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M99/430/H(2)M

MARKSCHEME

May 1999

PHYSICS

Higher Level

Paper 2

17 pages

SECTION A

General comments: If several marks have been allocated to a question, each sensible and relevant comment will gain a mark even if not anticipated by the markscheme. Throughout these questions, if not specified, allow a measurement margin of error of $\pm 10\%$.

A1. (a) *Solution:*

- For fixed lights 25 mm on film represents 30 m on runway, so 1 mm on film represents 30/25 = 1.2 m.
  Allow measurement 21→29 mm so,
  1mm on film represents 1.0→1.4 m

Marking:

- Knowing how to do it, *i.e.* method: *[1 mark]*
- Details, *i.e.* measurement and arithmetic *[1 mark]*

(b) **(i)** $v = 26/2 = 13$ mm s^{-1} on film.
Thus $V = 13 \times 1.2 = 15.6$ m $s^{-1} \simeq 16$ m s^{-1}
Should be 16 m s^{-1} but still accept 2 decimal places - reject 3

(ii) $v' = 50/2 = 25$ mm s^{-1} on film
Thus $V' = 25 \times 1.2 = 30$ m s^{-1} on runway

Marking: since both parts do the same thing, mark for *aspects* overall, as follows:

- Getting distance values off film *[1 mark]*
- Time interval 2 s and getting $\Delta s/\Delta t$ values *[1 mark]*
- Conversions to runway velocities *[1 mark]*

(c) *Solution:*
$\Delta V = 30 - 15.6 = 14.4$ m s^{-1} *[1 mark]*
$\Delta t = 6$ s *[1 mark]*
$a = \Delta V/\Delta t = 14.4 / 3 = 2.4$ m s^{-2}. *[1 mark]*

(d) *Solution:*
Either: Force approach:
On runway, motion is horizontal, and excess thrust (unbalanced/resultant force) causes acceleration (Newton II). *[1 mark]*
When ascending, component of gravitational force / weight opposes the thrust. *[1 mark]*
At this angle the speed is constant because net force is zero. *[1 mark]*

Or: Energy approach:
For horizontal motion, work done by resultant force goes into increasing the kinetic energy of the plane. *[1 mark]*
When ascending, the work goes into increasing the gravitational potential energy. *[1 mark]*
The kinetic energy and speed remain constant. *[1 mark]*

A2. **(a)**

(i) Right *[1 mark]*

(ii) 4 m *[1 mark]*

(iii) 5 cm *[1 mark]*

(iv) 0.5 m moved in 0.1 s, *i.e.* $v = 0.5 / 0.1 = 5 \text{ m s}^{-1}$. *[1 mark]*

(v) 0.8 s for 1 oscillation or wave, *i.e.* $f = 1 / 0.8 = 1.25$ Hz. *[1 mark]*

or $v = \lambda f \qquad f = \dfrac{v}{\lambda}$

(b)

(i) Drawn upward *[1 mark]*

(ii) Moves from 2 cm to 4.6 cm, *i.e.* displacement = 2.6 cm. *[1 mark]*

Time taken is $\Delta t = 0.1$ s, so $v = \Delta s/\Delta t = 2.6 / 0.1 = 26 \text{ cm s}^{-1}$ *[1 mark]*

(iii) 0.8 s *[1 mark]*

A3. **(a)** Same. *[1 mark]*

(b) For overall understanding (approach of balancing weight and magnetic force). *[1 mark]*

$F / l = (\mu o / 2\pi)\ I_A\ I_B / r$

$I_A I_B = (2\pi / \mu o)\ F\, r / l$ *[1 mark]*

$= (2\pi / \mu o)\ mg\, r / l$, since $F = mg$ *[1 mark]*

$= 1/ (2 \times 10^{-7}) \times (400 \times 10^{-6} \times 10 \times 5 \times 10^{-3}) / 0.25 = 400$ *[1 mark]*

$I_B = 400 / 8 = 50$ A *[1 mark]*

Alternative approach:

Weight = magnetic force *[1 mark]*

use of $f = B\,I\,l$ *[1 mark]*

use of B = Constant x I / r *[1 mark]*

Corrected substitution *[1 mark]*

Correct answer *[1 mark]*

(c) If $F = mg$, no net force, but once $F_{MAG} > mg$, even slightly, net force implies acceleration ***[1 mark]***, and as wire rises slightly, separation between wires decreases hence magnetic force increases, so acceleration increases ***[1 mark]***. *[2 marks]*

A4. **(a)** Downward, uniform. *[1 mark]*
Bowed out slightly at edges, but do not require this in marking.

