INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

MARKSCHEME

November 2000

PHYSICS

Higher Level

Paper 2

22 pages

SECTION A

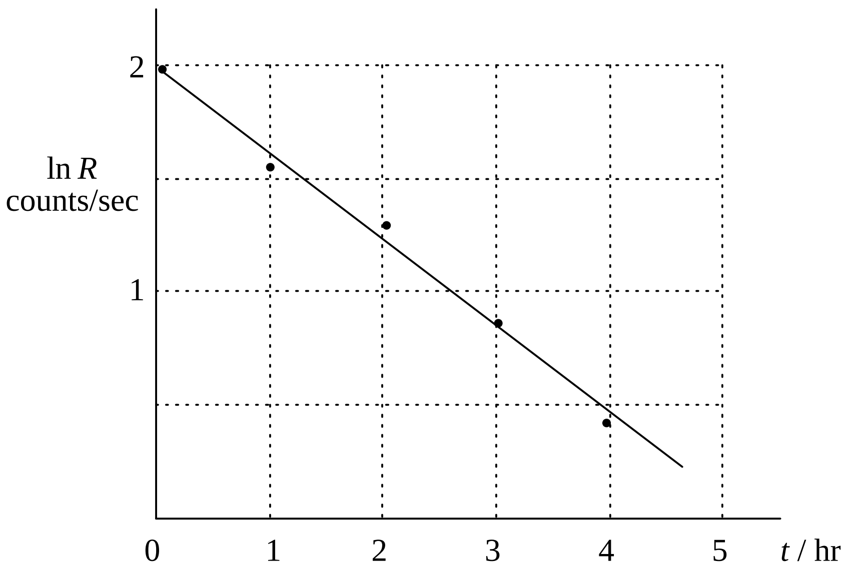
A1. (a) Activity: the number of radioactive disintegrations per unit time. ***[1]***

(b) $A(t) = A_0 e^{-\lambda t}$

$\ln A(t) = \ln A_0 - \lambda t$ ***[1]***

Plot $\ln A$ versus t ***[1]*** ***[2]***

(c)



Yes consistent, since the points lie on a straight line in a semilog plot. ***[1]***

(d) Does not matter since R is proportional to A and hence graph will have the same behaviour characterised by the decay constant. (The semilog graph will have the same slope.) ***[1]***

(e) From (b) above, slope of semilog plot is $-\lambda$.

From graph, slope is $\frac{1.5}{4} = 0.375\ \text{hr}^{-1}$. ***[2]***

(f) Half-life: the time required for the activity to drop to half. ***[1]***

(g) $A(t) = A_0 e^{-\lambda t}$

$A = \frac{A_0}{2}$, when $t = \tau$, *i.e.* $\frac{1}{2} = e^{-\lambda t}$. ***[1]***

So $\ln 2 = +\lambda t$, or $\tau = \frac{\ln 2}{\lambda}$. ***[1]*** ***[2]***

(h) $\tau = \frac{\ln 2}{\lambda} = \frac{0.693}{0.375} = 1.85$ hours. ***[1]***

A2. (a)

Physical System **Free-body Diagrams**

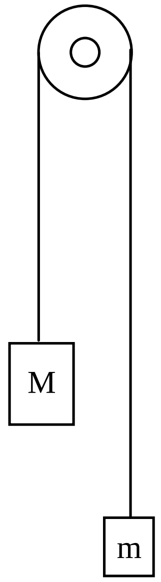


Figure 1

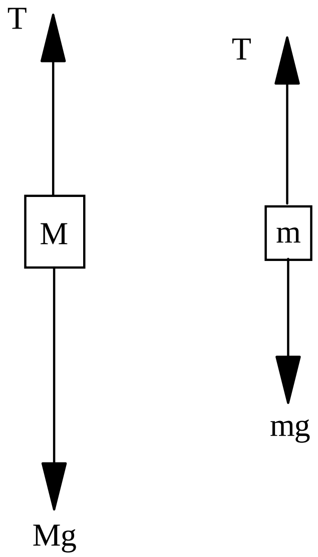


Figure 2

(Award marks as follows:
***[1]** for drawing two opposing forces on each block;*
***[1]** for drawing T less than Mg on M.*
[1]** for drawing T greater than mg on m.)* ***[3]

