmitter to the house. Thus the two waves can interfere, producing alternate constructive and destructive interference as the position of the aircraft changes. 4 (2 marks)

most important.

MULTIPLE CHOICE QUESTIONS

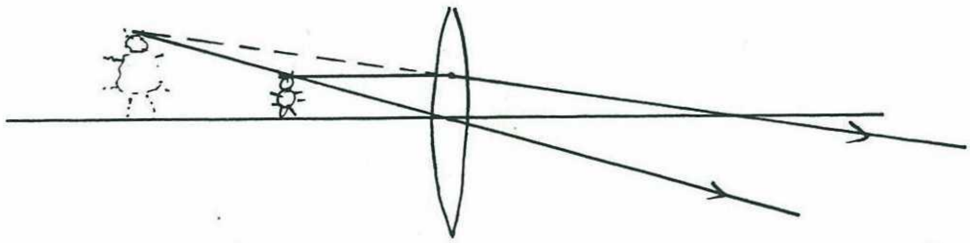
21. A 24. D 27. B 29. D

22. C 25. C 26. D

23. D 28. C 30. C

SECTION B

1. a)



(1)

(1 mark)

b) The image is virtual, on the same side of the lens as the ant, ~~and magnified~~.

(1 mark)

The position of the image is found from

$$^{1}/_{f} = {^{1}/_{u}} + {^{1}/_{v}}$$

$$^{1}/_{f} = {^{1}/_{17}} - {^{1}/_{13}} = {^{1}/_{55.2}} \quad - (1)$$

$m = \left|\frac{v}{u}\right|$

$= 4.25 \quad - (1)$

Thus the image is 55.2 mm from the lens. same side of lens. (~~1~~ 2 mark)

c) As the lens is moved further away from the ant, the image moves further away from the lens and increases in size. increase in magnification — (1) 1 (~~2~~ marks)

spherical aberration. — (1)

d) The magnification of any lens is limited absolutely by its focal length, but for this lens, spherical aberration will cause the image to become blurred as the magnification increases. (1 mark)

absolute magnification = $1 + \frac{25}{f}$

2. a) $f_1 / f_2 = \sqrt{T_1} / \sqrt{T_2}$

For the string with T_2 = 196 N

$$f_2 = f_1 \{ \sqrt{T_1} / \sqrt{T_2} \} = 320 \times \sqrt{\{ ^{196}/_{200} \}}$$
$$= 317 \text{ Hz}$$

Similarly, for the other string,

$$f_2 = 320 \times \sqrt{\{ ^{204}/_{200} \}} \times 320$$
$$= 323 \text{ Hz}$$

(2 marks)

b) When the two strings are sounded together, you will hear the sound increase and diminish in intensity six times per second since the sound waves coming from the two strings alternate between constructive and destructive interference.

need 6 beats/sec for (2)

(2 marks)

c) The name of the phenomenon is *beats*.
You can use it for tuning by tightening or loosening the strings so that the beat frequency gets smaller and smaller.

(2 marks)

3. a) The *mass defect* is the difference between the mass of the particles (nucleons) which combine to form a nucleus and the mass of the nucleus.
Binding energy is the energy which holds the nucleus together. (2 marks)
energy released as the nucleus is formed / energy equivalent to mass defect.

Poorly worded

b) When the nucleons combine to form a nucleus, their net mass is greater than the mass of the nucleus. This extra mass has been converted into the binding energy used to hold the protons and neutrons together in the nucleus. 1 (~~2~~ marks)

c) The nucleus of ${}_{16}S^{32}$ consists of 16 protons and 16 neutrons. The net mass of these particles is

$$m_{nucleons} = 16 \times 1.007825 + 16 \times 1.008665 = 32.26384 \text{ amu}$$ — (1)

The mass defect is

$$m_{nucleons} - m_{nucleus} = 32.26384 - 31.98224 = 0.2816 \text{ amu}$$

2 (~~1~~ mark)

If electrons are used, give full marks.

