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	Medium

Time allowed: 70

Score: /51

Percentage: /100

Question 1a

The distance from the Earth to the Sun is 1.5×10^{11} m. The mass of the Earth is 6×10^{24} kg and the mass of the Sun is 3.3×10^{5} times the mass of the Earth.

(a)
Estimate the gravitational force between the Sun and the Earth.

[2 marks]

Question 1b

Mars is 1.5 times further away from the Sun than the Earth and is 10 times lighter than Earth.

(b)
Predict the gravitational force between Mars and the Sun.

[3 marks]

Question 1c

(c)
Determine the acceleration of free fall on a planet 20 times as massive as the Earth and with a radius 10 times larger.

[2 marks]

Question 1d

(d)
Calculate the orbital speed of the Earth around the Sun.

[3 marks]

Question 2a

A satellite orbits the Earth with mass M above the equator with a period, T equal to 48 hours. The mass of the Earth is 5.972×10^{24} kg.

(a)
Derive an equation for the radius, r of the satellite's orbit.

[4 marks]

Question 2b

The mean radius of Earth is 6.37×10^6 m.

(b)
Calculate the height of the satellite above the Earth's surface.

[3 marks]

Question 2c

The Hubble Space Telescope is in orbit around the Earth at a height of 490 km above the Earth's surface.

(c)
Calculate Hubble's speed.

[3 marks]

Question 2d

(d)
Calculate the magnitude of the gravitational field on the Hubble Space Telescope at this height above the Earth's surface.

[2 marks]

Question 3a

Europa, a moon of Jupiter, has an orbital period of 85 hours and an orbital radius of 670 900 km.

(a)
Outline why Europa moves with uniform circular motion.

[3 marks]

Question 3b

(b)
Show that the orbital speed of Europa is 14 km s^{-1}.

[3 marks]

Question 3c

(c)
Deduce the mass of Jupiter.

[3 marks]

Question 3d

Ganymede is the largest of Jupiter's Moons. It has an orbital period of 7.15 days and an orbital speed of 10.880 km s^{-1}.

(d)
Calculate the orbital radius of Ganymede in terms of billions of km.
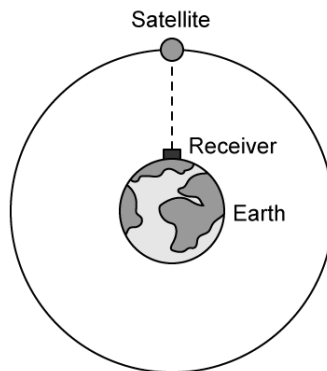
[3 marks]

Question 4a

(a)
Define Newton's universal law of gravitation.

[2 marks]

Question 4b

The diagram shows a satellite orbiting the Earth. The satellite is part of the network of global-positioning satellites (GPS) that transmit radio signals used to locate the position of receivers that are located on the Earth.

When the satellite is directly overhead the microwave signal reaches the receiver 62 ms after leaving the satellite.

(b)
Calculate the height of the satellite above the surface of the Earth.

[2 marks]

Question 4c

(c)
Explain why the satellite is accelerating towards the centre of the Earth even though its orbital speed is constant.

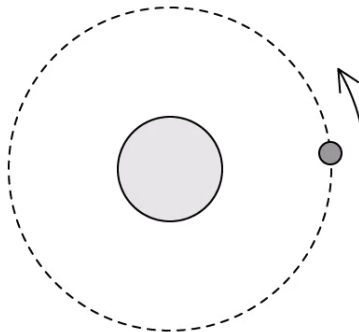**[2 marks]**

Question 4d

The radius of Earth is 6.4×10^6 m.

(d)
Calculate the gravitational field strength of the Earth at the position of the satellite.
　　Mass of Earth = 6.0×10^{24} kg

[2 marks]

Question 5a

A satellite is in a circular orbit around a planet of mass *M*.

(a)
Sketch arrows to represent the velocity and acceleration of the satellite.

[2 marks]

Question 5b

(b)

Show that the angular speed, ω is related to the orbital radius r by

$$r = \sqrt[3]{\dfrac{GM}{\omega^2}}$$

[2 marks]

Question 5c

Because of friction with the upper atmosphere, the satellite slowly moves into another circular orbit with a smaller radius before.

(c)

Suggest the effect of this on the satellites angular speed.

[2 marks]

Question 5d

Titus and Enceladus are two of Saturn's moons. Data about these moons are given in the table.

Moon	Orbit radius / m	Angular speed / rad s^{-1}
Titan	1.22×10^9	
Enceladus	2.38×10^8	5.31×10^{-5}

(d)

Determine the mass of Saturn.

[3 marks]