(b) (i)

Block M	Block m
$Mg - T = Ma$ ***[1]***	$T - mg = ma$ ***[1]***

[2]

(ii) Add the two equations to eliminate T:

$Mg - mg = Ma + ma$, so $(M - m)g = (M + m)a$ ***[1]***

$$a = \frac{g(M - m)}{(M + m)}$$ ***[1]***

To find T substitute a in first equation:

$$Mg - T = \frac{Mg(M - m)}{(M + m)}$$ ***[1]***

$$T = \frac{2Mmg}{(M + m)}$$ ***[1]***. ***[4]***

continued…

Question A2 continued

(c) (i) If M >> m, then M will essentially fall freely, with m having little effect on it. Thus predict accleration $\approx$ g. ***[1]***

Block m will then be accelerated upward at g, which requires that T $\approx$ 2 mg. ***[2]*** ***[3]***

(ii) $a = \frac{g(M-m)}{(M+m)}$ $\rightarrow$ g if M >> m ***[1]***

$T = \frac{2Mmg}{(M+m)}$ $\rightarrow$ 2 mg if M >> m ***[1]*** ***[2]***

A3. (a) Prediction and reasoning both wrong. ***[1]***
Reply: free (conduction) electrons throughout wire all start moving essentially together when the switch is closed. So bulbs light simultaneously. No need for any electron from the battery to have reached the bulbs. ***[1]*** *(Or answers to this effect.)* ***[2]***

(b) All equal brightness. ***[1]***

(c) A and C will get brighter, because the equivalent resistance of the circuit is less, so the current is greater. ***[1]***
B will get dimmer: the circuit current increases so the PD across A and C increases (***[1]***) so PD across B decreases (***[1]***). ***[3]***

(Note: It is incorrect reasoning to say that the current through B decreases since some of the current goes through D. Give ***[1]*** *for this 'local' reasoning, against* ***[2]*** *for the 'global' reasoning above.)*

(d) (i) 3 W. ***[1]***

(ii) Several methods.
One way is to look at resistor arrangement as a potential divider.
PD across B/D is one fifth of 30V since the parallel resistance is $\frac{1}{5}$ of the whole.
So PD across B is $\frac{30}{5} = 6$ V. ***[1]***
Original PD was 10 V.
Now $P = \frac{V^2}{R}$ *i.e. P* proportional to V^2. ***[1]***
So new power is $\left(\frac{6}{10}\right)^2 \times 3\text{ W} = 0.36 \times 3 = 1.08\text{ W}$ ***[1]***

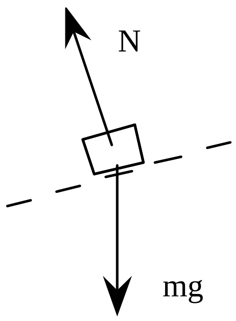
Another way would be to work out the resistance of a bulb (33.3 Ω) and then do a normal circuit calculation of equivalent resistances, currents, voltages and hence power. ***[3]***

SECTION B

B1. Part 1

(a) Yes it has acceleration because its velocity direction is changing ***[1]*** – toward the centre of the track. ***[1]*** ***[2]***

(b) ***[2]***



*(Award **[1]** for weight downward, **[1]** for normal force perpendicular to track. Subtract marks for non-existent or wrong forces.)*

(c) Yes, there is a resultant force: the car is not in equilibrium, but accelerating toward the centre of the circular track. ***[1]*** The resultant force on it is toward the centre, and in the force diagram it would be the resultant of the two forces shown. ***[1]*** ***[2]***

(d) Vertically there is equilibrium: $N\cos\theta = mg$ ***[1]***
Horizontally there is a net force and acceleration:
Net force $= N\sin\theta$ ***[1]***
$=\left(\frac{mg}{\cos\theta}\right)\sin\theta = mg\tan\theta$ ***[1]***
N II: $mg\tan\theta = \frac{mv^2}{r}$ ***[1]***
$v^2 = gr\tan\theta = 10\times30\tan17 = 91.5$ ***[1]***
$v = 9.6\ \mathrm{m\,s^{-1}}$ ***[4]***

Part 2

(a) 'heat gained = heat lost' or equivalent understanding, explicit or implicit. ***[1]***

