A Guide to Newton's Law of Universal Gravitation

Teaching Approach

Newton's law of universal gravitation is a general physical law derived from practical observation by Newton. It is very important to help learners understand how this law is applied to two bodies, especially because learners struggle with these calculations. Before the law of universal gravitation is introduced to learners, the basics of forces acting over a distance are explained in lesson one. Lesson two focuses on the topic of weight and the effect it has on bodies. Gravity is introduced in lesson 3. Learners struggle to differentiate between mass and weight and this is focussed on in lesson 4. The task lesson is provided as practice for the learners or can be used as an assessment tool to evaluate learning of this section of work.

Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

1. Introducing Universal Gravitation

Examples are used to investigate the fact that forces can act over a distance. Newton's law of universal gravitation is introduced and the relationship between the masses of the two bodies and the distance between their centres.

2. Weight

In this lesson weight is defined and calculated and the idea of weightlessness is investigated.

3. Gravity

The effect gravity has on heavier and lighter objects is examined. Galileo's experiment from the leaning tower of Pisa is explained and demonstrated. The effect of gravity on objects is explained and the reason why objects fall to the ground is clarified.

4. Mass vs. weight

In everyday usage, the mass of an object is often referred to as its weight, though these are in fact different concepts and quantities. Mass refers to matter whereas weight refers to the force experienced by any object due to gravity.

Resource Material

1. Introducing Universal Gravitation	http://easycalculation.com/physics/classical-physics/newtons-law.php	Newton Law of Gravity calculation.
	http://www.youtube.com/watch?v=OZZGJfFf8XI	A brief introduction to Newton's Law of Universal Gravitation for high school students.
2. Weight	http://phet.colorado.edu/en/contributions/view/3165	Universal gravitational lab.
	http://phet.colorado.edu/en/contributions/view/2921	Exploring gravitation.
3. Gravity	http://phet.colorado.edu/en/contributions/view/3805	Modelling universal law of gravitation
	http://phet.colorado.edu/en/contributions/view/3363	A resource on universal gravitation.
4. More on Periodicity	http://www.opened.io/#!/resources/114812	An educational video on universal gravitation.
5. Mass vs. Weight	https://www.khanacademy.org/science/physics/newton-gravitation/gravity-newtonian/v/introduction-to-newton-s-law-of-gravitation	An introduction to Newton's law of gravitation.

Task

Question 1

A photograph was taken to show the position of an object falling on a planet out in space. The photograph showed the positions of the object at 0,1 s intervals, and all these positions were superimposed on one another to make a 'multi-exposure' photograph. Use the table of values below to find the magnitude of the acceleration due to gravity (g) on this planet. You may use calculations or use a graph to communicate your results to others.

Time (s)	Position (m)
0,0	0,00
0,1	0,05
0,2	0,20
0,3	0,44
0,4	0,78

Question 2

An astronaut uses a special moon scale to find the weight of some rocks. He finds they have a weight of 480 N downwards when they are weighed on the moon. Find the mass of these rocks and their weight on earth.

$g_{moon} = 1,6\ m{\cdot}s^{-2}$ $g_{earth} = 9,8\ m{\cdot}s^{-2}$

Question 3

Two objects attract each other with a gravitational force of 16 units. Calculate the new force of attraction if the distance between the two objects is doubled.

Question 4

The mass of Mars is $6,6 \times 10^{23}$ kg and its radius is $3,2 \times 10^{6}$ m. Calculate the acceleration due to gravity on Mars.

Question 5

Use Newton's law of Gravitation to predict how the force between two objects changes if one mass doubles and the other one trebles.

Question 6

Use Newton's law of Gravitation to find the force between the objects if the one mass is multiplied by 4 and the distance between them halves.

Question 7

Calculate the force between the Earth and the Sun given the mass of the Earth is 6 $\times 10^{24}$ kg and the mass of the Sun is 2 $\times 10^{30}$ kg. The average radius of the Earth's orbit about the Sun is 1, 5 $\times 10^{8}$ km.

