

- 1 (a) Define *random error* and state a method to reduce the effects of it.

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[2]  
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- (b) The theory of gas flow through small diameter tubes at low pressures is an important consideration of high vacuum technique.

One equation which occurs in the theory is

$$Q = \frac{kr^3(p_1 - p_2)}{L} \sqrt{\frac{M}{RT}}$$

where  $k$  is a number without units,  $r$  is the radius of the tube,  $p_1$  and  $p_2$  are the pressures at each end of the tube of length  $L$ ,  $M$  is the molar mass of the gas,  $R$  is the molar gas constant and  $T$  is the thermodynamic temperature.

Use the equation to find the base SI units of  $Q$ .

base SI units of  $Q$  = ..... [2]

- (c) A factory produces solid copper cylinders. The length of a typical cylinder is measured as  $(28.0 \pm 0.1)$  cm and diameter  $(6.0 \pm 0.1)$  cm.
- (i) Given the density of copper is  $8.96 \text{ g cm}^{-3}$ , determine the mass of a copper cylinder and its absolute uncertainty to the appropriate number of significant figures.

$$\text{mass} = \dots \pm \dots \text{ kg} \quad [4]$$

- (ii) Explain the effect on the percentage uncertainty of the mass if the same length and diameter measurements were made using instruments of higher precision.

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