M01/430/H(2)M

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MARKSCHEME

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PHYSICS

Higher Level

Paper 2

20 pages

A1. Gas experiment

(a) Because the temperature will have changed when pressure was adjusted; ***[1]***
During waiting, heat flows in or out until the temperature regains its original value (room temperature); ***[1]***
[2 max]

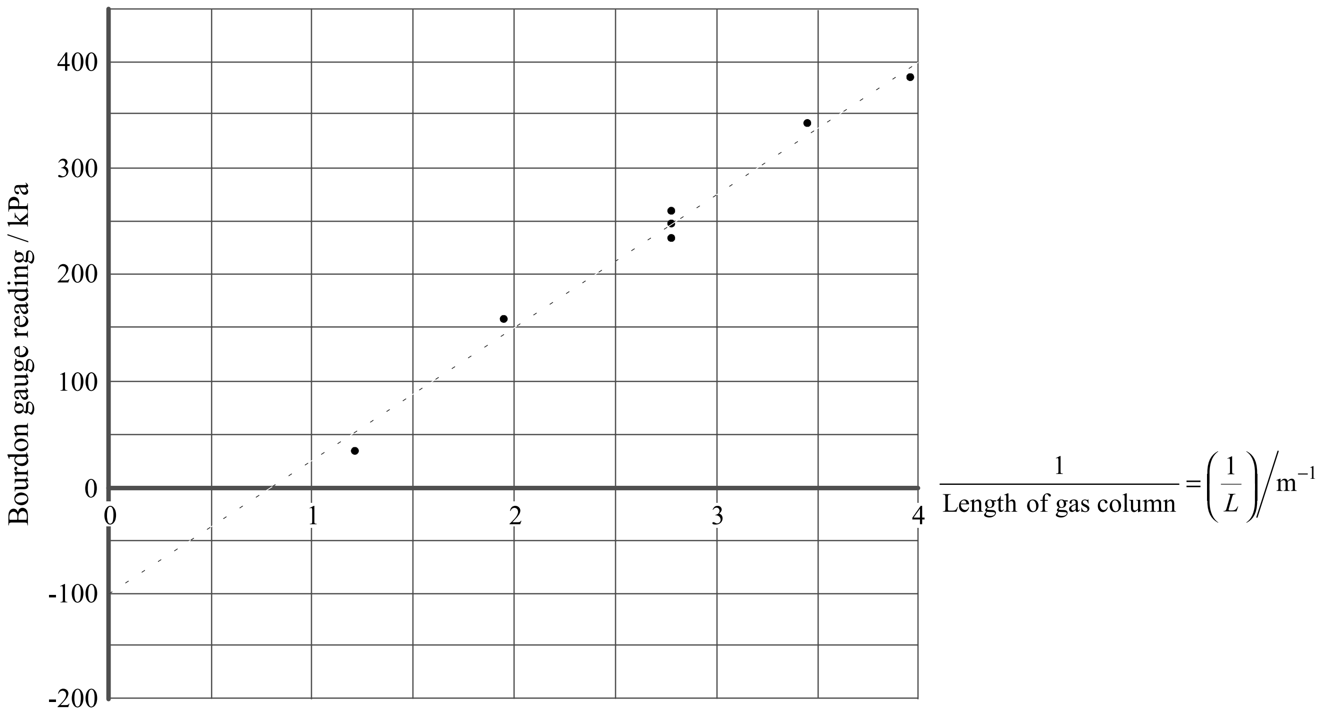
(b) Length of a (uniform) cylinder is proportional to volume; ***[1 max]***

(c) $P = K\left(\frac{1}{V}\right) = K'\left(\frac{1}{L}\right)$; ***[1]***

This is of form $y = mx$ if P is plotted versus $\frac{1}{L}$, ***[1]*** *i.e.* a straight line through origin;

[2 max]

(d) Straight line as below, reasonable best fit by eye with some points on each side of the line; ***[1 max]***



