6.2 Newton's Law of Gravitation

Question Paper

Course	DP IB Physics
Section	6. Circular Motion & Gravitation
Topic	6.2 Newton's Law of Gravitation
Difficulty	Easy

Time allowed: 80

Score: /59

Percentage: /100

Question 1a

(a)
State Newton's Law of Gravitation.

[2]

[2 marks]

Question 1b

Newton's Law of Gravitation can also be written in equation form:

$$F = G\frac{Mm}{r^2}$$

(b)
Match the terms in the equation with the correct definition and unit:

Term
F
G
M and m
r

Definition
Gravitational constant
Mass
Force
Radius

Unit
kg
N
m
$N\ m^2\ kg^{-2}$

[4]

[4 marks]

Question 1c

Newton's Law of Gravitation applies to point masses. Although planets are not point masses, the law also applies to planets orbiting the sun.

(c)
State why Newton's Law of Gravitation can apply to planets.

[1]

[1 mark]

Question 1d

The mass of the Earth is 6.0×10^{24} kg. A satellite of mass 5000 kg is orbiting at a height of 8500 km above the centre of the Earth.

(d)
Calculate the gravitational force between the Earth and the satellite.

[4]

[4 marks]

Question 2a

The circular motion of a moon in orbit around a planet can be described by:

$$v = \sqrt{\frac{GM}{r}}$$

(a)
Define each of the terms in the equation above and give the unit:

(i)
v

[1]

(ii)
G

[1]

(iii)
M

[1]

(iv)
r

[1]

[4 marks]

Question 2b

The moon Europa orbits the planet Jupiter at a distance of 670 900 km. The mass of Jupiter is 1.898×10^{27} kg.

(b)
Calculate the linear velocity of Europa.

[3]

[3 marks]

Question 2c

The mass of Europa is 4.8×10^{22} kg.

(c)
Calculate the gravitational force between Jupiter and Europa.

[2]

[2 marks]

Question 2d

A second, hypothetical planet orbits Jupiter at a radius twice that of Europa, with the same mass. The gravitational force between two bodies is based on a $\frac{1}{r^2}$ rule.

(d)
Determine the force between Jupiter and the second planet as a fraction of the the force between Europa and Jupiter.

[2]

[2 marks]

Question 3a

(a)

Complete the definition of Kepler's third law using words or phrases from the selection below:

For planets or satellites in a ______ about the same central body, the ______ of the time period is ______ to the ______ of the radius of the orbit.

circular orbit   linear velocity   square   cube   time

length   mass   proportional

[4]

[4 marks]

Question 3b

Kepler's third law can also be represented by the equation:

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

(b)
Define each of the terms in the equation above and give the unit:

(i)
T

[1]

(ii)
G

[1]

(iii)
M

[1]

(iv)
r

[1]

[4 marks]

Question 3c

Venus has an orbital period, *T* of 0.61 years and its orbital radius, *r* is 0.72 AU from the Sun.

(c)
Using these numbers, show that Kepler's Third Law, $T^2 \propto r^3$ is true for Venus. No unit conversions are necessary.

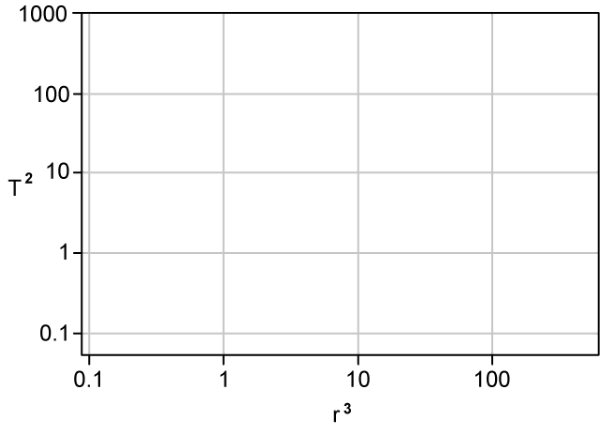
[3]

[3 marks]

Question 3d

Kepler's Third Law $T^2 \propto r^3$ can be represented graphically on log paper.

(d)
On the axes below, sketch a graph of $T^2 \propto r^3$ for our solar system, marking on the position of the Earth.

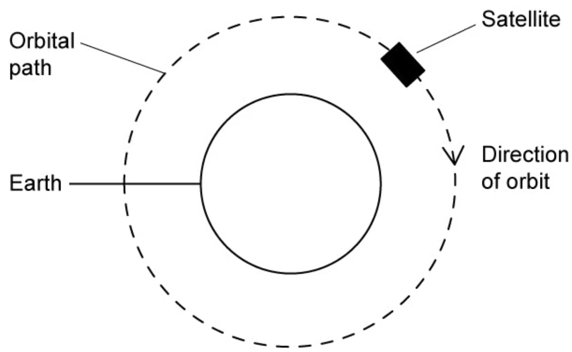


[3 marks]

[3 marks]

Question 4a

A satellite orbits the Earth in a clockwise direction.



(a)
Show on the diagram:

(i)
The centripetal force acting on the satellite when it is in orbit, *F*.

[2]

(ii)
The linear velocity of the satellite when it is in orbit, *v*.

[2]

[4 marks]

Question 4b

(b)
State the name of the force which provides the centripetal force required to keep the satellite orbiting in a circular path.

[1]

[1 mark]

Question 4c

The satellite has a mass of 7000 kg is in geostationary orbit and is constantly fixed above the same point on the Earth's surface. The radius of the geostationary orbit is 42 000 km. The Earth has a mass of 6.0×10^{24} kg.

(c)
Calculate the force required to keep the satellite in this orbit.

[3]

[3 marks]

Question 4d

All satellites in geostationary orbit are found at the same distance from the centre of the Earth, and are travelling at the same speed.

The equation linking speed of a satellite *v* and it's orbital radius, *r* is:

$$v^2 = \frac{GM}{r}$$

where *G* is the gravitational constant and *M* is the mass of the Earth.

(d)
Discuss why the speed is the same for every satellite in geostationary orbit, including the relevance of the satellite's mass.

[2]

[2 marks]

Question 5a

(a)
Define the following terms:

(i)
Gravitational field

[2]

(ii)
Gravitational field strength

[2]

[4 marks]

Question 5b

Gravitational field strength can be written in equation form as:

$$g = \frac{F}{m}$$

(b)
Define each of the terms in the equation above and give the unit:

(i)
g

[1]

(ii)
F

[1]

(iii)
m

[1]

[3 marks]

Question 5c

An astronaut of mass 80 kg stands on the Moon which has a gravitational field strength of 1.6 N kg^{-1}.

(c)
Calculate the weight of the astronaut on the Moon.

[3]

[3 marks]

Question 5d

The mass of the Earth is 5.972×10^{24} kg and sea level on the surface of the Earth is 6371 km.

(d)
Show that the gravitational field strength, *g*, is about 9.86 N kg^{-1} at sea level.

[3]

[3 marks]