$m_i\ s_i\ (15°) + m_i\ L_i + m_i\ s_w\ (T-0) = m_w\ s_w\ (30-T)$ ***[1]***
$2\times2.1\times10^3\times15 + 2\times340\times10^3 + 2\times4.2\times10^3\times T = 10\times4.2\times10^3\times(30-T)$ ***[1]***
$63+680+8.4T = 42(30-T) = 1260-42T$
$50.4T = 517$
$T = 10.2\ ^\circ\mathrm{C}$ ***[1]*** ***[4]***

(b) Energy is conserved, but is used to break bonds between molecules in the solid – rather than increasing the KE of the molecules and hence the temperature. ***[2]***
Energy goes into increased intermolecular potential energy. ***[1]*** ***[3]***

continued…

Question B1 continued

Part 3

(a) When two or more waves are present the resultant disturbance at any point is the vector sum of the disturbances due to each wave – or the resultant waveform is the vector sum of the individual waveforms – or words to that effect, showing understanding of superposition. ***[2]***

(b) Point P: Both displacements maximum in same direction hence resultant is double ***[1]***
Point Q: Vector sum OK (may estimate magnitudes). ***[1]***
Point R: Displacements equal and opposite hence cancel to give zero. ***[1]*** ***[3]***

(c) (i) **A**: From graph, period is 1 ms so frequency is 1000 Hz. ***[1]***
B: From graph, period is 0.9 ms so frequency is 1100 Hz. ***[1]*** ***[2]***

(ii) Beat frequency: A maximum intensity every 10 ms so beat frequency is 100 Hz. ***[2]***

(d) (i) This beat frequency is too high to be perceived as loudness variations. ***[1]***

(ii) Frequency difference must be smaller in order to decrease the beat frequency. ***[1]***

(e) Sound string and fork together and listen for beats. ***[1]***
Tune so that beats get slower, meaning string is getting closer to fork frequency. ***[1]*** ***[2]***

B2. Part 1

(a) Forces equal ***[1]***; by Newton's third law. ***[1]*** ***[2]***

(b) Move in the direction of the truck, *i.e.* to the left. ***[1]***
Total system momentum before collision was to the left and must remain so after the collision, by conservation of momentum. ***[1]*** ***[2]***

(c) Momentum before = momentum after (*award* ***[1]*** *for explicit or implied*).

$m \times 60 - 2m \times 60 = (m + 2m)V$ ***[1]***

$-m \times 60 = 3m\ V$

$V = \frac{-60}{3} = -20\ \text{km h}^{-1}$ (*i.e.* $20\ \text{km h}^{-1}$ to the left). ***[1]*** ***[3]***

(d) Car acceleration is greater (***[1]***), because force on car and truck is the same but car mass is smaller (***[1]***). ***[2]***

(e) Car driver.
Because car reverses direction, change of velocity is greater in the same time, *i.e.* acceleration is greater (***[1]***), hence force by seatbelt greater (for same mass person). ***[1]*** ***[2]***
OR: Acceleration of car driver is greater than of truck driver (inferred from (d)) ***[1]***
Hence force by seatbelt greater on car driver (for same mass person of course). ***[1]***

(f) Not violated, since some energy goes into deformation and heat… ***[1]***

Part 2

(a) Average kinetic energy. ***[1]***

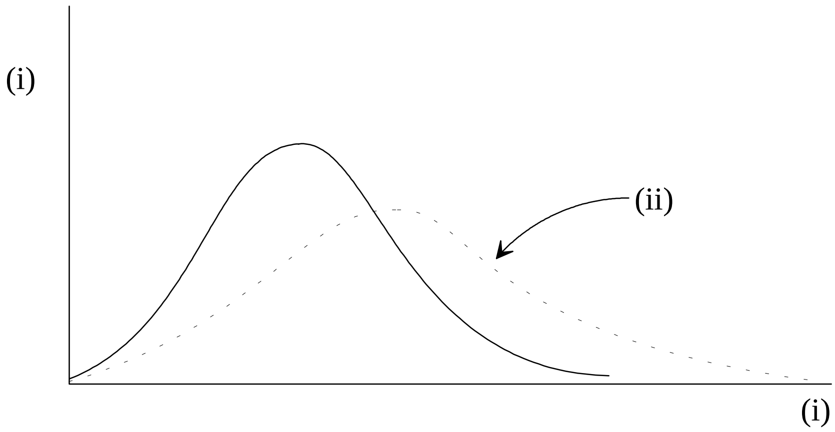
(b) Collisions between molecules changes their motions. ***[1]*** Even if they had the same speed before they interacted, they would not afterward. ***[1]***
(Especially considering they interact at various angles and the velocities change in both magnitude and direction.) ***[2]***