(e) approximately –100 kPa, corresponding to line drawn; ***[1 max]***

(f) (i) Error bar drawn to cover spread of the three points; ***[1 max]***

(ii) Note that uncertainty is roughly about 15 kPa (half 30 kPa spread of points) and is not precise, so accept reasonable values that show understanding; ***[1]***
For example acceptable answers are (250 ± 15) kPa or $(2.5 \pm 0.1) \times 10^5$ Pa or $(2.5 \pm 0.2) \times 10^5$ Pa; ***[1]***

[2 max]

(g) (i) Even an extreme fit, taking error bars into account; ***[1]***
would not pass through origin; ***[1]***
thus random uncertainty is too small to account for deviation from expected straight line through the origin; ***[1]***

[3 max]

(ii) Data gives intercept on pressure axis of –100 kPa, which we note is the value of atmospheric pressure. This may trigger realisation that the Bourdon gauge registers 'gauge' pressure, *i.e.* pressure relative to atmospheric pressure, rather than absolute pressure; ***[1]***

This would account for the offset from the origin, since Boyle's law involves absolute pressure; ***[1]***

[2 max]

(iii) If adjustment of 100 kPa is made, the graph will pass through zero absolute pressure; ***[1]***
and hence data are consistent with Boyle's law; ***[1]***

[2 max]

(iv) Student 3's interpretation is best, and the gas obeys Boyle's law; ***[1 max]***

A2. Levitated wire

(a) (i) When CD is near AB the magnetic force on CD (in the magnetic field of AB) is greater than CD's weight; ***[1 max]***

(ii) As CD gets further away, the magnetic force diminishes. When it is equal to CD's weight the net force on CD is zero and CD can remain in equilibrium; ***[2]***

[2 max]

(b) $\frac{F}{L} = \frac{\mu_0}{2\pi}\left(\frac{I_1 I_2}{d}\right)$; ***[1]***

At equilibrium $F = mg$

i.e. $L \times \frac{\mu_0}{2\pi} \frac{I_1 I_2}{d} = mg$; ***[1]***

thus $d = L \times \left(\frac{\mu_0}{2\pi}\right)\frac{I_1 I_2}{mg}$; ***[1]***

$$d = \frac{0.3 \times \left(\frac{4\pi \times 10^{-7}}{2\pi}\right) 1000 \times 80}{\left(10 \times 10^{-3}\right) \times 10}$$; ***[1]***

$= 4.8 \times 10^{-2}\ \text{m} = 4.8\ \text{cm}$; ***[1]***

[5 max]

(c) (i) Rod is *moving* as it reaches the equilibrium position of zero force, so it continues upwards, decelerating, stops higher up, then comes back down, going past the equilibrium position again, *etc*.; ***[2 max]***

(ii) Oscillation would *not* be simple harmonic because the net force is not proportional to the displacement from equilibrium position; ***[2 max]***

(d) Conductor is moving perpendicular to a magnetic field, so emf arises (force on electrons); ***[1]***
(or express in terms of changing flux though circuit)
Charge separation means ends become charged; ***[1]***
resulting in PD between ends of rod; ***[1]***

[3 max]

(e) As CD falls,

(i) it falls faster; ***[1]***

(ii) the magnetic field of AB gets greater as CD gets closer; ***[1]***

[2 max]

B1. Part 1. Children and bicycle

(a) His feet will stop when they hit the ground but his body will still be travelling forward at the bike speed, so he will fall over forwards or alternative ways of expressing the same ideas; ***[2 max]***

(b) $(m_1 + m_2 + m_3)v = (m_1 + m_2)v' + m_3 \times 0$; ***[2]***

$(10 + 40 + 30)\ v = (10 + 40)\ v'$; ***[1]***

$v' = v \times \frac{80}{50} = 1.6\ v = 1.6 \times 2.5 = 4\ \text{m s}^{-1}$; ***[1]***

Marking: essentially ***[3]*** for knowing what to do, by setting up the right equation and right substitutions, and ***[1]*** for detail & arithmetic.

