10.2 Fields at Work

Question Paper

Course	DP IB Physics
Section	10. Fields (HL only)
Topic	10.2 Fields at Work
Difficulty	Easy

Time allowed: 70

Score: /52

Percentage: /100

Question 1a

A planet is in orbit around a star.

(a)
State two reasons why a centripetal force is needed for a planet to maintain a circular orbit.

[2]

[2 marks]

Question 1b

The mass of the planet is 9×10^{24} kg, the mass of the star is 2×10^{30} kg and the radius of the planet's orbit R is 5×10^{10} m.

(b)
Calculate the value of the centripetal force.

[2]

[2 marks]

Question 1c

A spacecraft is launched from the surface of the planet to escape from the planet-star system. The radius of the planet is 8×10^{6} m.

(c)
Calculate the gravitational potentials which are:

(i)
Due to the planet.

[2]

(ii)
Due to the star.

[2]

(iii)
Due to both the planet and the star.

[1]

[5 marks]

Question 1d

(d)
Calculate the escape speed of the spacecraft from the planet-star system.

[2]

[2 marks]

Question 2a

The moon Ganymede moves around the planet Jupiter in a circular orbit.

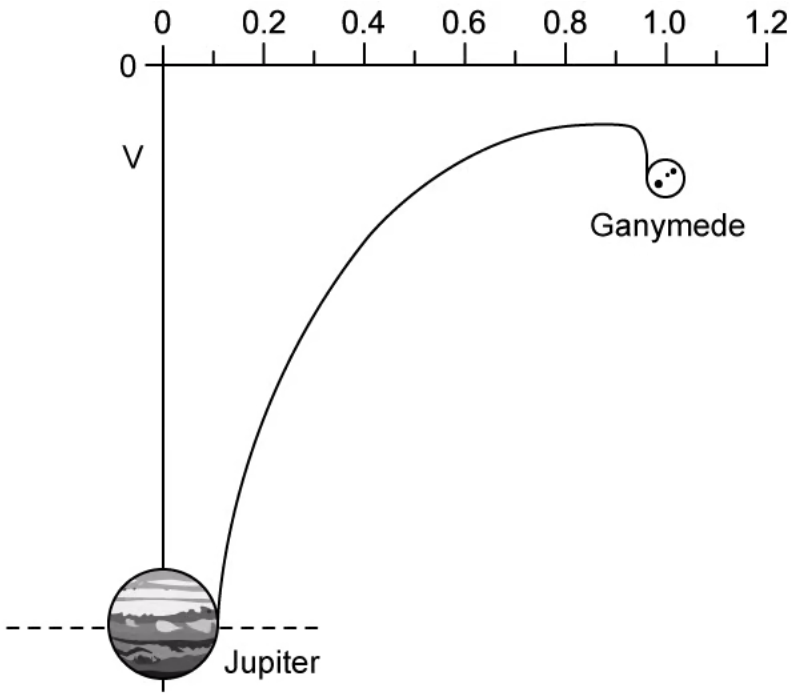
(a)
State the force responsible for this motion and outline why it does no work on Ganymede.

[2]

[2 marks]

Question 2b

The graph shows the variation of the gravitational potential between Jupiter and Ganymede with distance from the centre of Jupiter. The distance from Jupiter is expressed as a fraction of the total distance between the centre of Jupiter and the centre of Ganymede.



(b)

Identify a word equation for the distance at which the gravitational force between Jupiter and Ganymede is zero.

[1]

[1 mark]

Question 2c

(c)

By equating the expressions for the gravitational force due to Jupiter and Ganymede, where gravitational potential is at a maximum, show that:

$$\frac{M_J}{(0.9)^2} = \frac{M_G}{(0.1)^2}$$

Where M_G is the mass of Ganymede and M_J is the mass of Jupiter.

[4]

[4 marks]

Question 2d

(d)
Taking the mass of Jupiter as 1.898×10^{27} kg, determine the mass of Ganymede.

[2]

[2 marks]

Question 3a

Titan is a moon of Saturn and is much smaller than Earth. The radius of Earth is 2.48 times the radius of Titan and it is 40 times more massive.

The escape velocity from Earth is 11.2 km s^{-1}.

(a)
Determine the ratio of the escape velocities of Earth and Titan

[2]

[2 marks]

Question 3b

(b)
Hence calculate the escape velocity from Titan.

[1]

[1 mark]

Question 3c

Titan orbits Saturn at a distance between the centres of mass, *R* with an orbital period of revolution *T*.

(c)
State which forces must be in equilibrium for this orbit to be maintained.

[1]

[1 mark]

Question 3d

(d)
Hence, by using equations for centripetal acceleration and gravitational force, derive an expression in terms of the mass of Saturn for the time period, *T*.

[3]

[3 marks]

Question 4a

The forces between two masses are described as having an inverse-square relationship.

(a)
State the meaning of 'inverse-square relationship', both mathematically and qualitatively (in words).

[2]

[2 marks]

Question 4b

A planet with mass M and radius R has escape velocity v_{esc}.

A prototype rocket is launched with a speed which is only half of the escape speed.

(b)
Write an expression, in terms of M and R, which can be used to calculate the total energy of the rocket at its maximum height.

[2]

[2 marks]

Question 4c

(c)
Write an expression in terms of M and R to calculate the total energy at the launch of the prototype rocket in part (b).

[4]

[4 marks]

Question 4d

The prototype rocket, fired with half the escape velocity on Earth, launches with the energy determined in part (c). Assume that air resistance is negligible.

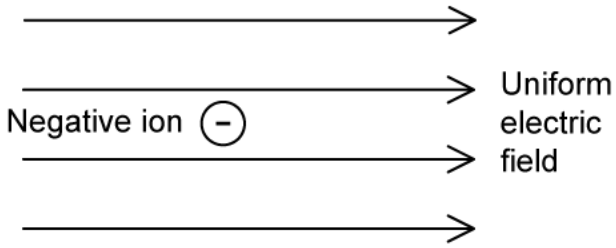
(d)
Determine, in terms of R, the maximum height h which the rocket achieves upon launch.

[3]

[3 marks]

Question 5a

The diagram shows a negative ion which is free to move in a uniform electric field.



(a)
For the negative ion:

(i)
State the direction of the electrostatic force acting on it.

[1]

(ii)
Explain your answer with reference to the electric field lines in the diagram.

[2]

[3 marks]

Question 5b

4.0×10^{-16} J of work is done on the ion to accelerate it through the field a distance of 63 mm in a line parallel to the field lines.

(b)
Calculate the magnitude of the electrostatic force acting on the negative ion.

[5]

[5 marks]

Question 5c

(c)
Complete the sentences to describe similarities between electrostatic and gravitational fields.

I. The magnitude of the gravitational and electrostatic force between two point masses or charges follows the _____ relationship with the separation distance between the point masses or charges.

II. Field lines around a point mass and negative point charge are both _____ and point _____ the mass or charge.

III. The field lines in uniform gravitational and electrostatic fields are both _____ and _____.

[3]

[3 marks]

Question 5d

(d)

Complete the sentences, using words or phrases, to describe the differences between electrostatic and gravitational fields.

I. The gravitational force acts on particles with _____ whilst the electrostatic force acts on particles with _____.

II. The gravitational force is always _____ whilst the electrostatic force can be _____.

III. The gravitational potential is always _____ whilst the electric potential can be either _____.

[3]

[3 marks]