(b) Magnetic field is into the page. *[2 marks]*
(If just say perpendicular to page, or say out of page, give ***[1 mark]*** only)

(c) ***[1 mark]*** for overall grasp of what to do, *i.e.* combining two parts plus step marks as follows: *[1 mark]*

Acceleration phase:
$E_k = 1/2\ m\ v^2 = e\ V_1$
$v^2 = 2\ e\ V_1\ /\ m$ *[1 mark]*

Between plates:
$eE = e\ v \times B$ *[1 mark]*

Thus $B = E / v = V_2 / dv = (V_2 / d) \sqrt{(m / 2e\ V_1)}$ *[1 mark]*

SECTION B

B1. 1. (a) *Solution and markscheme:*

'General method marks' for grasping the 'whole picture' approach required, *i.e.* knowing there are two stages, that momentum conservation applies in the collision, work-energy applies in the skidding, and how they are connected via the combined velocity. ***[3 marks]***

Then the other marks for details of steps in each stage, as follows:

Collision phase: Conservation of momentum:
$m_v v_v = (m_v + m_c)\,V$ (Eqn 1). 2 unknowns v_v and V ***[2 marks]***

Skidding phase: Work-energy:
$1/2\,(m_v + m_c)\,V^2 = F.d = \mu\,W_c\,d = \mu\,(3/8)\,m_c g\,d$ (Eqn 2). ***[3 marks]***
$V^2 = (m\;3/8\;m_c\;g\;d)\,/\,1/2\,(m_v + m_c)$
$= (0.8\;\;3/8\;\;800\;\;10\;\;15)\,/\,(1/2\;2000) = 36$
$V = 6\text{ m s}^{-1}$ ***[2 marks]***

Substituting this in Eqn 1:
$v_v = V\,(m_v + m_c)/m_v = 6\;\;(2000)\,/\,1200 = 10\text{ m s}^{-1}$ ***[2 marks]***

In case of doubt, general principle is that the two 'stages' should each be worth ***[6 marks].*** A more detailed breakdown of the markscheme is as follows:

Overall approach / linking of phases ***[3 marks]***
Use of work = energy or constant acceleration equation ***[1 mark]***
Use of momentum conservation ***[1 mark]***
Appropriate linking together ***[1 mark]***

Skidding phase ***[5 marks]***
Use of $f = \mu R$ ***[1 mark]***
R = 3/8 of 8000 N (=3000 N) ***[1 mark]***
Rearrangement to give velocity ***[1 mark]***
Correct substitution of values ***[1 mark]***
Correct Answer $v = 6\text{ ms}^{-1}$ ***[1 mark]***

Collision phase ***[4 marks]***
Momentum before = mass of van x unknown velocity ***[1 mark]***
Momentum after = total mass x velocity after ***[1 mark]***
Correct substitution of values ***[1 mark]***
Correct answer = 10 ms^{-1} ***[1 mark]***

B1. 1. (b) *Safety belt:*

(Use overall judgement in marking out of 3, but following may be a guide).

Belt is no use in collision. Impact is from behind, the seat pushes her forward, belt plays no part. ***[1 mark]***.

However during the skidding, vehicles are decelerating ***[1 mark]***, and seat belt would restrain her from continuing forward at constant velocity to hit steering wheel/windshield ***[1 mark]***. ***[3 marks]***

Headrest.

(Use overall judgement in marking out of 3, but following may be a guide).

During collision, car and seat accelerated forward. If no headrest, seat pushes drivers body forward ***[1 mark]***, but not head, which is 'left behind' so neck is bent back and 'whiplash' injury occurs to neck ***[1 mark]***. Headrest plays no part in skidding phase however ***[1 mark]***. ***[3 marks]***

B1. 2. (a) Parabola shape with intital section horizontal. ***[1 mark]***

(b) Use judgement of understanding of approach, linking two connected phases.