(c) The faster molecules escape from the surface, leaving the slower behind. ***[1]***
Thus the average KE of the molecules remaining is reduced, hence the temperature is lower. ***[1]*** ***[2]***

continued…

Question B2 Part 2 continued

(d) *y*: Relative number of molecules per unit speed interval. ***[1]***
x: Speed ***[1]*** ***[2]***



(Mark graph in conjunction with the explanations:)

- New dotted distribution shown shifted to the right – since molecules are moving faster. ***[1]***
- Max of curve is lower, since total number of molecules is the same – or: is lower since there are more molecules out at higher speeds now, leaving less at the lower speeds. ***[2]*** ***[3]***

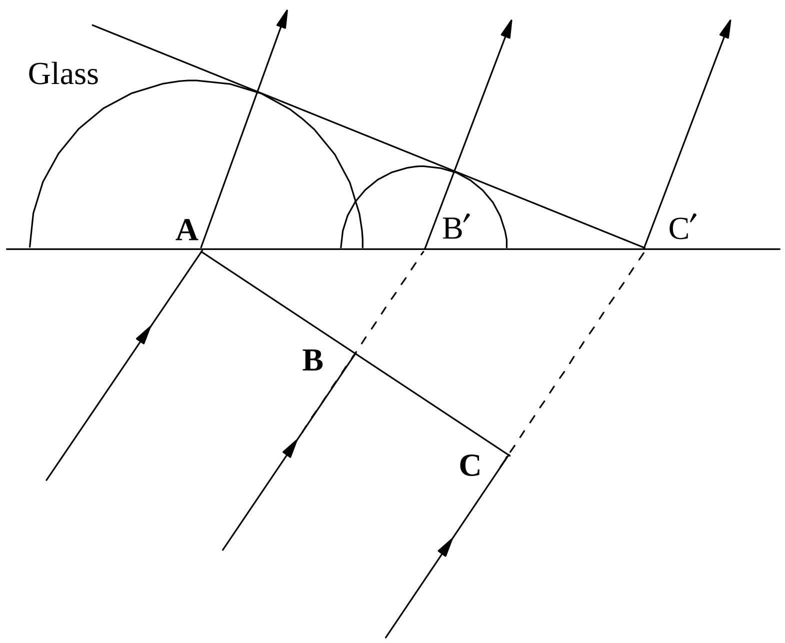
(iii) It is the higher speed molecules that escape (***[1]***), *i.e.* those at the high end tail of the distribution. ***[1]*** Comparing the two curves in the high end region, we see that at higher temperature the proportion of molecules above a certain speed has increased dramatically. ***[1]*** ***[3]***

continued…

Question B2 continued

Part 3

Solution diagram:



(a) ***[3]*** for correct wavelets; the relative speed of light in the two media should be taken into account, so that radius of larger wavelet should be $\frac{2}{3}$ of CC'. ***[3]***

