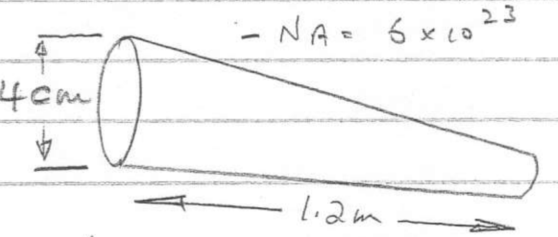
Heat – Topic Test (2) A Phys..i

Heating gases.... Basic gas laws.... Ideal gas eq.... advanced kinetic theory.

Question ...	1	2	3	Total
mark				
out of ...	8	14	16	38.

Absolute zero = −273 °C
- Gas constant $R = 8.3\ J\,mol^{-1}K^{-1}$
- James Clark Maxwell says... "$PV = \frac{1}{3} Nm\langle c^2\rangle$"
- C_V for air $= 21\ J\,mol^{-1}K^{-1}$
- $N_A = 6\times10^{23}$

1. The diagram shows a fluorescent light tube. It contains gas a pressure of 2×10^3 Pa at 20°C.



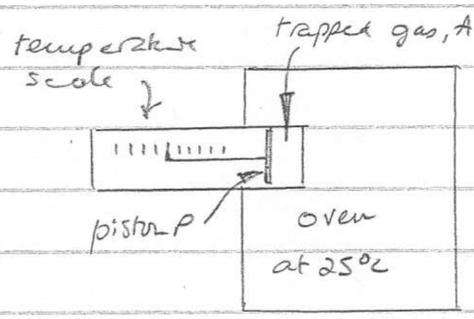
a) Show that the volume of gas is $1.51\times10^{-3}\ m^3$ (2)

b) Calculate the number of moles of gas (2)

c) The tube is switched on and the gas temperature rises to 55°C. If the specific heat of the gas at constant volume is $26\ J\,mole^{-1}K^{-1}$, calculate the heat energy needed to heat up the gas. (2)

d) The light is kept on, but the temperature stays at 55 °C. Explain why the temperature is constant. (2)

2 The diagram shows a simple oven thermometer. A piston P traps a fixed mass of gas, which has a volume of $50\times10^{-6}\ m^3$ at 25°C. The piston is free to move, and the gas is always at 1 atmosphere (1×10^5 Pa) pressure.



a) The oven is heated from 25°C to 200 °C. Calculate the new gas volume. (2)

b) Explain what C_p and C_V mean, with units (4)

c) Use the data at the top of this page to calculate C_p for air (2)

d) Calculate the heat energy needed to heat the trapped gas from 25 to 200 °C (4)

e) Calculate the work done by the trapped gas in expanding (2)

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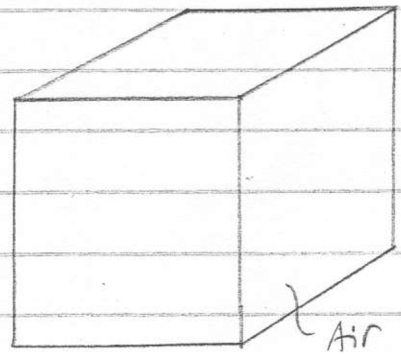
A Physics

3 James Clark Maxwell's kinetic theory gives us the formula...

$$PV = \frac{1}{3} N m \langle c^2 \rangle.$$



a) Explain the meaning of each term, with units (5)

b) Air has a density of 1.3 kg/m³ at 20°C and 1×10^5 Pa. Calculate the number of moles in 1 m³. (2)

c) Calculate the average mass of an air molecule. (2)

d) Calculate the r.m.s. speed of air molecules under the conditions given in (b). (2)

e) What is the internal energy of 1 m³ of air under the conditions in (b)? (2)

(f) The mass of air in (b) is heated at constant volume from 20°C to 200°C. Calculate the new rms particle speed. (3)

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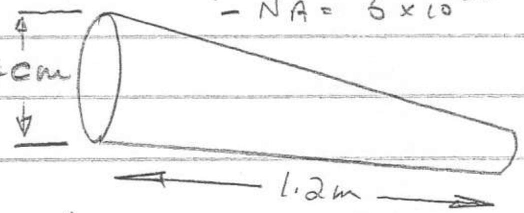