Possible guideline as follows:

Sliding on ramp: conservation of energy:

$1/2\ mv^2 = mg\ h_1$ ***[1 mark]***

$v^2 = 2\ g\ h_1$ or $v = \sqrt{(2gh_1)}$ ***[1 mark]***

In the air: projectile motion:

Vertical component of motion:

Time to fall: $s = 1/2\ a\ t^2$ ***[1 mark]***

So $t^2 = 2s/a = 2\ h_2/g$, $t = \sqrt{(2h_2 / g)}$ ***[1 mark]***

Horizontal component of motion:

$x = vt = \sqrt{(2gh_1)} \times \sqrt{(2h_2 / g)} = 2\sqrt{(h_1\ h_2)}$ ***[2 marks]***

(c) Method via x and y velocity components at impact: general grasp: ***[2 marks]***

Then ***[3 marks]*** for x, y and ratio as follows:

$v_x = v = \sqrt{(2gh_1)}$ ***[1 mark]***

$v_y = at = g\sqrt{(2h_2 / g)} = \sqrt{(2gh_2)}$ (or else by conservation of energy) ***[1 mark]***

$\tan\theta = v_y / v_x = \sqrt{(h_2 / h_1)}$ ***[1 mark]***

B2. 1. (a) Current I is proportional to potential difference V,
or equivalently resistance R is constant, independent of V and I. ***[1 mark]***

(b) Different ways of reasoning, so use judgement in marking answer and reasoning out of ***[3 marks]***.
Answer: A brightest, then B, then C and D equally.
One way of reasoning:
All current goes through A, so brightest. It then splits, but more goes to B than to C and D since the latter two are in series and their path offers twice the resistance of path B. Hence B next brightest. Then C and D get equal currents and are equally bright, though dimmer than all the others. ***[3 marks]***

(c) Various ways of answering so use judgement out of ***[6 marks]***.

One possible answer scheme:
Equivalent resistance of the circuit:
C and D in series: 6 ohms equivalent.
This in parallel with B: 2 ohms equivalent
This in series with A: 5 ohms equivalent ***[2marks]***

Total current is 15 V / 5 ohms = 3A ***[1 mark]***

Current splits in ratio 2:1, so 1/3 or 1A goes to right branch, bulbs C and D. ***[1 mark]***

PD across D: $V = IR = 1 \times 3 = 3V$ ***[1 mark]***

Power for D: $P = I \times V = 1A \times 3\ V = 3\ W$. ***[1 mark]***

(d) Along these lines:
Conduction electrons accelerate in electric field due to applied PD, gaining KE, ***[1 mark]*** but then collide with lattice atoms, losing their energy to them ***[1 mark]***, which appears as increased vibration / thermal energy of the atoms, *i.e.* increased temperature ***[1 mark]***.
Judge overall. ***[3 marks]***
If answer is in terms of non-microscopic model (resistance heating *etc.*) award a maximum of ***[1 mark]***.

(e) Mark answer and reasoning together out of ***[3 marks]***. Various ways of explaining; use judgement.
Answer: Less than.
Reasoning: A gets hottest since it has greatest current. Hence resistance of A is larger than the others ***[1 mark]***. Hence it has a relatively greater PD across it than in the simple ohmic case. ***[1 mark]***.
This leaves less PD across the others, including D ***[1 mark]***. ***[3 marks]***
Bald 'less than' without explanations gains ***[1 mark]***.

(f) Ammeter in series with D. ***[1 mark]***
Voltmeter across bulb D. ***[1 mark]***

(g) Voltmeter reading increases.
Voltmeter now essentially reads the PD across bulb B. This is greater than was the PD across C or D before. ***[2 marks]***
(Furthermore, the PD across B increases when D burns out, since current through A decreases, so PD across A decreases so PD across B is larger than before — however do not require this answer!)
Bald 'increases' without explanations gains ***[1 mark]***.