(b) Wavefront tangent to two arcs and also has one end at C'. ***[1]***

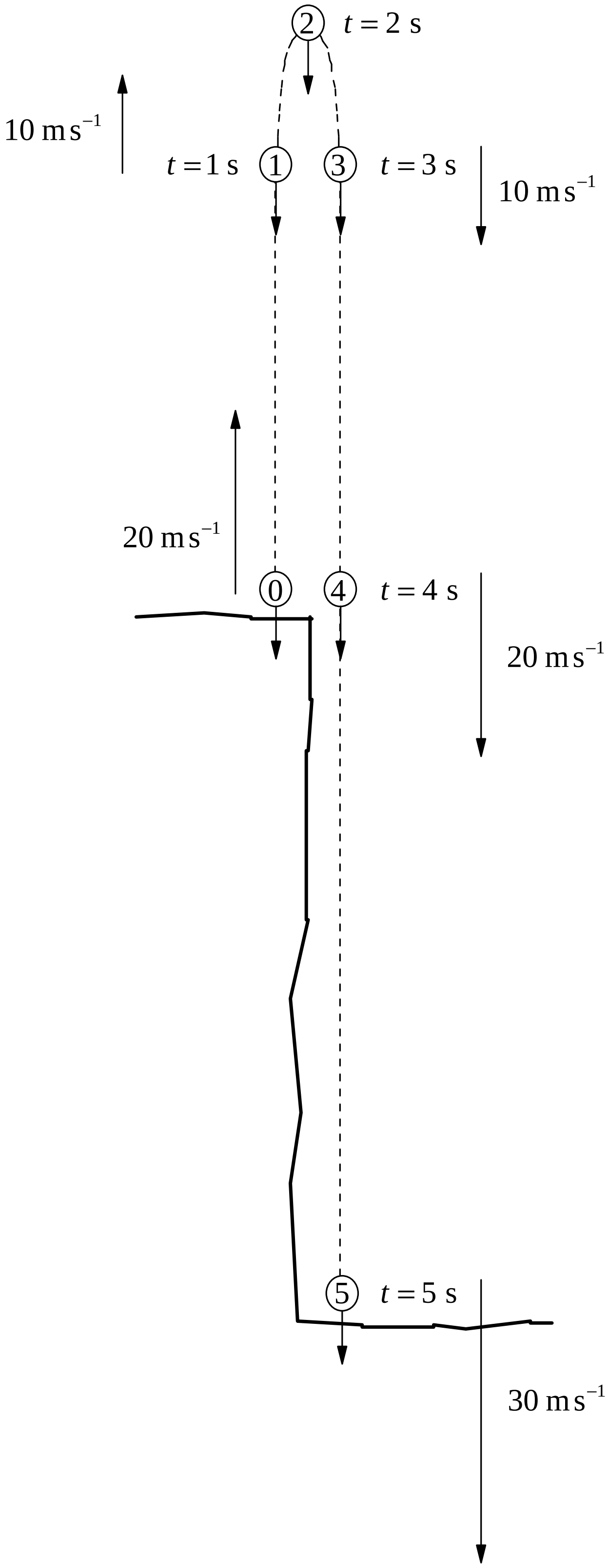
(c) Beam perpendicular to wavefront. ***[1]***

B3. Part 1

(a) (i) Downward. ***[1]***

(ii) Downward. ***[1]***

(ii) Downward. ***[1]***



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Question B3 Part 1 continued

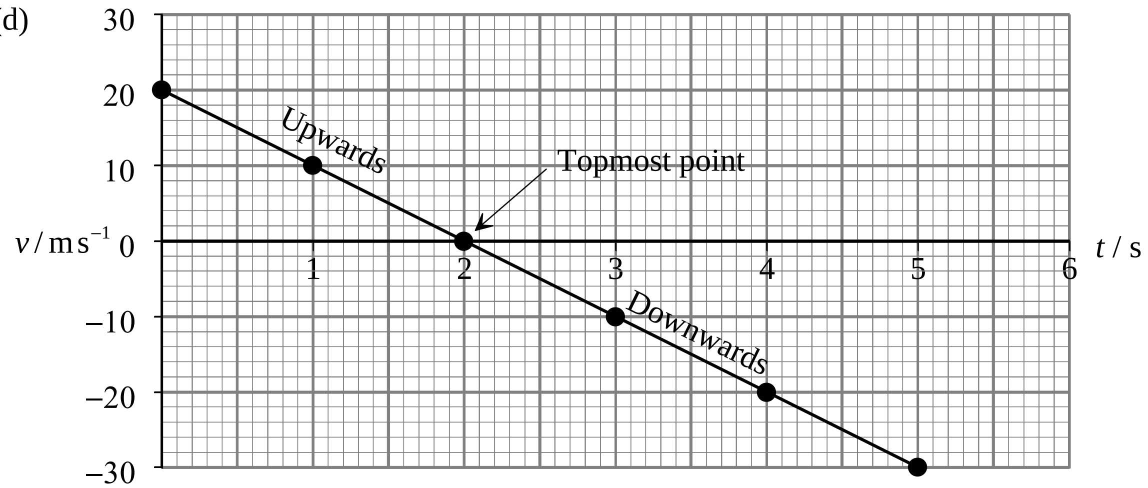
(b) *Answer:* Given vector of 20 $m\,s^{-1}$: then 10 $m\,s^{-1}$ upward, zero (no vector), 10 $m\,s^{-1}$ downward, 20 $m\,s^{-1}$ downward and 30 $m\,s^{-1}$ downward.