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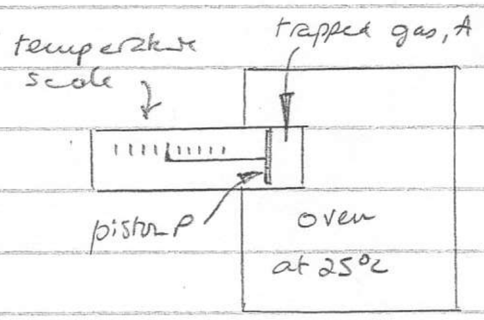

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1(c) corrected Mar '00

Topic test – Heat (2) **Answers** | A Physics

1. a) $V = \pi r^2 l$ ① $= \pi \times (2\times10^{-3})^2$ ① $\times 1.2 = 1.51\times10^{-3}\ m^3$ (2

b) $PV = nRT$ ① $\rightarrow n = PV/RT$ ① $= 2\times10^3 \times 1.51\times10^{-3} / 8.3\times 293 = \underline{1.24\times10^{-3}\ mol}$ ①

c) Heat Energy $E = \underline{n\,C_V\,\Delta T}$ ① $= 1.24\times10^{-3} \times 26 \times (55° - 20)$

$= \underline{1.13}$ Joules ①.

d) The gas / light is losing heat to the surroundings ①
at the __same__ rate ① as it is supplied by electric current [8]

2. a) at constant pressure V/T = constant or $V \propto T$ (in k) ①

so for T: 25 °C → 200 °C ⇒ 298 k → 473 k increased by 1.59 ×

so Volume increases by 1.59 times to $50\times10^{-6} \times 1.59$

$= \underline{79.3\times10^{-6}\ m^3}$

(or... $V_1/T_1 = V_2/T_2 \rightarrow V_2 = V_1 \times \frac{T_2}{T_1} = 79.3\times10^{-6}\ m^3$ etc...)

b) C_p : specific heat of gas at __constant pressure__ ① ; $\underline{J\ mole^{-1}\ k^{-1}}$ ①

C_V : sp. heat at __constant volume__ ① $J\ mole^{-1}\ k^{-1}$ ① (4)

c) Only told C_V for air $= 21\ J\,mole^{-1}\,k^{-1}$ & need C_p... hmm...

use $C_p - C_V = R$ ① so $C_p = R + C_V = 8.3 + 21 = \underline{29.3\ J\,mol^{-1}\,k}$

d) Heat energy $E = n\,C_p\,\Delta T$ ① ... need n ... $PV = nRT$ ①

$= 2.02\times10^{-3} \times 29.3 \times 175$ so $n = PV/RT$ ① $= \dfrac{1\times10^5 \times 50\times10^{-6}}{8.3 \times 298}$

$= \underline{10.4\ J}$ ① $= \underline{2.02\times10^{-3}}$ moles ① (4

e) Work $W = P\Delta V$ ① $= 1\times10^5 \times (79.3\times10^{-6} - 50\times10^{-6})$

$= 2.93\ J$ ① (2)

3. a) __P__ressure Pa or N/m² ① ; __V__olume m³ ① ; __N__o. of molecules ① __m__ass of each (kg) ①

$\langle c^2 \rangle$ = mean square velocity (m/s) ① (5)

b) $PV = nRT$ ① $\rightarrow n = PV/RT = 1\times10^5 \times 1 / 8.3\times 293 = \underline{41.1\ moles}$ ①

c) 41.1 moles $= 41.1 \times 6\times10^{23} = \underline{2.47\times10^{25}}$ ① molecules have mass 1.3 kg

so 1 average molecule has mass $\dfrac{1.3}{2.47\times10^{25}} = 5.27\times10^{-26}$ kg ①

d) $PV = \frac{1}{3} N m \langle c^2 \rangle \rightarrow 1\times10^5 \times 1 = \frac{1}{3} \times 2.47\times10^{25} \times 5.27\times10^{-26} \langle c^2 \rangle$

so $\langle c^2 \rangle$ = mean square speed $= 2.31\times10^5\ (m/s)^2$ ① so r.m.s. speed = 480 m/s ①

e) Internal energy $= \underline{\frac{3}{2} RT\ /mole}$ ① so Int. Energy $= \frac{3}{2} \times 8.3 \times 298 \times 41.1 = \underline{1.5\times10^5\ J}$ ①

(f) Int. energy ∝ T (k) ① so for T increase of $\dfrac{473}{298} = 1.59\times$ ①

new energy $= \frac{1}{2} m \langle c^2 \rangle$ is increased by 1.59×
so r.m.s. speed is increased by $\sqrt{1.59}\times$ ⇒ $480 \times \sqrt{1.59} = \underline{605\ m/s}$ ① (3

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