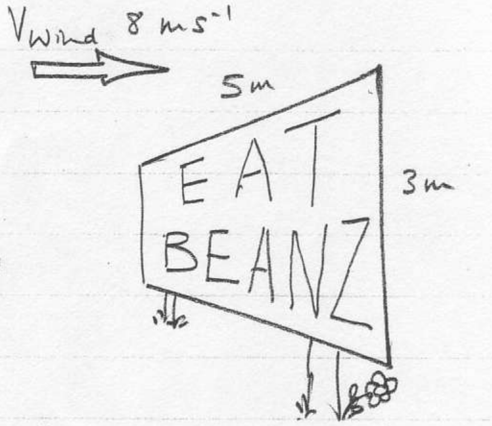
Momentum & Moving Air

Air Density = $1.3\ kg\,m^{-3}$



1\. a) The density of air at $20°C$ and 1 atmosphere (100 kPa) is about $1.3\ kg\,m^{-3}$. Explain what this means (please) (1)

b). What is the mass of air in a room $10 \times 5 \times 2$ m.? (2)

(c) What volume of air has a mass of 80 kg? (about the same mass as a lean Science teacher) If this air was in a cube shape, what would be the size of the cube? (4)

d) If the air gets warmer at constant pressure its density decreases – why? (2)

2\. The wind blows steadily on the advertising sign shown above. The air is deflected sideways so it loses all its forward velocity.

a) What volume of air blows against the sign in 1 second? (2)

b) What is the change in forward momentum of this volume of air? (4)

c) What is the force on the advertising sign? (2)

d) The posts can withstand a maximum sideways force of 2000 N – what wind speed does this represent? (2)

e) Can you show that the wind force on the sign is $DWhV^2$ Newtons, where D is air density in $kg\,m^{-3}$, W and h are width and height of the sign in m, and V is wind speed in ms^{-1}? (2)

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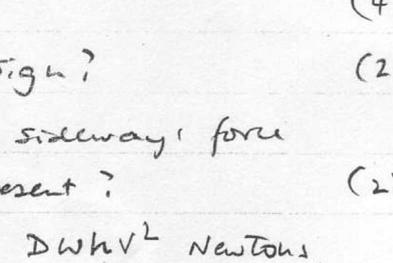
3\. The diagram shows a plane with engines running ready for take off. No wind blows.



a) Calculate the area swept out by each propellor in 1 revolution (2)

b) If the propellor sets the air directly behind it moving at 70 m/s, calculate the volume of air set moving in 1 second by 1 propellor (2)

c) Calculate the forward thrust produced by 1 propellor (2)

d) Calculate the initial acceleration of the plane when brakes released (2)

(e) Show that the change in momentum of the air behind 1 propellor in 1 second is $\pi r^2 v^2 D$ – where r (m) is propellor radius and v is air velocity (ms^{-1}) (2)

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Q... 1/9

TRN 08.03

Momentum + Moving Air — Answers

A2 Physics

1 a) $\rho_{air} = 1.3\ \text{kg m}^{-3}$ means a 1 m cube of air has mass of 1.3 kg. /1

b) Volume $= 10 \times 5 \times 2 = 100\ m^3$ (1) $M = DV = 1.3 \times 100 = \underline{130\ kg}$ (1) /2

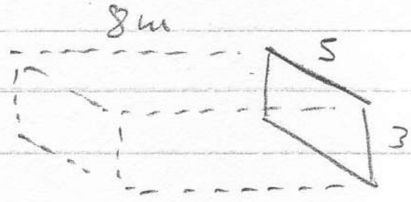
c) $M = DV \Rightarrow v = M/D$ (1) $= 80/1.3 = 61.5\ m^3$ (1)

For a cube of side l m $\quad l^3 = 61.5$ (1) $\Rightarrow l = \sqrt[3]{61.5} = \underline{3.95\ m}$ (1) /4

d) Warmer air .... particles vibrate faster + further (1) ... air expands. (1)

So fewer particles in $1\ m^3$ ... so density decreases /2

2. a) Volume of air $= 8 \times 5 \times 3 = 120\ m^3$ (1)(1) /2



b) Change in momentum $\Delta p = m \times$ change in forward velocity (1)

Mass $= D \times V = 1.3 \times 120 = \underline{156\ kg}$ (1) ... So $\Delta p = 156 \times 8 = \underline{1248\ \text{kg m s}^{-1}}$ (1)

Assume air deflected sideways (1) /4

c) Use $F \times t = m\Delta v$ (1) $\Rightarrow$ Force $F = m\Delta v / t$ = change in momentum/sec. /2

So force on sign is $\underline{1248\ N}$. (1)

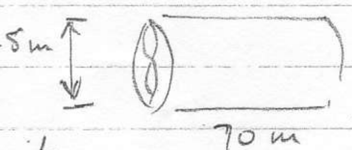
d) $F_{max} = 2000\ (N) = m\Delta v = 5 \times 3 \times v \times 1.3 \times v = 19.5 \times v^2$

So max wind speed $v = \sqrt{2000/19.5} = \underline{10.1\ m/s}$ (a bit more than 8 m/s)

e) Force $F = \dfrac{m \times \Delta v}{t}$ — where $t = 1$ sec $\quad$ But $m = D\underset{\text{volume }(m^3)}{V} = D \times v \times w \times h$

So force $F = D \times v \times w \times h \times v = D w h v^2$ $\quad$ } 2.

3. a) Area swept by prop $= \pi r^2$ (1) $= \pi \times 0.75^2 = \underline{1.77\ m^2}$ /2



b) Vol of air from 1 prop $= A \times v$ (1) $= 1.77 \times 70$

$= \underline{124\ m^3}$ (1) /2

c) $F_{thrust} = m\Delta v / t = DV \times \Delta v$ in 1 second $= 1.3 \times 124 \times 70$ (1) $= \underline{1.13 \times 10^4\ N}$ (1) /2

d) F_{thrust} from 2 propellors $= 2.25 \times 10^3\ N$

$a = F_{thrust}/m$ (1) $= 2.25 \times 10^3 / 8000 = \underline{2.8\ \text{m s}^{-2}}$ (1)

e) Change in momentum Δp of air $= m\Delta v$

mass $m = DV = D \times \pi r^2 \times v$

So $\Delta p = D \times \pi r^2 \times v \times v = \underline{\pi r^2 v^2 D}$.

Q ...	1	2	3	Total
	/9	/12	/10	/31

TJN
03.09.