[4 max]

(c) Before: $\text{KE} = \frac{1}{2}(80)(2.5^2) = 250\ \text{J}$; ***[1]***

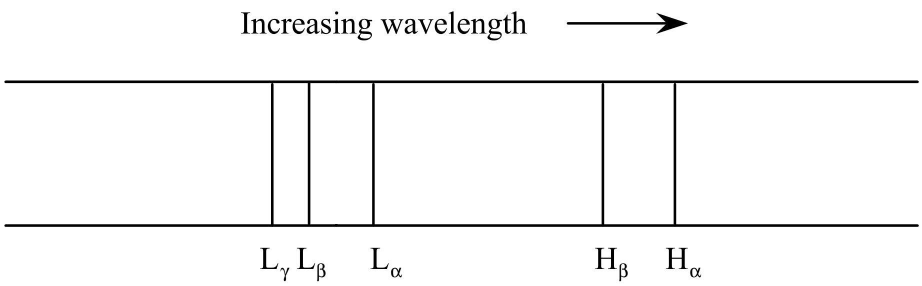
After: $\text{KE}' = \frac{1}{2}(50)(4^2) = 400\ \text{J}$; ***[1]***

Increase in KE ***[1]*** is due to energy provided or work done by boy pushing on the bicycle ***[1]***; ***[4 max]***

B1. Part 2. Hydrogen atom and spectrum

(a) Explanations mentioning one or more of the following:
- Attractive system, so energy is less than at infinite separation, which is taken as zero reference point;
- Work must be done to separate particles to infinity, which is taken as zero energy; ***[2 max]***

(b)



Marking:

[1] *for correct ordering;*

[1] *for relative spacing, i.e. larger gap between L and H series than within L series;*

[2 max]

(c) $E_1 = \frac{-k}{1^2} = -k = -13.6\text{ eV}$; ***[1]***

$E_4 = \frac{-k}{4^2} = \frac{-k}{16} = \frac{-13.6}{16}\text{ eV}$; ***[1]***

$\therefore \Delta E = E_4 - E_1 = \frac{15 \times 13.6}{16}$; ***[1]***

$\Delta E = hv = \frac{hc}{\lambda}$; ***[1]***

$\therefore \lambda = \frac{hc}{\Delta E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8 \times 16}{15 \times 13.6 \times 1.6 \times 10^{-19}}$

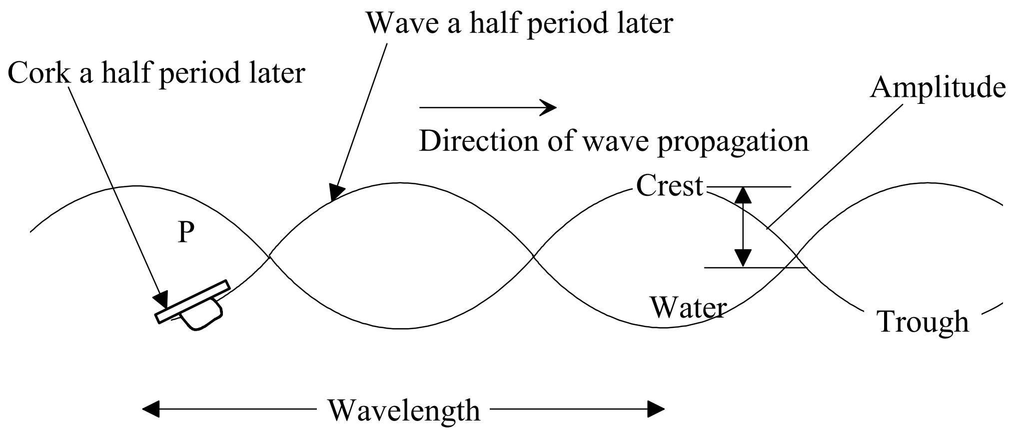
$= 98\text{ nm}$; ***[1]***

[5 max]

(d) This is ultraviolet region; ***[1 max]***

B1. **Part 3. Waves in a ripple tank**

(a) (i) – (iii) ***[3 max]*** for correct drawing and labelling of each of these;



