Time-of-flight calculations

Education in Chemistry
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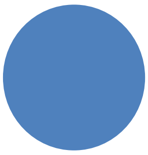
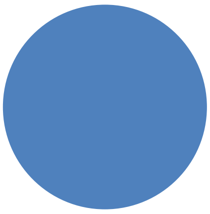
rsc.li/2VjI2Mc

One way to introduce time-of-flight calculations is to use another context, something outside chemistry, for example a bowling alley. Here is a set of questions with model answers.

At the bowling alley



Mass = 0.5 kg
Velocity = 4 ms^{-1}



Mass = 2.0 kg
Velocity = 2 ms^{-1}

1. Which bowling ball has the greatest kinetic energy?

In the question above, both bowling balls have 4 J of kinetic energy. This introduces students to the concept that two objects with different masses and different velocities can have the same kinetic energy.

2. How long will each ball take to travel 12 m down the bowling alley?

This question helps students to become familiar with rearranging $= \frac{d}{t}$. The smaller the velocity, the longer it takes to travel the distance. In addition, by relating this to question 1, students can see that, for two bowling balls with the same kinetic energy, the ball with the bigger mass will be travelling slower and therefore take longer to travel down the bowling alley. (We've made the numbers particularly nice for this question, but the length of a bowling alley is actually 18.44 m or, if you want an extra challenge, 60 feet).

3. A ball with a velocity of 1.5 ms^{-1} has a kinetic energy of 3.375 J. What is its mass?

This question requires the student to rearrange $KE = \frac{1}{2}mv^2$ so that m is the subject.

$$m = \frac{2KE}{v^2} = \frac{2 \times 3.375}{1.5^2} = 3kg$$

Alternatively, students may wish to proceed without rearranging the equation in the first instance:

$$3.375 = \frac{1}{2} \times m \times 1.5^2$$

$3.375 = 1.125m$, etc.

4. A third bowling ball has a mass of 0.75 kg with a kinetic energy of 9.375 J. What is its velocity?

Students can answer this straightforward question using $KE = \frac{1}{2}mv^2$ and rearranging for v.

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2 \times 9.375}{0.75}} = 5\ ms^{-1}$$

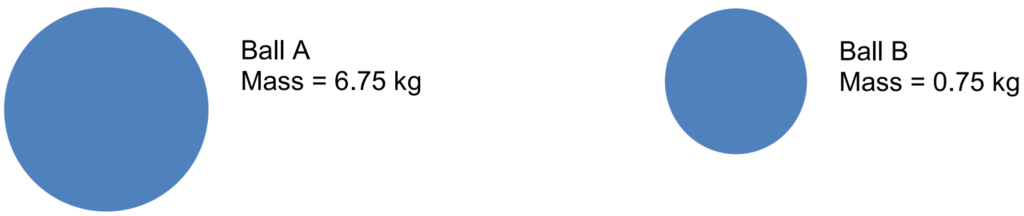
Some students may prefer to carry out the calculation in two steps, calculating v^2 and then finding the square root in a second step.

$$9.375 = \frac{1}{2} \times 0.75 \times v^2$$

$$9.375 = 0.375v^2$$

$25 = v^2$, etc.

5. A new member at the bowling club has brought along a giant bowling ball. When thrown, each bowling ball has the same kinetic energy of 1.5 J. How long will it take for each ball to travel 12 m?



This question requires students to substitute $v = \frac{d}{t}$ in $KE = \frac{1}{2}mv^2$.

$$KE = \frac{md^2}{2t^2}$$

$$t^2 = \frac{md^2}{2KE}$$

$$t = \sqrt{\frac{md^2}{2KE}}$$

This can be simplified to $t = d\sqrt{\frac{m}{2KE}}$ but is not a necessary step for the calculation and may complicate things for students who are less comfortable with algebra and rearranging equations.

Plugging numbers into the equation gives the following answers.

Ball A with mass 6.75 kg:

$$t = \sqrt{\frac{6.75 \times 12^2}{2 \times 1.5}} = 18\ s$$

Ball B with mass 0.75 kg:

$$t = \sqrt{\frac{0.75 \times 12^2}{2 \times 1.5}} = 6\ s$$

This question provides an opportunity to help students explore how changing variables in the equation impacts on the time taken to travel down the bowling alley. Ball A takes three times as long to travel down the bowling alley, which is what we would expect by looking at the equation.

The ratio of masses of Ball A to Ball B is $\frac{6.75}{0.75} = 9$. Since m increases by a factor of 9, the time increases by a factor of $\sqrt{9} = 3$.