This mass is equivalent to an energy $E = m c^2$. Converting the mass to kg and the energy to eV

$$\text{Binding energy} = 0.2816 \times 1.66 \times 10^{-27} \times (3 \times 10^8)^2 / 1.6 \times 10^{-19} \text{ eV}$$
$$= 262.944 \text{ MeV}$$

This is the binding energy of the whole nucleus. Dividing this by 32 gives the binding energy per nucleon, which is 8.22 MeV per nucleon. (2 marks)
(1.32×10^{-12} J/nucleon) (8.19 MeV (using 931 MeV = 1u))

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4. a) The gravitational attraction is (1)

$$F = G M m / d^2 = 6.67 \times 10^{-11} \times 6.55 \times 10^3 \times 187.5 / 64$$
$$= 1.28\ \mu N$$ 1.28×10^{-6} N (2 marks)

b) The astronaut could get back to the space ship by pushing the tool box in a direction directly away from the ship. To travel 10 m in 20 seconds requires a velocity of 0.5 ms^{-1}. (1 mark)

Direction worth (1)

The velocity which must be given to the tool box in order to give the astronaut this velocity can be calculated from the conservation of momentum

$$(m_A + m_b)\, v_{both} = m_A v_A + m_b v_b$$ 1 (~~2~~ marks)

where the subscripts A and b refer to the astronaut and toolbox respectively. Thus

(1) for -ve.

$$187.5 \times 0.35 = 170 \times -0.5 + 17.5 \times v_b$$

$$v_b = \{187.5 \times 0.35 + 170 \times 0.5\} / 17.5$$
$$= 8.61 \text{ ms}^{-1}$$

Thus the astronaut has to kick the box away at a velocity of 8.61 ms^{-1}. (This velocity is relative to the space shuttle. Relative to the astronaut, the velocity is 9.11 ms^{-1}.) 3 (~~2~~ marks)

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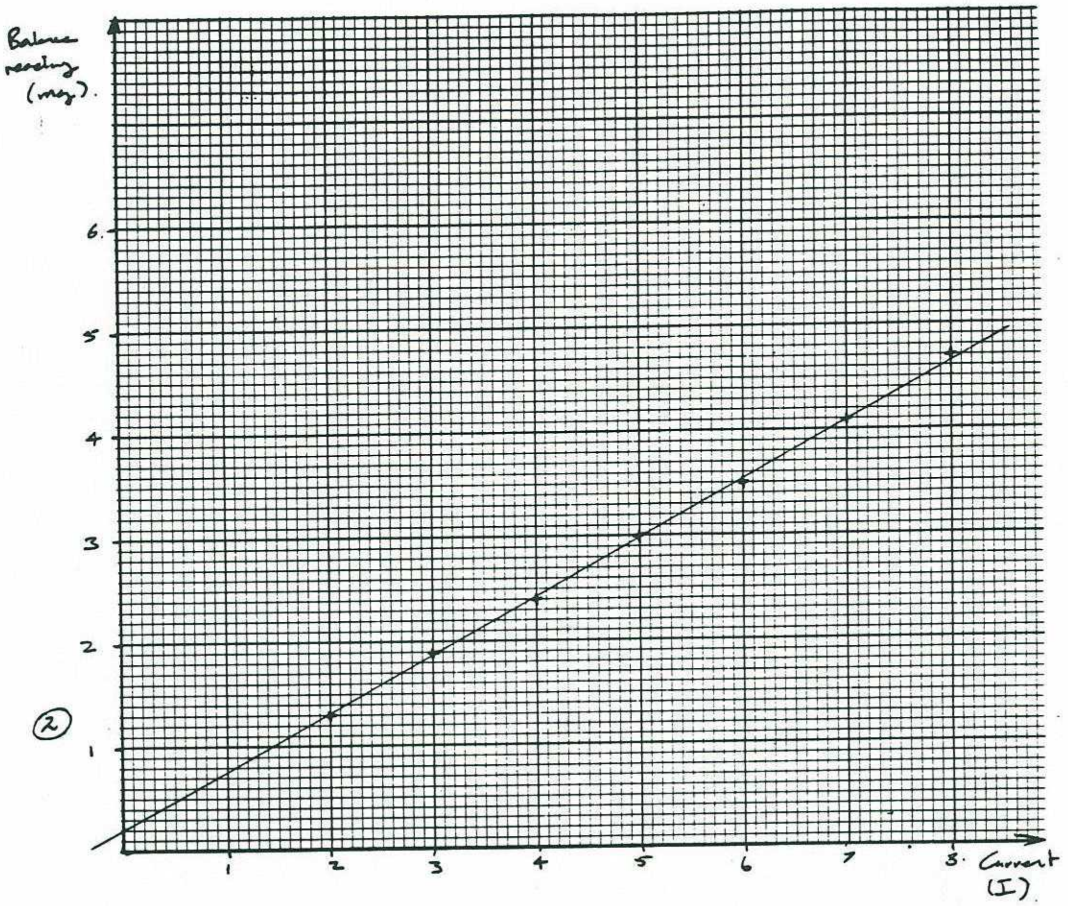
5. a)