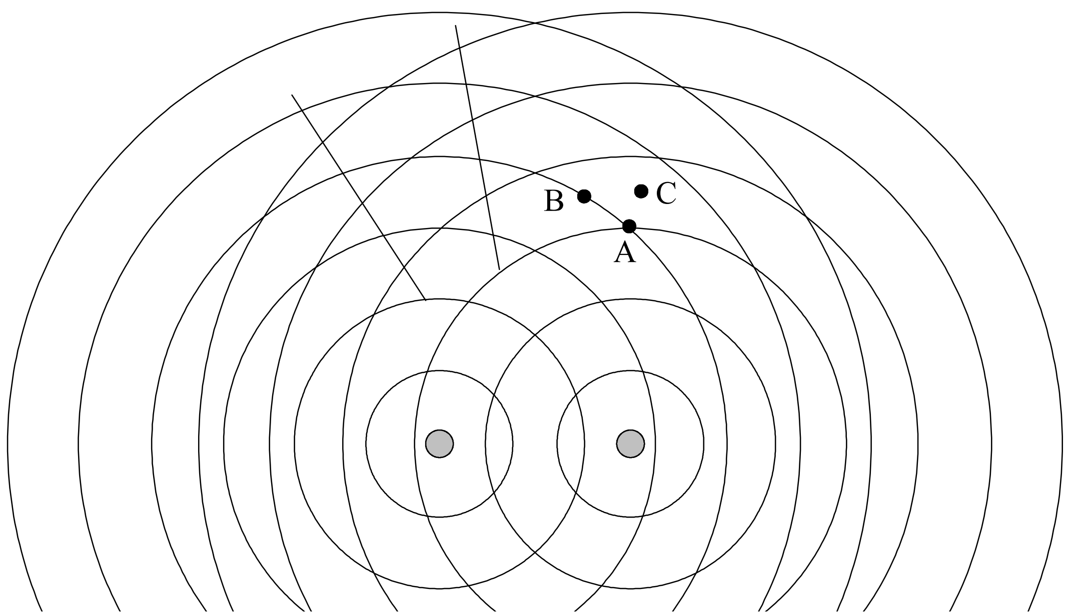
(b) New wave a half wavelength shifted to the right; ***[1]***
Cork on surface of new wave, shifted vertically but not horizontally; ***[1]***
[2 max]

(c) Cork at A: Moves up and down; ***[1]***

Cork at B: Cork does not move; ***[1]***

Cork at C: Moves up and down; ***[1]***
[3 max]

(d) Nodal lines go through points where crests from one source coincide with troughs from the other. Two possible lines are shown; ***[2 max]***



B2. Part 1. Pole vault

(a) *Any four of the following five energy aspects, provided the narrative makes sense.*

- KE in runup; ***[1]***
- Is converted to Elastic PE and Gravitational PE while swinging up on bending pole; ***[1]***
- Also muscular energy used doing work while going up; ***[1]***
- Energy is nearly all Gravitational PE at top of vault; ***[1]***
- PE converted to KE on way down; ***[1]***

[4 max]

(b) $\frac{1}{2}mv^2 = mgh$; ***[1]***

$h = \frac{v^2}{2g}$; ***[1]***

$= \frac{9^2}{2\times10} = 4$ m (increase in height of centre of gravity); ***[1]***

But centre of gravity starts off 1 m above the ground,
so max height vaulted should be 4 + 1 = 5 m approximately; ***[2]***

[5 max]

(c) Going up, pulling self up by say ½ m (from experience of pulling self upward?);
Near the top, pushing down, to raise self another ½ m say;
Gives extra height of 1 m in all;

[2 max]

(d) World record: 5 + 1 = 6 m approximately; ***[1 max]***

B2. Part 2. Electric kettle

(a) Hot water rises by convection; ***[1]***

In a partly filled kettle an element low down would still be immersed; ***[1]***
[2 max]

