Calculating gravitational acceleration (g) on another planet

What if you start getting questions where the object is on another planet?

There is another formula you can use to calculate the value of g (gravitational acceleration) on any planet.

$$g = \frac{G.M}{r^2}$$

G – universal gravitational constant ($6{,}67 \times 10^{-11} N.m^2.kg^{-2}$)

g – gravitational acceleration on any planet ($m.s^{-2}$)

M – mass of the planet **(NOT OF THE OBJECT)** (Kg)

r – radius of that planet (m)

Question 1

1.1 Calculate the value of the gravitational acceleration on a planet that has a mass of 3×10^{23} and a radius of 4×10^6

$$g = \frac{G.M}{r^2}$$

$$g = \frac{6{,}6{,}7 \; x \; 10^{-11}.(3 \; x \; 10^{23})}{(4 \; x \; 10^6)^2}$$

$= 1{,}25 \; m.s^{-2}$

This mass needs to be the mass of the planet. The acceleration on a planet is dependent on the mass of that planet, and not on the mass of an object that happens to be on the planet.

This is a lot smaller than the value of g on earth – but it make sense, since the planet is a lot lighter than earth is.

Now if they ask you to calculate the weight (which is the gravitational force) on an object on that planet, you must use this value of 1.25 instead of $9{,}8 \; m.s^{-2}$.

1.2 Calculate the weight on a 20kg object on the above planet

Fg/W = m.g

= 20(1,25)

= 25 N towards the planet

Or

Alternatively you could have calculated the above in one step from scratch.

F = $\frac{G.m1.m2}{r^2}$

F = $\frac{[6{,}67\ x\ 10^{-11}(\ 3\ x\ 10^{23})(20)]}{(\ \ 4\ \ x\ 10^{6})^2}$

= 25,01 N

Question 2

Calculate the weight/gravitational force on an object with a 50 kg mass. The object is on a planet with a mass of 2 x 10^{26} kg and it has a radius of 5 x 10^{7} m, using both methods shown above (do this in your own book and then check the answer below to see if you are on the right track)

Method 1:

g = $\frac{G.M}{r^2}$

g = $\frac{6{,}6{,}7\ x\ 10^{-11}.(\quad x\ 10^{-})}{(5\ x\ 10^{7})^2}$

= 5,336 m.s^{-2} (don't round just yet)

Fg = m.g

= 50 (5,336)

= ________ N towards the planet

Or method 2

$$F = \frac{G.m1.m2}{r^2}$$

$$F = \frac{[6{,}67 \times 10^{-11}(2 \times 10^{26})(50)]}{(5 \times 10^7)^2}$$

= _______ N towards the planet

Question 3

Calculate the weight/gravitational force on an object with a 70 kg mass. The object is on a planet with a mass of 5,6 x 10^{28} kg and it has a radius of 6 x 10^{9} m, using both methods shown above (do this in your own book and then check the answer below to see if you are on the right track)

Fg/W = _______ N

Questions using ratio's

Now you are going to start getting questions where you need to decide by what factor a force will change by, when the masses and or distance between the objects is changed.

Watch this little video first showing you how to approach these questions.

Examples

1. The force of attraction between 2 objects is 1F. By what factor will this force change if the following happens?

1.1 the mass of one object doubles

F = $\frac{G.2m1.m2}{r^2}$

*now take all the numbers out of the equation

= $\frac{2}{1}\frac{(G.m1.m2)}{r^2}$

= 2 ($F_{original}$)

Thus the force will double the size of the original force

1.2 Both object's masses double

F = $\frac{G.2m1.2m2}{r^2}$

*now take all the numbers out of the equation

= $\frac{4}{1}\frac{(G.m1.m2)}{r^2}$

= 4 ($F_{original}$)

Thus the force will quadruple

1.3 The distance between the object's halve

F = $\frac{G.2m1.m2}{(½)r^2}$

*now take all the numbers out of the equation

And remember to square the ½

= $\frac{1}{¼}\frac{(G.m1.m2)}{r^2}$

= ______ ($F_{original}$)

Thus the force will quadruple

1.4 One object's mass doubles and the distance between them doubles.

$$F = \frac{G.2m1.m2}{(2)r^2}$$

$$\frac{2}{4}\frac{(G.m1.m2)}{r^2}$$

$= \_\_\_\_\_\_ F$ or $\frac{F}{\ }$

Thus the force will halve

Exercise 2:

The following exercise needs to be done in your book, and then sent to your teacher on MS teams. This needs to by done by: Sunday 19 July at 5pm.