slope = $\frac{mg}{I}$ = 5.576×10^{-7}

Data plotted on graph. (2 marks)

b) The slope of the graph is

$$(8 - 1.4) / \{ (\overset{4.68}{\cancel{4.18}} - 1.0) \times 10^{-6} \} \text{ Akg}^{-1} \quad = 1.793 \times 10^{6}$$ (1 mark)

The force exerted by the current is

$$F = i \ell B = m g$$

where i is the current, M is the length of the wire and B is the magnetic field. Thus

$$i = \{ {}^{g}/_{\ell B} \} m$$ (1 mark)

From this, we can see that the slope of the graph is equal to ${}^{g}/_{\ell B}$. Rearranging terms,

$$B = {}^{g}/ (\ell \times \text{slope})$$
$$= \{ 9.8 / 36.5 \times 10^{-3} \} \times \{ 3.18 \times 10^{-6} / 6.6 \}$$
$$= \overset{148}{\cancel{129}} \ \mu T \quad 1.48 \times 10^{-4} \ T \ (\pm 0.2 \times 10^{-4})$$ (2 marks)

c) The most probable reason that the graph does not pass through zero is that the balance was not set to zero for zero current. (Other reasons can be given which are quite acceptable, such as zero error in the ammeter) (1 mark)

zero error in ammeter, any reasonable consistent error, plotting

(Be very lenient)

6. a) The electric field between the plates is

$$E = 200 / 15 \times 10^{-3} \text{ Vm}^{-1} \quad = 1.333 \times 10^{4}$$

Thus the force exerted on the electron is

$$F = E q = 200 \times 1.6 \times 10^{-19} / 15 \times 10^{-3} \text{ N} \quad = 2.133 \times 10^{-15}$$

Thus the acceleration of the electron is

$$a = F / m = 200 \times 1.6 \times 10^{-19} / \{ 15 \times 10^{-3} \times 9.11 \times 10^{-31} \} \quad = 2.342 \times 10^{15}$$

(2 marks)

The time taken to reach the positive plate can be found from

$$s = u t + \tfrac{1}{2} a t^2$$

so

$$t = \sqrt{\{2 s / a\}}$$

$$= \sqrt{\{(2 \times 7.5 \times 10^{-3} \times 15 \times 10^{-3} \times 9.11 \times 10^{-31}) / (200 \times 1.6 \times 10^{-19})\}}$$

$$= 2.53 \text{ ns}$$

(2 marks)

b) Since the electron is accelerated through 100 V, it will have 100 eV of energy when it arrives at the plate. $= 1.60 \times 10^{-17}$ J.

(1 mark)

($\frac{1}{2}$ mark for "no" in mind) c) It would not take twice the time since although the electron will take the same time as that obtained above to travel the first half of the distance, it will be moving at the instant it starts the second half and so will take a shorter time for this half. Needs an explanation.

(1 mark)

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7. a) When the coil is turned, the amount of magnetic flux which passes through it changes constantly. This change in flux generates an emf which drives a current which generates a magnetic field, whose action is to oppose the change in magnetic flux (by Lenz's law). Thus the system opposes the motion, and this opposition appears as a torque.

(2 marks)

b) i) Increasing the number of turns in the coil effectively increases the change in magnetic flux, so the torque would **increase.**

ii) Increasing the strength of the magnetic field would increase the change in magnetic flux so the torque would **increase.**

Must have reasons. ($\frac{1}{2}$ mark "in mind").

iii) Increasing the value of the resistor would reduce the size of the induced current and hence there will be less opposition to the change in magnetic flux. Thus the torque would **decrease.**

iv) Shorting the resistor would enable a larger induced current to flow. This is exactly the opposite of iii), and so the torque would **increase** (substantially).