B2. 2. (a) Maximum amplitude: about 3.2 divisions @ 0.1 V / div = 0.32 V ***[1 mark]***

(b) 4 divisions @ 200 ms / div, so Period is 800 ms. ***[1 mark]***
Frequency $f = 1/\,0.8\ s^{-1} = 60/\,0.8\ min^{-1} = 75$ beats per minute. ***[2 marks]***

(c) Sketch where pulses occur at half the grid spacing, *i.e.* two divisions apart. ***[2 marks]***
Ignore any amplitude changes, any trace with a higher frequency gains ***[1 mark]***

(d) Time base:
Need to expand by a factor of about 4 or 5 (faster sweep). ***[1 mark]***
i.e. change time per division from 200 ms / div to say 50 ms / div. ***[1 mark]***
accept 50 or 20 ms / division

Vertical sensitivity:
Need to expand vertically by a factor of about 4 or 5. ***[1 mark]***
i.e. increase sensitivity from 0.1 V / div to say 20 mV / div. ***[1 mark]***
accept 50, 20 or 10 mV / division

B3. 1. (a) (**(a)** and **(b)** should be read together.)
'Heat gained' = 'heat lost' (in common though disputed terminology) ***[1 mark]***

$$m_i s_i (0 - T_i) + m_i L_i + m_i s_w (T_f - 0) = m_w s_w (T_w - T_f)$$

$$120 \times 2.1 \times 12 + 120\, L_i + 120 \times 4.2 \times 15 = 400 \times 4.2 \times 7$$ ***[4 marks]***

(Here for simple numbers have kept masses in g and energies in kJ. Then L_i value would be in kJ g^{-1}. Alternatively, safe to put masses in kg and energies in J)
[1 mark] for mathematically representing each term in symbol or numbers for part (a)

(b) Terms in the order above:
Heat gained by ice warming + heat gained by ice melting + heat gained by melted ice warming = heat lost by water cooling ***[4 marks]***
[1 mark] for each of the four energy transfer terms in the equation for part (b)

B3. 1. (c) No heat exchange with the environment. ***[1 mark]***

(d) Description in terms of energy provided to molecules, breaking bonds between them. *i.e.* bringing them out of the intermolecular potential energy well. ***[2 marks]***

During process, energy supplied goes into increased PE of molecules, rather than increased KE, hence no temperature increase. ***[2 marks]***

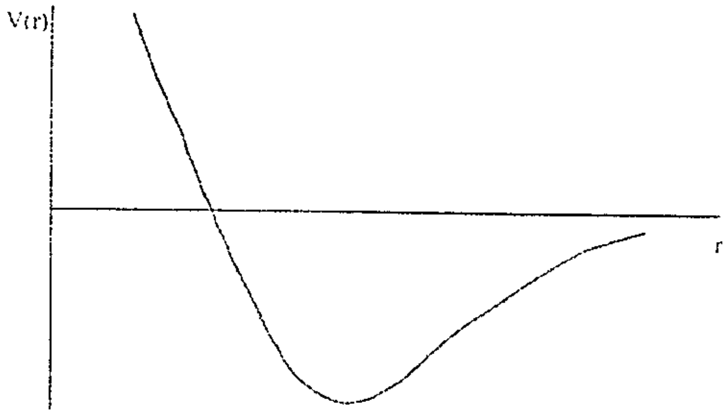
B3. 2. (a) The heat flow will be the same through both layers — they are in series with no other path for heat to flow, so heat flow through one must continue through the other. ***[2 marks]***

(b) Different approaches; two given below.
Marking: By judgement out of ***[5 marks]***, looking for the main issues, *e.g.*

METHOD 1:
Since the heat flow rate Q/t, thickness L and area A are the same for both layers,
$Q/t = k_w A \ \Delta T_w / L = k_B A \ \Delta T_B / L$
$\therefore kw \ \Delta T_w = k_B \ \Delta T_B$ ***[2 marks]***
$\therefore \Delta T_B / \Delta T_w = k_w / k_B = 2 / 1$ ***[1 mark]***
$\therefore (25 - T) / (T - (-5)) = 2$ where T is the temp of the interface ***[1 mark]***
$\therefore (25 - T) = 2 (T+5)$
$\therefore T = 5\ ^\circ C$ ***[1 mark]***
(Note that this is closer to -5 °C than 25 °C)

METHOD 2:
This is equivalent, but by thinking in terms of ratios one can do the problem mentally, as follows: (Mark allocation is merely a guide – look for understanding of issues).
Since the ratio of the conductivities board : wood is 1:2
and heat flow rate is the same ***[1 mark]***
the ratio of the temperature differences must be 2:1. ***[1 mark]***
Thus the total temperature difference of 30 ° must be divided up in the ratio 2:1, ***[1 mark]***
i.e. as 20 ° in the board and 10 ° in the wood. ***[1 mark]***
The interface temperature must thus be 5 °C. ***[1 mark]***

B3. 3. **(a)** Normal sketch of asymmetric curve, steeper to left of dip than to right. ***[2 marks]***
This is essentially 2 or zero.