*(Award **[1]** for all directions right, **[1]** for relative vector lengths, **[1]** for magnitudes.)* ***[3]***

(c) All force vectors down and of same length (***[1]***). Origin: gravitational force to earth (***[1]***). ***[2]***

*(Subtract up to **[2]** for any wrong or nonexistent forces (judge overall understanding of dynamics of motion).)*

(d)



*(Award **[2]** for the graph and **[1]** for all correct labels.)* ***[3]***

(e) The stone's acceleration. ***[1]***

(f) $s = ut + \frac{1}{2}at^2$

$= 20 \times 5 + \frac{1}{2}(-10)\,25 = 100 - 125 = -25$ m. ***[3]***

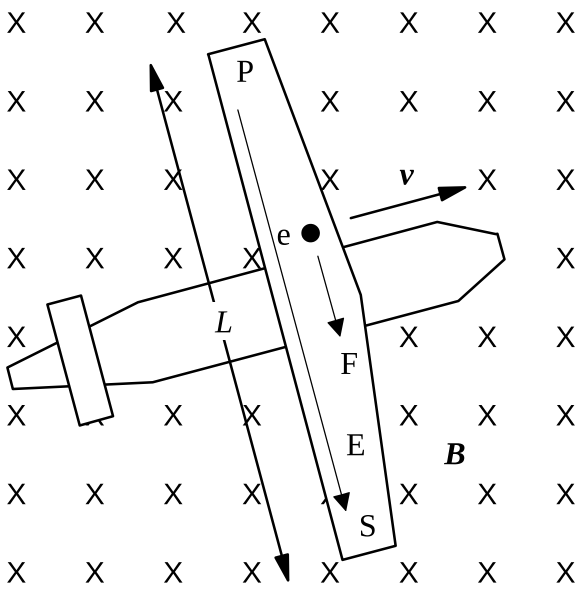
*(Award **[1]** for approach and equation, **[1]** for correct substitutions and signs, **[1]** for calculation and implicit interpretation of minus sign.)*

continued…

Question B3 continued

Part 2

(a) (i) Toward wingtip S as shown. ***[1]***



(ii) $F = q\boldsymbol{vB} = e\boldsymbol{vB}$ ***[1]***

(b) (i) Electrons move toward S and build up there, leaving deficit of electrons at P. This charge separation sets up an electric field between the net positive and net negative wingtips. ***[1]***
Vector shown above from tip P to tip S. ***[1]*** ***[2]***

(ii) The charge separation causes an electric field which provides an opposing force to the magnetic force (***[1]***) and eventually equilibrium between the magnetic and electric forces on the electrons is reached and further motion stops (***[1]***).
(Alternatively could say the electrons that accumulate at one end repel any further electrons coming along, counteracting the magnetic force.)
If the forces were not equal, charge would move until they were. ***[2]***

(c) Equilibrium:
Magnetic force = electric force
$e\boldsymbol{vB} = eE$ ***[1]***
$E = \boldsymbol{vB}$ ***[1]***

continued…

Question B3 Part 2 continued

(d) Can do this either from work against magnetic force or electric force.

Either magnetic:

$W = F \times d$ ***[1]*** $= (e\boldsymbol{vB})\,L$ ***[1]***

So $V = \dfrac{W}{q} = \boldsymbol{vB}L$ ***[1]***

Or electric:

$W = F \times d$ ***[1]*** $= eE \times L$ ***[1]***

So $V = \dfrac{W}{q} = eE\dfrac{L}{e} = EL = \boldsymbol{vB}L$ ***[1]*** ***[3]***

(e) $V = \boldsymbol{vB}L = 200 \times 8 \times 10^{-5} \times 30 = 48 \times 10^{-2}\ \text{V} = 480\ \text{mV}$, *i.e.* almost half a volt. ***[1]***