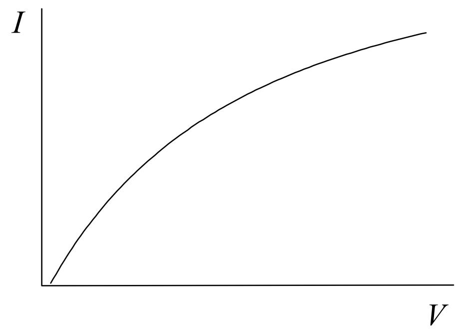
(b) Advantages: *(Any two for **[2]**)*
- Electrically insulating material reduces risk of electric shock;
- Plastic conducts heat less than metal, reduces heat loss;
- Not hot to the touch;

[2 max]

(c) $V_{rms} = \frac{V}{\sqrt{2}}$, so $V = \sqrt{2}\, V_{rms}$
$\sim 1.4 \times 220 \sim 308$ V ; ***[1 max]***
(Award mark for method not arithmetic)

(d) $P = IV$ so $I = \frac{P}{V} = \frac{1100}{220} = 5$ A ; ***[1 max]***

(e) $R = \frac{V}{I} = \frac{220}{5} = 44$ ohms ; ***[1 max]***

(f) 

Explanation: Resistance increases as the element gets hotter, hence I-V curve has decreasing slope, or else say that current increases less than linearly with V since R increases with temperature. Or similar;

Marking:
Right shape; ***[1]***
Increased temp and resistance; ***[1]***
Relate this to curve; ***[1]***

The assumption above is that element temperature increases. If candidate makes and justifies a different assumption, that temperature is constant due to water immersion, then mark accordingly - graph should then be a straight line;

[3 max]

(g) Power will be greater than 1100 W since resistance is lower than rated resistance when element is cold; ***[1 max]***

(h) $ms\,\Delta T = Pt$; ***[1]***

$s = \dfrac{Pt}{m\Delta T}$ with $\Delta T = 100 - 20 = 80$; ***[1]***

$= \dfrac{1100 \times 170}{0.5 \times 80}$; ***[1]***

$= 4675 = 4700\ \text{J kg}^{-1}\ {}^{\circ}\text{C}^{-1}$; ***[1]***

Assumption: no heat losses; ***[1]***
[5 max]

(i) Too high. If there are heat losses, then more heat has to be supplied to raise the temperature a given amount; ***[1]***
hence calculated SHC value will be greater; ***[1]***
[2 max]

B3. Part 1. Charge-measuring device

(a) Field lines uniform and from + to – as shown. Do not require edge effect; ***[1 max]***

(b) Positive; ***[1 max]***

(c)