(b) Equilibrium separation of atoms is r-value at the dip, when zero force. But atoms vibrate about this value, and because of asymmetry of curve about this point, thermal vibrations extend a little more to the right than to the left (vibrations represented by horizontal line in well). Thus the average separation is slightly larger than at the dip (see dot on line). As temperature increased (higher line shown), the average separation increases as shown. Thus the solid will expand slightly with temperature (because of the asymmetry essentially).

Marking: Judge overall out of ***[4 marks]***, looking for the main issues of asymmetry, thermal vibrations, average separation while vibrating, and increased average separation as temperature increases. ***[4 marks]***

(c) $\Delta l / l = k\,\Delta T = 1.2 \times 10^{-5} \times 100 = 1.2 \times 10^{-3}$ ***[2 marks]***
Percentage expansion = $1.2 \times 10^{-3} \times 100 = 0.1\ \%$ ***[1 mark]***

B4. The lack of consistency in significant figures through the question means we have to be generous and accept all but gross errors *i.e.* only answers of 5 or more digits lose the mark (unless already lost).

(a) **(i)** Three. *[1 mark]*

(ii) Released neutrons necessary to initiate further fission reactions. *[1 mark]*
Some neutrons will escape from sample, so more than one neutron is needed for a self sustaining chain reaction. *[1 mark]*

(iii) Appears as kinetic energy of the various particles after fission. *[1 mark]*

(iv) 1 u = 931 MeV (problem simplified by using this conversion, but not necessary)
So 0.22 u = 0.22×931 = 200 MeV approx. *[2 marks]*
Other unit conversions will be longer.

(b) **(i)** Conversion of 200 MeV = 3.2×10^{-11} joules *[1 mark]*
Maths to calculate the number of fissions *[1 mark]*
Correct answer *[1 mark]*
Any **one** sensible assumption *[1 mark]*

(ii) In one second, energy into water is
$mc\,\Delta T = 30 \times 10^3 \times 4.2 \times 10^3 \times 9 = 1.13 \times 10^9$ J
Power loss is 1130 MW. *[2 marks]*

(iii) No. Second law of thermodynamics says conversion of heat entirely into work (in a cyclical process) is impossible — there must always be some heat output in the cycle. *[2 marks]*
Bald answer of 'no' award *[1 mark]*

(iv) Overall approach / method: *[2 marks]*
Plus marks for details of each step as follows:

550 MW output + 1130 MW loss = 1680 MW total power. *[1 mark]*

Number of reactions per second
$= 1680 \times 10^6 / 3.2 \times 10^{-11} = 5.25 \times 10^{19}\ s^{-1}$ *[1 mark]*

Each reaction corresponds to
Uranium mass of $235 \times 1.7 \times 10^{-27}$ kg = 4×10^{-25} kg *[1 mark]*

Thus mass of U-235 per second is $5.25 \times 10^{19} \times 4 \times 10^{-25} = 21.2\ mg\ s^{-1}$
(This is 667 kg/yr) *[1 mark]*

B4. **(c)** **(i)** $A / A_o = \exp(-\lambda t) = \exp(-\ln 2 \; t/t_h)$ *[1 mark]*

$1 / 100 = \exp(-0.693 \; t/29)$ if t in years *[1 mark]*

$-\ln 100 = -0.7 \, t / 29$ *[1 mark]*

$t / 29 = \ln 100 / 0.7 = 4.6 / 0.7 = 6.6$
$t = 193$ years *[1 mark]*
Use of half-lives to calculate answer - maximum 3 out of 4
'Between 6 and 7 half lives' - 2 out of 4

(ii) As nuclei decay with time, there are fewer left to decay in the sample. *[1 mark]* The overall activity of the sample is proportional to the number of radioactive nuclei left in the sample, and hence it decreases. *[1 mark]*

(d) **(i)** Any two sensible fossil advantages, or else any two nuclear problems avoided. *[2 marks]*

(ii) Any two sensible fossil disadvantages, or else any two nuclear advantages not gained. *[2 marks]*