(f) Not between the wingtips, because the magnetic field and plane's motion are both horizontal. ***[1]***

(g) No reading, because electrons in connecting wires subject to the same magnetic forces as in the wings. Equilibrium situation. No current would flow round the wing–wire circuit through the meter. ***[2]***

(h) No. The magnetic force on the electrons is perpendicular to the plane's velocity, *i.e.* transverse to the plane not along it. ***[1]***

B4. Part 1

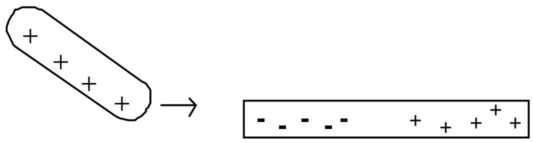
(a) Electrons are transferred from the rubber to the fur, leaving the rubber with a net positive charge. ***[1]***

(b) Where the rubber touches the metal, electrons flow from the metal to the rubber to neutralise the excess positive charge on the rubber in that area only (rubber being an insulator). ***[2]***

(c)

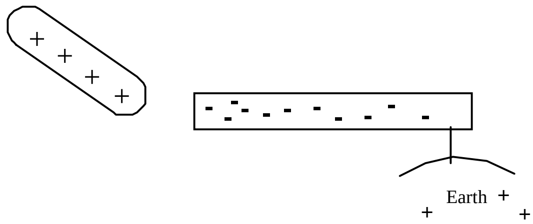
(i) The charged rubber rod is brought close to the metal rod. ***[1]***

Electrons are attracted toward the positive rod, leaving the other end with a net positive charge.



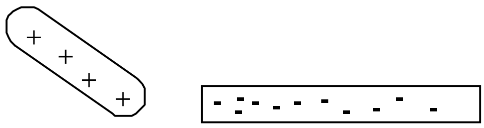
(ii) The metal rod is connected to earth. ***[1]***

Electrons flow in from earth, leaving earth with net positive charge.



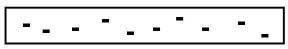
(iii) The earth connection is removed. ***[1]***

Charge distribution remains, with left end somewhat more negative.



(iv) The rubber rod is removed. ***[1]***

Excess negative charge spreads out.



(d) Yes it would work. The rubber rod would cause charge separation in the rod–earth system, as before. ***[1]***

(e) No it would not work. The induced charge separation would not be there when the rod was unearthed, so no effect. ***[1]***

(f) Induction simply separates charge in the metal rod/earth system, so the metal rod becomes negative and earth becomes equally positive, so charge is conserved. Charge on rubber is unaffected. *(Award **[2]** for the essence of this.)* ***[2]***

continued…

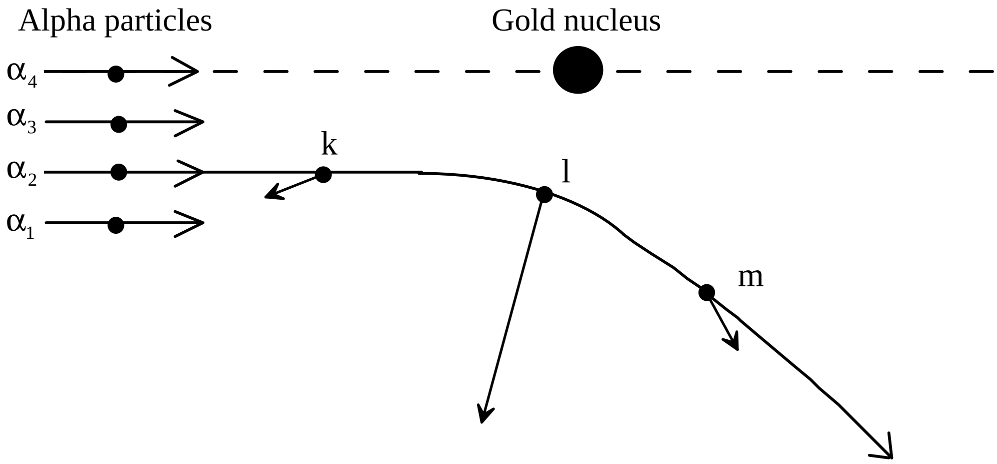
Question B4 continued

Part 2

(a) He concluded that the atom must consist of a very small positive nucleus carrying almost all the mass, surrounded by a much larger cloud of negative electrons, (***[1]***) since only if the alphas encountered a small massive charged object could they be turned back the way they came. ***[1]*** ***[2]***