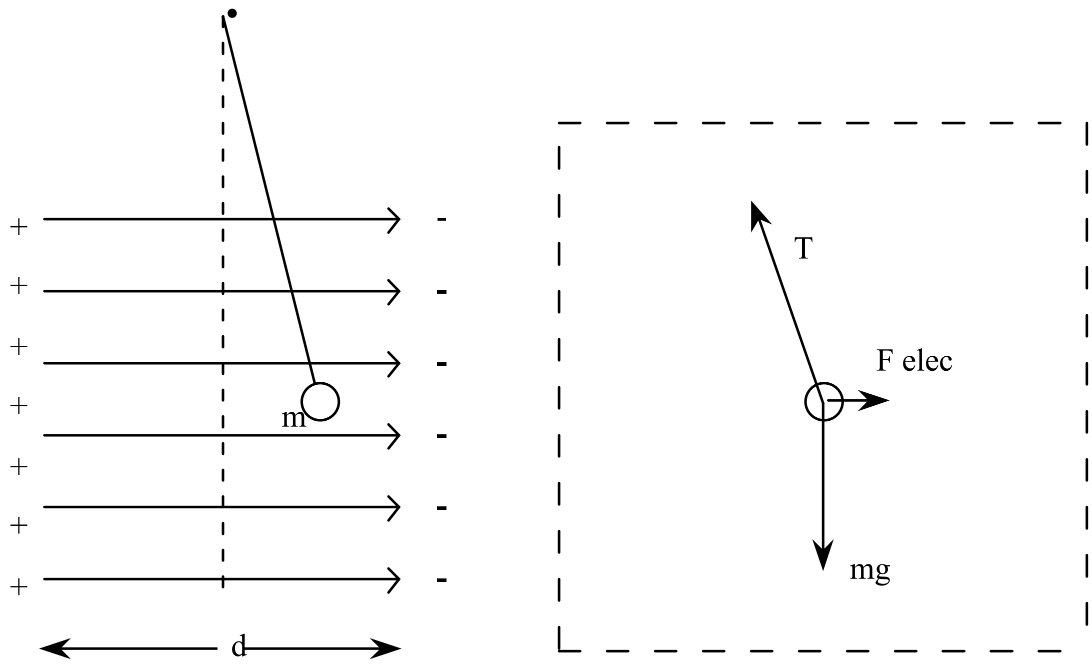


Figure 1: Physical situation **Figure 2**: Free-body diagram

Marking: ***[1]*** for each force in the diagram and its label. Penalise two missing labels but not one; ***[3 max]***

However if the candidate has wrong or missing forces, indicating lack of understanding of the equilibrium situation also, give max of ***[1]*** out of ***[3]***.

(d) $W = F.d$ and $F = q\,E$; ***[1]***

so $W = qEd$; ***[1]***

Then $V = \frac{W}{q}$; ***[1]***

$= \frac{qEd}{q} = Ed$; ***[1]***

Rewriting gives $E = \frac{V}{d}$;

[4 max]

(e) Vertical components $T\cos\theta = mg$; ***[1]***

Horizontal components $T\sin\ \theta = F_{elec} = qE$; ***[1]***

Dividing: $\tan\ \theta = \frac{Eq}{mg} = \frac{Vq}{dmg}$; ***[1]***

Rewriting: $q = \frac{m\,g\,d\ \tan\theta}{V}$ ***[1]*** $= 40\times10^{-6}\times10\times6\times10^{-2}\times\frac{\tan 20^\circ}{480}$; ***[1]***

= 18 nC; ***[1]***

The above is only a guide. Mark by judgement, assessing understanding of equilibrium situation, treatment of force vectors, expressions for forces and algebraic steps.

[6 max]

(f) *Any two of the following for* ***[2 max]***
- Smaller mass;
- Higher voltage;
- Smaller separation *(not as good since it limits the hanging angle, but accept)*;
- Longer string — note this is a difficult one: the angle of hanging would be unaffected, but the sideways displacement would be greater; so it depends on what is measured. Accept.

B3. Part 2. Nuclear reaction

(a) $^{1}_{1}\text{H} + ^{7}_{3}\text{Li} = ^{4}_{2}\text{He} + ^{4}_{2}\text{He} + Q$; ***[2 max]***

(b) Sum of rest masses is greater before the reaction; ***[1 max]***

(c) The incident proton is repelled by the Coulomb force of the Li nucleus; ***[1]***
If proton energy is too low it will be repelled before reaching the nucleus; ***[1]***
[2 max]

(d) Potential at the surface of the Li nucleus is

$V = \frac{kQ}{r}$; ***[1]***

$= \frac{9\times10^{9}\times3\times1.6\times10^{-19}}{2.5\times10^{-15}}$; ***[1]***

$= 1.7\times10^{6}\ \text{V} = 1.7\ \text{MV}$; ***[1]***

So electric potential energy of proton at the surface is q V $= 1.7$ MeV ; ***[1]***

This is therefore the min incident kinetic energy required, *i.e.* 1.7 MeV (or 2.76×10^{-3} J); ***[1]***

Note this has ignored the radius of the proton ***[1]***. If this is included the proton does not have to approach as close to react and the required energy would be a bit less.