(1 mark each part)

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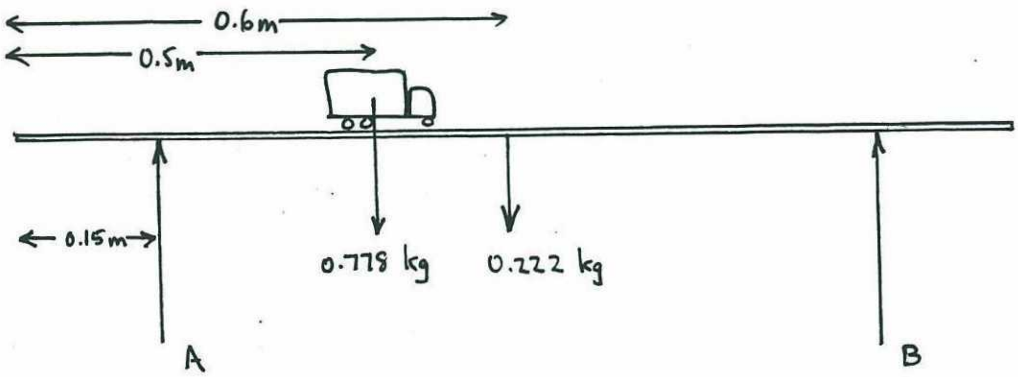
8. a)



Let m_A and m_B be the readings of balances A and B respectively. Now let us calculate the torque about the point where balance A makes contact with the board. The condition for equilibrium is

clockwise torque = anticlockwise torque (1 mark)

$0.778 \times 0.35\,g + 0.222 \times 0.45\,g = m_B \times 0.9\,g$ (1 mark)

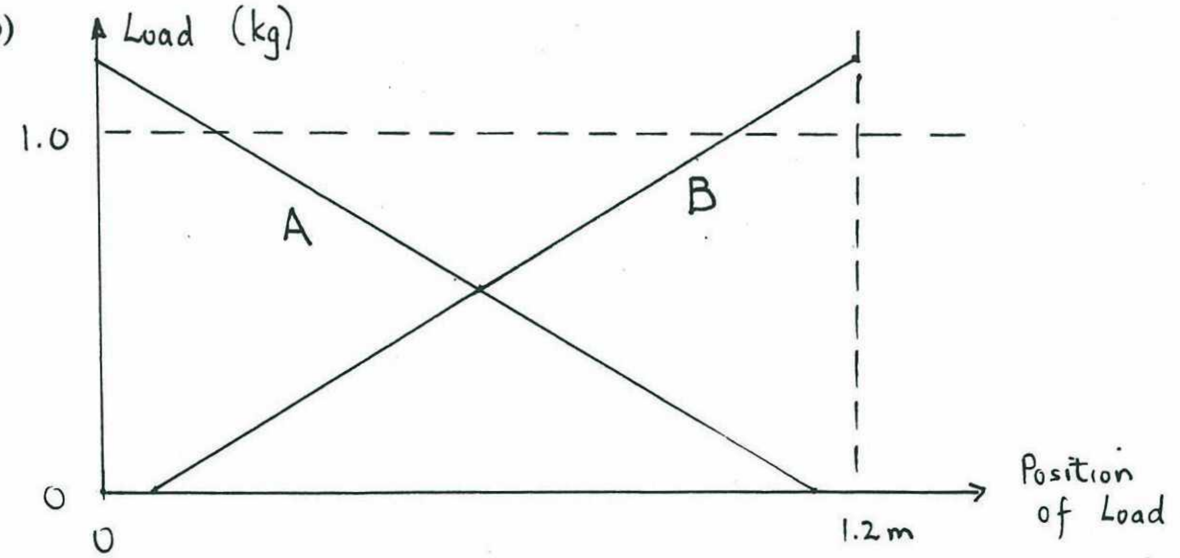
$m_B = (0.778 \times \cancel{0.55}^{0.35} + 0.222 \times 0.45) / 0.9$

$= 0.413$ kg (4.05 N) (1 mark)

The condition for equilibrium of forces gives $m_A + m_B = 1$ kg. Thus the reading of balance B must be 0.586 kg (5.75 N)

(1 mark)

b)



straight line relationship ..... (1 mark)
graph lines in approximately the correct position ..... (1 mark)
two lines add up to 1 kg ..... (1 mark)