Lesson 3 Rate of Change of Momentum

Introductory notes(10mins)

Here's a reminder of an equation you might have come across before - you might even have referred to it as 'Newton's Second Law'. This is not entirely true, but it is useful in many circumstances. Here's a bit more detail about this equation and what it tells us about changes in momentum - follow the steps carefully to understand the link:

Force = mass x acceleration

and

acceleration = (change in velocity) / time taken

So, substituting this for acceleration in the first equation we get

Force = mass x (change in velocity)/time taken

Usually we use symbols in algebra like this, so we'll use F for Force; m for mass; u for the velocity before the Force was applied; v for the velocity after it was applied and t for the time taken.

The change is velocity is (v - u), so putting all these symbols into the equation gives:

$$F = m (v-u) / t$$

Or

$$F = (mv - mu) / t$$

That is, the force is equal to the change of momentum (mv - mu) divided by the time it takes to change. This is the true definition of Newton's Second Law of Motion - force is equal to the *rate* of change of momentum.

I.e. if momentum changes quickly then t will be small and force will be large according to the equation - this has important consequences in collisions. Very fast collisions result in large forces. If the collision is between two vehicles, there will be large forces on the vehicles and the people inside them. Safety features are often designed to slow down collisions by making them last longer using crumple zones or air bags. It is also important in bungee jumping where the bungee slows you down gradually - if it was a normal rope it would be more like being hung, with a sudden stop and a large force!

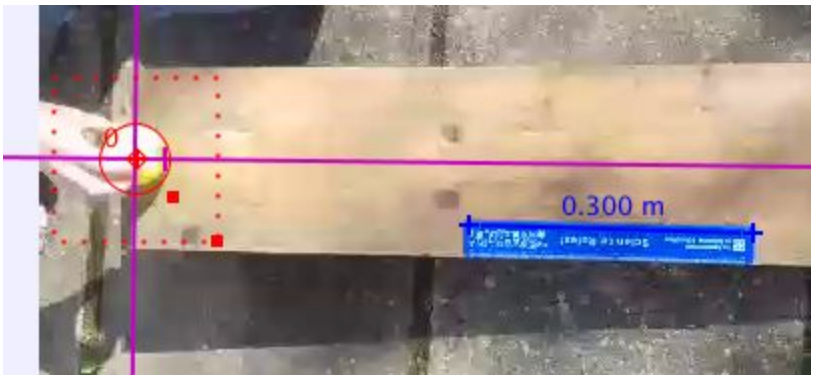
Investigating rate of change of momentum (20mins)

Open your copy of Tracker and load this video of a tennis ball rolling down a ramp:

Tennis Ball.mp4

Set up:

1. The 0.3m calibration stick along the blue ruler
2. The axes centred on the ball in the first frame
3. Point Mass A centred on the ball - drag the target marker out to the size of the ball and drag to increase the size of the search window so that it looks similar to this before you start:

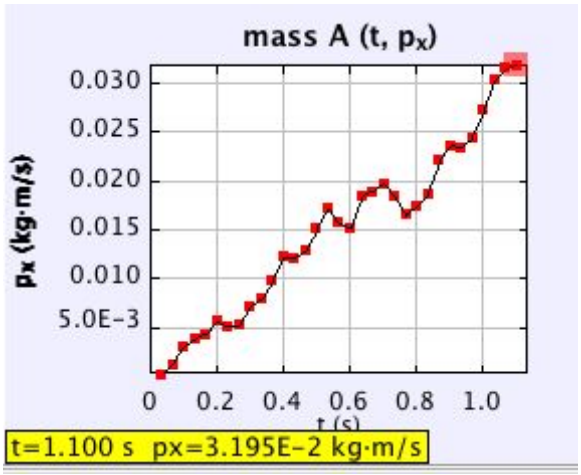


4. Enter the mass of the tennis ball 0.059kg in the box at top left

5. Change the x-axis to display px (kg m/s)

6. Track !

7. Look at the graph - you should be able to select a region that looks something like this, with a fairly steady, upward gradient - select, cut and paste a copy into your Physics notes:



Analysis:

1. Select the final data point as shown and record the following results in a table in your Physics notes using your own values instead of the example values:

Momentum at Start (kg m/s)	Momentum at End (kg m/s)	Change in Momentum (kg m/s)	Change in Time (s)	Rate of Change of Momentum (kg m/s2)
0.00000	0.03195	(0.03195-0.00000) = 0.03195	(1.100-0.000) = 1.100	(0.03195/1.1) = 0.029

2. Now repeat the process for this video of a hard ball with a mass of 0.071kg and produce a second table of the new results.

Hard Ball.mp4

3. Compare the two results and state which ball has the largest rate of change of momentum - write this in your Physics notes.

Force and Rate of Change of Momentum (10mins)

Look at this page from BBC Bitesize GCSE Physics. It explains that the rate of change of momentum is equal to the force applied to a mass (or vice-versa). This is an important equation that you will need to know about and be able to use:

https://www.bbc.co.uk/bitesize/guides/z32h9qt/revision/3

Write the equation into your Physics notes along with the worked example; the equation triangle if you like using them and a reminder of the alternative equation linking force and acceleration.

Example (10mins)

Try both parts A and B of this example and write a comment on why you should bend your knees on impact when jumping during a sport:

https://isaacphysics.org/questions/gcse_ch2_19_q8

Copy and complete this sentence into your Physics notes as an important introduction to the next lesson:

'When impact time is longer impact force is _____'