Task Answers

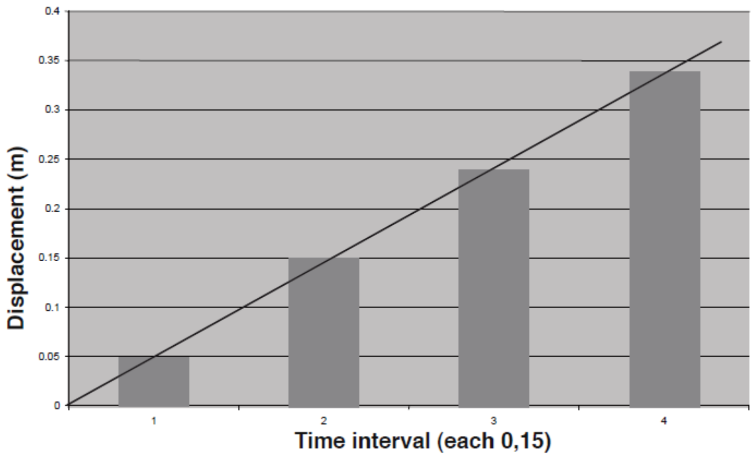
Question 1

Time (s)	Position (m)	Time Interval	Increase in Displacement	Average Velocity	Acceleration
0,0	0,00				
0,1	0,05	1	0,05 - 0,00 = 0,05	0,05/0,1 = 0,5	
0,2	0,20	2	0,20 - 0,05 = 0,15	0,15/0,1 = 1,5	(1,5 - 0,5)/0,1 = 10
0,3	0,44	3	0,44 - 0,20 = 0,24	0,24/0,1 = 2,4	(2,4 - 1,5)/0,1 = 9
0,4	0,78	4	0,78 - 0,44 = 0,34	0,34/0,1 = 3,4	(3,4 - 2,4)/0,1 =10

Average acceleration = 9,7 $m \cdot s^{-2}$

Using a graph:

Time (s)	Position (m)	Time Interval	Increase in Displacement
0,0	0,00		
0,1	0,05	1	0,05 - 0,00 = 0,05
0,2	0,20	2	0,20 - 0,05 = 0,15
0,3	0,44	3	0,44 - 0,20 = 0,24
0,4	0,78	4	0,78 - 0,44 = 0,34



The gradient of the line = (Δ in increase of displacement per 0,1 s) / 0,1 s

$= \frac{(0,34 - 0,05)/0,1}{0,3} = 9,9\ m.s^{-2}$ (approximately 10 $m.s^{-2}$)

Question 2

Weight on moon = mg_{moon}

480N = m (1, 6 $m \cdot s^{-2}$)

$m = \frac{480}{1,6}$

= 300kg

Weight on earth = mg_{earth}

= (300kg)(9,8 $m \cdot s^{-2}$)

= 2 940N

Question 3

If the distance is increased by a factor of 2, then force will be decreased by a factor of 4 (2^2). The new force is then a 1/4 of the original 16 units.

F = 16/4 = 4 units
Or given in an algebraic explanation:
$F \propto 1/r^2$
$F \propto 1/(2)^2$
Therefore F= ¼ units

Question 4

$$g = \frac{Gm}{r^2}$$

$$= \frac{6{,}67 \times 10^{-11} \times 6{,}6 \times 10^{23}}{(3{,}2 \times 10^{6})^2}$$

$= 4{,}3\ m \cdot s^{-2}$

Question 5

If F is directly proportional to the product of the two masses and one mass is doubled while the other mass is tripled the force would increase by the product, 6.
$F \propto m_1 m_2$
m_1 x2 and m_2 x 3
F x 6

Question 6

If F is directly proportional to the product of the two masses and inversely proportional to the square root of the distance between the masses then one mass is increased by four and the radius is halved. But due to the square root the radius is even smaller; therefore the force is multiplied by 16.

$$F \propto \frac{m_1 m_2}{r^2}$$

m_1 x 4 and r x ½
but r^2 x¼
F x 16

Question 7

$$F = \frac{Gm_1 m_2}{r^2}$$

$$F = \frac{(6{,}67 \times 10^{-11})(6 \times 10^{24})(2 \times 10^{30})}{(1{,}5 \times 10^{8})^2}$$

$= 3{,}56 \times 10^{28}$ N

Acknowledgements

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Credits

http://upload.wikimedia.org/wikipedia/commons/2/22/Christa_McAuliffe_Experiences_Weightlessness_During_KC-135_Flight_-_GPN-2002-000149.jpg