{The first 3 questions were done as a part of this worksheet}

4. Two bodies of mass 7 000 kg and 8×10^4 kg are separated by a certain distance

4.1 Calculate the distance between the 2 objects if they exert a 400 N attractive force on each other.

5. Two bodies of mass 5×10^7 kg and $2,5 \times 10^4$ kg are separated by a certain distance

5.1 Calculate the distance between the 2 objects if they exert a 3000 N attractive force on each other.

6. Two **identical** objects which are placed with their centres 20 m apart, exert a gravitational force of $6,67 \times 10^{-5}$ N on each other. Calculate their masses

7. Objects A and B, which are placed with their centres 40 mm apart, exert a gravitational force of $6,67 \times 10^{-2}$ N on each other. Calculate the mass of object b if A has a mass of 200 kg.

8. Calculate the acceleration due to gravity on a planet that has a mass of 6×10^{28} kg and a radius of 8×10^8 m.

9. The mass of the planet is approximately $\frac{1}{80}$ th the mass of the Earth. Its radius is $\frac{1}{4}$ the radius of the Earth.

9.1 Calculate the gravitational acceleration on that planet.

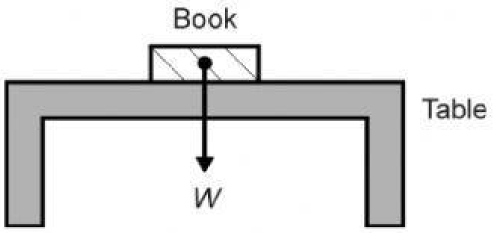
9.2 Calculate the weight of a 50 kg person on that planet.

10. An astronaut of mass 100 kg is standing on the surface of mars. Mars has a radius half that of the earth and a mass a tenth of the earth's.

10.1 Calculate the weight of the man on Mars

11. The gravitational acceleration on earth is $9.8 m.s^{-2}$. What is the value of g on planet Y if it has a mass and radius twice that of the earth.

12 A book rests on a horizontal table, as shown in the following diagram. The force, *W*, represents the weight of the book.



According to Newton's third law of motion, the force that is paired with the weight is …

A the force that the table exerts upwards on the book

B the force that the book exerts on the Earth

C the force that the book exerts on the table

D the force that the Earth exerts on the book

13 An object has a mass m on the surface of the Earth. A rocket transports the object to a planet that has a mass 8 times that of the Earth and a radius twice that of the Earth. Which of the following is the mass of the object on the planet?

A 8m

B 4m

C 2m

D m

14. Two objects of masses m_1 and m_2 are placed at a certain distance from each other. m_1 exerts a force F on m_2. If the mass of m_1 were to be made three times bigger and that of m_2 was doubled, while the distance remains constant, what would be the new force that m_1 exerts on m_2

15 What is the difference between g and G?

16. In each of the following cases, how does the gravitational pull, between two objects change, if:

16.1 One of the masses is doubled

16.2 Both masses are doubled

16.3 One of the masses is halved

16.4 Both masses are halved

16.5 The distance between the objects is halved

16.6 The distance between the objects is doubled

16.7 both masses are doubled and the distance is halved

16.8 One mass is halved and the distance is trebled

16.9 One mass is doubled and the other halved and the distance doubled

17. An astronaut with a weight of 980 N on earth, finds himself on a planet where his weight is 539 N.

17.1 What is his mass on the planet?

17.2 What is the magnitude of the gravitational acceleration on the planet?

17.3 Mars has virtually no atmosphere, a radius half that of the earth and a mass a tenth that of the earth. An object has a weight ,W, on the surface of the earth. What is the weight of the object on Mars?

18. The gravitational acceleration on earth is 9,8 $m.s^{-2}$. On planet Y with both its radius and mass twice that of the earth. Calculate the gravitational acceleration on planet Y.

19. What is gravitational force?

20. What two factors influence the gravitational force between two objects

{questions 21 to 23 were removed}

24. A man of mass 80 kg is standing on the surface of the earth.

a) Calculate the magnitude of the attractive force that the earth exerts on the man
b) How does your answer in a compare to the magnitude of the force that the man exerts on the earth?
c) Use you answer in a to calculate the radius of the earth.
(Mass earth = 6 x 10^{24} kg; G = 6,67 x 10^{-11} Nm^2kg^{-2}; g = 9.8 ms^{-2})

25. A man of mass 100kg stands on the Earth.

a) Calculate his weight.

b) If the mass of the Earth is 6×10^{24}kg, calculate the radius of the Earth and give the answer in kilometres.

26. The centres of two metal spheres, with masses of 8×10^4 kg and 2×10^3 kg respectively, are 340cm from each other. Calculate the gravitational force between them.

27. The gravitational pull between two ships, with masses of 6×10^4 kg and 2×10^5 kg respectively, is $1{,}64 \times 10^{-2}$ N.
    a. Calculate the distance between the two ships.
    b. How will the force be influenced if the distance between the ships is halved?

28. A planet has a radius of 10 times bigger than that of earth and a mass 300 times that of earth. Calculate the weight (gravitational pull) of a man on that planet if his weight on earth is 500 N