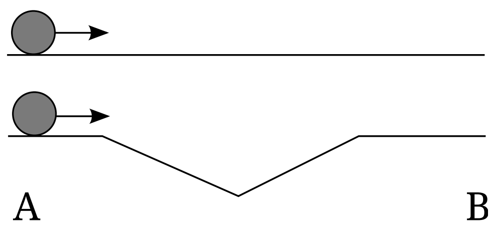
# University Physcis Problems 1

23rd January 2013

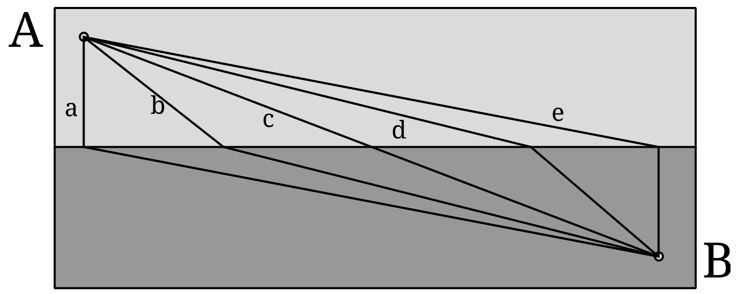
## 1 Rolling

Two balls of identical mass and shape with coefficient of friction $\mu = 0$, are set rolling at the same initial velocity from point A. Ignoring air resistance, which reaches the end of the track, point B, first and why?




## 2 Running

Runners race from point A to point B. The first section is smooth tarmac where there is good grip, the second is soft sand. Which of the five possible paths, a to e, is the fastest and why? Explain your answer.




Which area of physics is the applicable to? How would you solve this numerically?

## 3 Dropping

A slinky is suspended at the top and hangs under its own weight. The top is released. Does the bottom initially:

a) move up,

b) move down,

c) stay still?

## 4 Molecules in the Atmosphere

Calculate the number of molecules in each of your breaths that was inhaled by Julius Ceasar in his final breath. What assumptions have you made? Use the radius of the earth to be roughly 6 300 km.

## 5 Floating

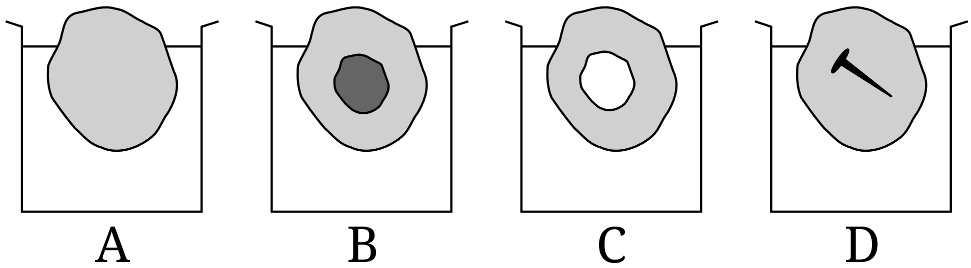
Four vessels each contain a block of floating ice in water. In the first vessel, the ice is solid; in the second, the ice has a large air buble trapped inside; the third has a region of water trapped and the fourth contains a large iron nail.

What happens to the level of the water in each vessel when all the water has melted?

a) move up,

b) move down,

c) no change?



# University Physcis Answers 1

23rd January 2013

## 1 Rolling

The total displacement is the same in each case, but it is clear that the second ball will travel a greater distance. We must consider the velocity changes. For the flat sections in both cases, the velocity is the same since there is not friction so no way to loose energy. The downill and uphill sections however must change the velocity.

Looking only at the second case, if we examine the average velocity, we have two sections at the initial velocity, one secion of positive acceleration, one section at a hig

## 2 Running

## 3 Dropping

## 4 Molecules in the Atmosphere

Assume the following:

- The volume of an average breath is 0.5 litres (actual value 0.3 to 2.0 litres depending on physical activity, gender etc.)
- The atmosphere is roughly 10 km high (actual value is considerably larger but majority of mass contained within 10-15 km)
- The density of the atmosphere is $1.2\,\mathrm{kg\,m^{-3}}$ and composed entirely of nitrogen (actual value at sea level but then decreases steadily to zero, and nitrogen is 78%)
- Julius Caesar lived to 50 years (actually 55)

First we need to work out the number of molecules in the whole atmosphere, so we need the volume of the atmosphere. This is approximated as the difference between the volume of the sphere of the earth plus the atmosphere and the sphere of just the earth.

$$\begin{aligned}
V &= \frac{4}{3}\pi r^3 \\
V_{atmos} &= \frac{4}{3}\pi \times (6\,300 \times 10^3 + 10 \times 10^3) - \frac{4}{3}\pi \times (6\,300 \times 10^3) \\
V_{atmos} &= 5 \times 10^{18}\,\mathrm{m}^3
\end{aligned}$$

This means the mass of the atmosphere is easy to calculate,

$$\begin{aligned}
M_{atmos} &= \text{density} \times \text{volume} \\
M_{atmos} &= 1.2 \times 5 \times 10^{18} \\
&= 6 \times 10^{18}\,\mathrm{kg}
\end{aligned}$$

The average atomic mass of nitrogen is 14, so

$$\begin{aligned} 14\,\mathrm{g} &= 1\,\mathrm{mol} \\ 14\times 10^{-3}\,kg &= N_A\,\text{molecules} \\ \Rightarrow 1\,\mathrm{kg} &= \frac{N_A}{14\times 10^{-3}}\,\text{molecules} \\ &= 4\times 10^{25}\,\text{molecules per kilogram} \\ \Rightarrow N_{atmos} &= (4\times 10^{25})\times(6\times 10^{18}) = 2.5\times 10^{44}\,\text{molecules} \end{aligned}$$

For the number of molecules in each breath, we know that 1 litre is $10^{-3}\,\mathrm{m}^3$, so the number of molecules in each breath is $N_{breath}$.

$$M_{breath} = 0.5\times 10^{-3}\times 1.2 = 6\times 10^{-4}\,\mathrm{kg}$$

We know the number of molecules of nitrogen per kilogram, so

$$\begin{aligned} N_{breath} &= 4\times 10^{25}\,\text{molecules per kilogram}\times 6\times 10^{-4}\,\mathrm{kg} \\ &= 2.4\times 10^{22}\,\text{molecules} \end{aligned}$$

Assuming that, in the intervening time, the molecules from Caesar's last breath are now evenly distributed throughout the atmosphere, when randomly selecting a molecule from the air, there is a small chance that is was one of Caesar's last, given by

$$P = \frac{2.4\times 10^{22}}{2.5\times 10^{44}}$$

But since there are such a large number of molecules in each of your breaths, this probability becomes quite high. So for each lungfull of air, there is, on average,

$$\begin{aligned} M &= \frac{2.4\times 10^{22}}{2.5\times 10^{44}}\times 2.4\times 10^{22} \\ &\approx 2 \end{aligned}$$

molecules from Caesar's final breath.