

# Motion and Force in a Gravitational Field

## Revision Problems 4: Universal Gravitation

Due: \_\_\_\_\_

Name: \_\_\_\_\_

1. What are mass and weight and how are they different? (3 marks)

**Mass is the amount of matter something is made of. Weight is the mass acted on by gravity. [1 mark]**

**Mass doesn't change. [1 mark]**

**The weight can change depending on the amount of gravity acting on the mass e.g. weight on Earth is different to weight on moon. [1 mark]**

2. It is possible that man could be walking on the moon in as little as 20 years. If an astronaut has a mass of 165 kg on Earth just before it steps into the rocket ship, what would be his weight on Mars were the acceleration due to gravity is 38% of that of Earth? (2 marks)

$$\begin{aligned}\text{weight Earth} &= mg = 165 \times 9.8 \\ &= 1617 \text{ N}\end{aligned}\quad [1 \text{ mark}]$$

$$\begin{aligned}\text{weight Mars} &= 165 \times 0.38 \times 9.8 \\ &= 614.46\end{aligned}\quad \underline{\text{weight on Mars} = 614 \text{ N}} \quad [1 \text{ mark}]$$

3. Pluto, which is now a dwarf planet, has a mass of  $1.27 \times 10^{22}$  kg and a radius of 2320 km. Our moon has a radius of 3467 and a mass of  $7.35 \times 10^{22}$  kg. Which would have the higher acceleration due to gravity and by how much? (3 marks)

$$g' = \frac{Gm}{r} \quad \begin{array}{l} g_{(\text{moon})} : g_{(\text{Pluto})} \\ \frac{Gm_m}{r_m^2} : \frac{Gm_p}{r_p^2} \end{array} \quad [1 \text{ mark}]$$

$$\begin{array}{l} G \text{ cancels as well as } \times 10^{22} \\ g_{(\text{moon})} : g_{(\text{Pluto})} \\ \frac{7.35}{3467^2} : \frac{1.27}{2320^2} \end{array} \quad [1 \text{ mark}]$$

$$6.11 \times 10^{-7} : 2.36 \times 10^{-7}$$

$$\frac{6.11}{2.36} = 2.59$$

**so moon has higher acceleration due to gravity by 2.59**  
[1 mark]

4. One of Jupiter's moons, Io, has a radius of  $4.10 \times 10^5$  kg. Io has a circular orbit and it takes 42.1 hours to orbit Jupiter.

a. What is Io's orbital speed? (2 marks)

$$t = 42.1 \times 60 \times 60 \\ = 151560 \text{ s} \\ \text{[1 mark]}$$

$$v = \frac{2\pi r}{T} = \frac{2 \times \pi \times 4.2 \times 10^5}{151560}$$

$$v = 1.74 \times 10^4 \text{ ms}^{-1} \quad \text{[1 mark]}$$

b. What is the mass of the planet Jupiter? (3 marks)

$$F_c = F_g$$

$$m_J = \frac{v^2 r}{G} = \frac{(2.74 \times 10^4)^2 \times 4.2 \times 10^8}{6.67 \times 10^{-11}} \quad \text{[2 marks]}$$

$$\frac{m_I v^2}{r} = \frac{G m_J m_I}{r^2}$$

$$m_J = 1.91 \times 10^{27} \text{ kg} \quad \text{[1 mark]}$$

$$v^2 = \frac{G m_J}{r}$$

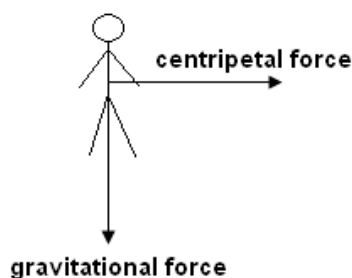
5. Astronauts in orbit are considered to be "weightless".

a. Why do you think the word "weightless" is in inverted commas? (2 marks)

**This is not true weightlessness as the astronaut is in free fall around the Earth and so has gravity acting on him. [1 mark]**

**To be truly weightless the astronaut experiences no force on him such as in very deep space or if his net weight is zero. [1 mark]**

b. Draw a free body diagram of an astronaut in a stable orbit above the Earth. (2 marks)



- c. The astronaut is in a rocket which is in a stable orbit around the Earth. Which of the following statements is always true?

- the period of the rocket must equal the period of the Earth's rotation.
- the Earth's gravitational force does not affect the rocket.
- the centripetal force acting on the rocket will be the gravitational force.
- the net force on the rocket is zero

answer: **iii**  
**[2 mark]**

One of the above statements is sometimes correct. Which one and in what circumstance?

**If the satellite is in a geostationary orbit then it would be correct, but satellites can be in a stationary orbit and not be geostationary. [1 mark]**