(If a candidate answers that the Thomson plum pudding model with positive charge throughout the volume of the atom would give very little deflection of any alphas as they passed through it, give ***[1]****.)*

(b)



Force vectors: in right direction and of quarter the length at k and m than at l. ***[1]***
Forces are due to nucleus, electrostatic repulsion. ***[1]*** ***[2]***

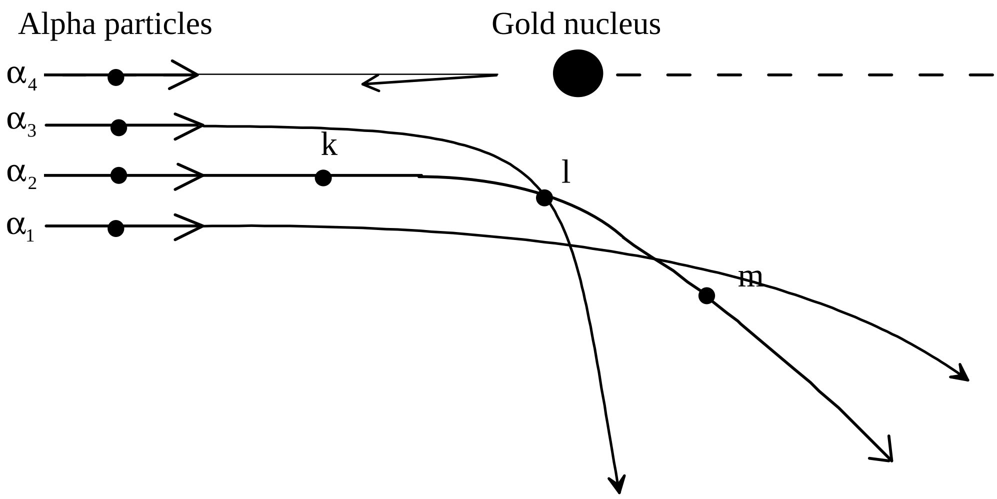
(If any non-existent forces are shown, e.g. along the path, subtract a mark.)

(c) Electric PE increases till l, then decreases, while KE decreases till l, then increases. ***[1]*** ***[2]***
Total energy remains constant. ***[1]***

continued…

Question B4 Part 2 continued

(d)



Alpha paths as shown in diagram above, supported by reasons below. *(Mark path and reason together.)*

- Generally, correct shapes of paths, *i.e.* curved more closer to nucleus and tending to straight path further away. ***[1]***
- α_1 is further from nucleus, hence smaller coulomb force, hence less deflection. ***[1]***
- α_3 is approaches nearer to nucleus, hence larger coulomb force, hence greater deflection. ***[1]***
- α_4 approaches head-on, repulsive force is against its motion and so it is repelled back the way it came. ***[1]*** ***[4]***

(e) At closest approach distance *d*, electrical potential energy is $qV = kq\frac{Q}{d}$.

This must equal the kinetic energy E_k, *i.e.* $kq\frac{Q}{d} = E_\mathrm{k}$.

So $d = kq\frac{Q}{E_\mathrm{k}}$

$$= (9\times10^9)\times2\mathrm{e}\times\frac{79\mathrm{e}}{5\times10^6\,\mathrm{e}}$$

$$= 4.6\times10^{-14}\ \mathrm{m}.$$ ***[6]***

(Award marks as follows:
[1] *for knowing KE goes to PE;*
[2] *for correct PE in a coulomb field;*
[1] *for equating and rearranging to get expression for d;*
[1] *for using correct charges of two particles;*
[1] *for calculations.)*

continued…

Question B4 Part 2 continued

(f) Smaller atomic number means smaller nuclear charge and hence the coulomb repulsion is smaller so alphas will be able to approach closer. ***[1]***

(Note: True, the nuclear radius is also smaller, but this is proportional only to cube root. This aspect is not expected in candidates' answers.)

(g) ${}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} = {}^{1}_{0}\mathrm{n} + {}^{12}_{6}\mathrm{C}$ ***[2]***