How far do air molecules travel?

From seeing Brownian motion, you should be convinced that gas molecules travel very fast but collide with each other very often. How far do you think a gas molecule travels during a 60-minute lesson? How different do you think its distance travelled and displacement would be?

Distance Travelled

1) Use $p = \frac{1}{3}\rho\overline{v^2}$ to calculate the RMS speed ($v_{\mathrm{rms}} = \sqrt{\overline{v^2}}$) of an air molecule in a Physics lab.
(*Standard atmospheric pressure = 101 kPa, Density of Air = 1.2 kgm^{-3}*)

2) Hence calculate the distance travelled by an air molecule in a 60-minute lesson.

Distance travelled = ……………………….
(*if you've got the right answer, this is about the distance from London to Rome*)

Displacement

The RMS displacement from the origin of a particle engaged in a random walk over a period of *N* random steps is given by $d_{\mathrm{rms}} = \sqrt{N}$. We therefore need to know how many collisions the air molecule undergoes in a 60-minute lesson. There are several ways of doing this, but the easiest involves the idea of a **mean free path**. This is the distance a particle typically travels between collisions. It obviously varies widely with pressure but, at RTP, the mean free path of an air particle is about 6.7×10^{-8} metres[1].

3) Use your previous result and the figure above to calculate the number of collisions an air molecule will make in a 60-minute lesson.

4) Now use $d_{\mathrm{rms}} = \sqrt{N}$ to calculate the RMS displacement (in metres) of an air molecule over a 60-minute period. Remember that the above equation will give d_{rms} expressed in step-lengths, where each step length equals one mean free path.

So, over a 60-minute lesson, an air molecule travels the equivalent of London to Rome, but only gets from one end of a ruler to the other.

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[1] Mean free path can be calculated using $\lambda = \frac{1}{\sqrt{2}\pi d^2 n}$ where *d* is the diameter of the molecule and *n* is the number of molecules per unit volume.