Topic	Free fall, gravity and acceleration.	**Level**	GCSE
Outcomes	1. **To calculate the acceleration of a falling object** 2. To explain why heavier objects fall to the Earth faster than lighter objects 3. **To distinguish acceleration from velocity**		

Teacher Commentary	Student Commentary	Thinking going on inside the student's brain!	Demonstration carried out by the teacher
A football and a bowling ball are dropped from the same height. Which one will hit the floor first?			
	The bowling ball because it is heavier.		
OK, let's find out.			Hold the two balls and at the same height and drop them. Both balls will hit the ground at the same time.
		"This doesn't make sense and goes against my everyday experiences. Light	

		things fall slower than heavier things."	
OK, let's try another experiment. What will hit the ground last, a feather or a bowling ball?			
	The feather because it has more air resistance. This is easy.	*"I now know that the weight of an object doesn't affect how quickly it falls so I'm going to say air resistance."*	
			Teacher drops a feather and a ball. The ball hits the ground first.
	See, I was right. The feather has more air resistance!	*"This makes sense to me – the feather experiences a greater air resistance and this slows it down."*	
The ball actually has a larger surface area and so will collide with more air particles than the feather. The ball has a larger air resistance than the feather!			
		"Uh, he's right. This doesn't make sense to me. Why did the feather hit the ground last then?"	
OK, let's think about the forces acting on the ball and the feather. To make it easier let's remove air			

resistance! We can do this if we carry out the experiment in the vacuum.			
			Show the video of dropping a feather and a bowling ball in a vacuum.
	But why does the feather fall at the same speed as the bowling ball?	*"I'm confused, I don't really get this."*	
There are no air particles in a vacuum and so there is no air resistance. The only force acting on the ball is due to gravity. This force of gravity causes both the ball and the feather to accelerate downwards towards the Earth. The force of gravity experienced by an object depends upon the mass of the object and this is called its weight. The ball has a greater mass and so experiences a greater force of gravity – it has a greater weight.			
So, why does the ball not hit the ground before the feather if it has a larger weight?			
	I don't know.	*"My brain hurts. I'm going to switch off soon."*	
Ok, let's think about trying to accelerate a car and a lorry – which one will require the greater force?			
	That's easy – the lorry because it is		

<table>
<tr><td></td><td>That’s easy – the lorry because it is heavier. I will need to push it harder.</td><td></td><td></td></tr>
<tr><td>OK, so Newton's second law states that the acceleration of an object is directly related to the overall force acting and inversely related to its mass i.e. acceleration = net Force / mass.

This is because the mass of an object resists acceleration. The greater the mass of an object the more force it needs to accelerate it. Makes sense – think about the force needed to accelerate a car and a lorry.</td><td></td><td></td><td></td></tr>
<tr><td>Let’s put some numbers on our example and see if that helps:

<table><tr><td></td><td>Ball</td><td>Feather</td></tr><tr><td>Mass (Kg)</td><td>100 Kg</td><td>1 Kg</td></tr><tr><td>Net Force acting due to gravity (m x g)</td><td>100 x 10 = 1000 N</td><td>1 x 10 = 10 N</td></tr><tr><td>Acceleration (F_{net}/m)</td><td>1000 / 100 = 10 N/Kg</td><td>10 / 1 = 10 N/Kg</td></tr></table></td><td></td><td></td><td></td></tr>
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	But I thought the units of acceleration were m/s^2		
That's a good question. N/Kg is a funny unit for acceleration isn't it, but this is actually the same as m/s^2. Let's have a look at why by putting in the units on our equation below: acceleration = Force / mass T his is the same as saying: acceleration = (mass x acceleration) / mass Now let's put in some units into the second equation: $\text{acceleration} = \frac{\text{Kg x } m/s^2}{\text{Kg}}$ We can then simplify this equation by removing Kg. $\text{acceleration} = \frac{\cancel{\text{Kg}} \text{ x } m/s^2}{\cancel{\text{Kg}}}$ This leaves us with the units for acceleration, m/s^2 acceleration = m/s^2			

	I get it!!		
Now let's practice some examples for free fall.			
So why does a feather hit the ground after the ball when we drop them in the classroom?			
	Is it because the air resistance of the feather is big compared to the small force of weight and so slows down the feather? By is too small to slow down the heavy ball?		
Let's do another calculation. We know that acceleration is calculated by finding the overall force acting on an object and dividing it by the mass. acceleration = F_{net}/m Let's say the force of air resistance acting on the feather and the ball was 2 N we can do some maths to find out the acceleration of each object.			

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	Ball	Feather
Mass (Kg)	100 Kg	1 Kg
Force acting due to gravity (m x g)	100 x 10 = 1000 N	1 x 10 = 10 N

Progress: further resources on forces are available here: http://www.thescienceteacher.co.uk/forces/