[6 max]

(e) Protons not incident 'head-on' to a nucleus will be deflected off to an angle; ***[1]***
and will not approach as close to the nucleus; ***[1]***
[2 max]

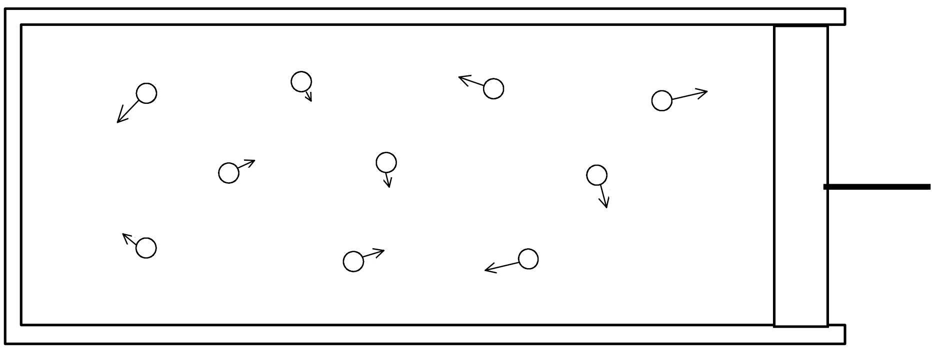
B4. Part 1. Gas expansion

(a) Molecules strike the face and rebound. Explanations of force arising during the collision can be in terms of momentum change, or, acceleration, change of velocity, *etc.*; ***[1]***
Many collisions leads to average force and average pressure; ***[1]***
[2 max]

(b) If they strike the bottom they rebound; ***[1]***
Their average velocities are high compared to any speed they would gain downward due to gravity, between collisions; ***[1]***
(Thus effect of gravity on their motion is negligible).
Look for explanations along the lines of rebounding and comparative effect of gravity.
[2 max]

(c) Average KE of molecules is the same; ***[1]***
since temperature is the same; ***[1]***
[2 max]

(d)



The molecules are more spread out, but have similar representative velocity vectors since the temperature is the same as before; ***[2 max]***

(e) There are fewer collisions of molecules with the piston face per unit time; ***[1]***
because the molecules have further to go before returning or any reasonable expression of the basic ideas, *e.g.* molecules are further apart, so strike the walls less often; ***[1]***
[2 max]

(f) $P_1 V_1 = P_2 V_2$; ***[1]***

$P_2 = \frac{P_1 V_1}{V_2} = 300 \times \frac{1}{2} = 150 \text{ kPa}$; ***[1]***
[2 max]

(g) Yes work is done; ***[1]***
It is done *by* the gas; ***[1]***
[2 max]

(h) Yes, heat flows *in*; ***[1]***
As piston moves out, gas would cool, so heat flows in through the conducting walls until temp is that of the surroundings as before; ***[1]***
[2 max]

(i) Heat *is* completely converted into work in the expansion stage; ***[1]***
but a cyclical process is required for a continuously operating device, *i.e*. the gas must be returned to its initial state in some way; ***[1]***
and some heat must be given *out* during this returning stage; ***[1]***
[3 max]

B4. Part 2. Puck on a spring

(a) $T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\left(\frac{0.4}{10}\right)} = 1.26\text{ s}$;

[1] for involving pendulum formula and *[1]* for correct substitutions. Do not penalise an arithmetic error; ***[1]***

[2 max]

(b) This is a dynamic system: the bob reaching the bottom of its swing tends to continue in a straight line, rather than a curve, exerting an additional pull on the spring; ***[1]***
extending it beyond the 'static' 0.40 m extension; ***[1]***
Or similar ideas. *e.g.* circular motion requires a centripetal force …

[2 max]

(c) When hanging in equilibrium, spring force $F_S = m\,g$; ***[1]***

When in circular motion, spring length is the same so force is the same ***[1]***, *i.e.* $F_S = m\,g$;

So $F_S = m\,g = \frac{m\,v^2}{r}$ so $v = \sqrt{rg}$; ***[1]***

Period $T = \frac{2\pi\,r}{v}$; ***[1]***

$= \frac{2\pi\,r}{\sqrt{rg}} = 2\pi\sqrt{\frac{r}{g}} = 1.26\text{ s}$; ***[1]***

[5 max]

(d) No. Unextended length exerts no force on the puck, so there is no centripetal force to cause circular motion; ***[2 max]***