10.2 Fields at Work

Question Paper

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

Time allowed: 50

Score: /40

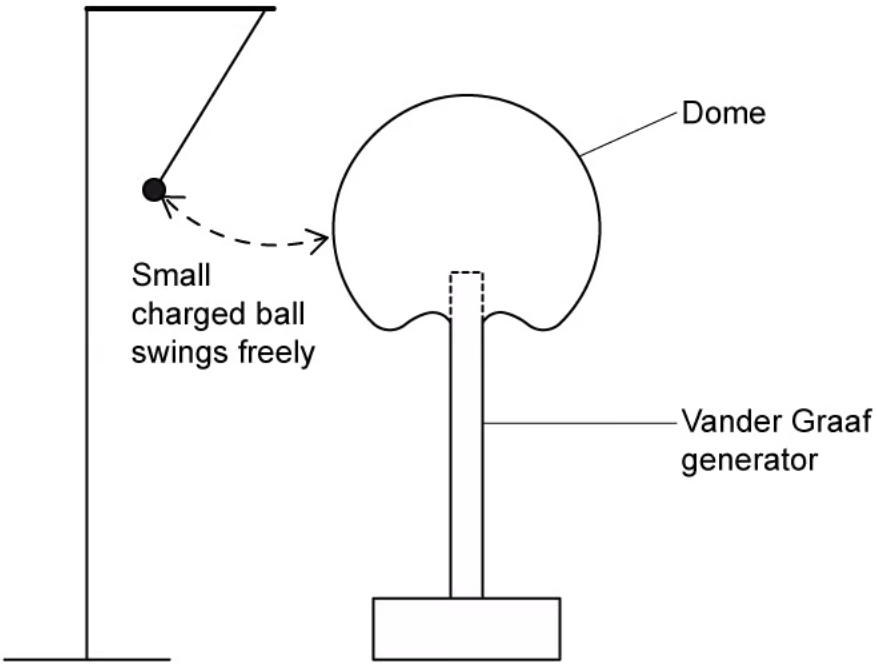
Percentage: /100

Question 1a

This question is about forces on objects held in fields. The first part is about electrically charged objects and the second part concerns bodies moving in gravitational fields.

The dome of a Van der Graaf generator can be treated as a conducting metal sphere with radius 20 cm. The dome is charged so that it has uniform surface charge + 13.1 μC. A stand is set up nearby, so that a pith ball with radius 1 cm, mass 11 g and charge + 1.8 μC can swing freely near to the dome.

The line of motion of the ball can be treated as normal to the surface of the dome.



The pith ball is held at a point 40 cm from the surface of the dome and pushed, so that it moves towards the dome with initial speed of 2.2 m s^{-1}. It stops moving and hangs suspended at a certain distance from the surface of the dome.

(a)
Calculate the distance between the surfaces of the dome and the pith ball when the ball stops moving.

[4]

[4 marks]

Question 1b

In an experiment a coin of 0.5 cm in diameter held at a distance of 55.3 cm from the eye appeared to be exactly the same size as the Moon. The coin was measured using a micrometer screw gauge and the distance to the eye using a metre rule.

The distance to the Moon is 384 400 km and the gravitational field strength on the surface of the Moon is 1.63 N kg^{-1}.

(b)
By referring to the data

(i)
Calculate the mass of the Moon.

[3]

(ii)
Determine the percentage error in the answer.

[3]

[6 marks]

Question 1c

The gravitational field strength on the surface of a particular planet is 1.6 N kg^{-1}. The planet orbits a star of similar density, but the diameter of the star is 100 times greater than the planet.

(c)
Calculate the gravitational field strength at the surface of the star.

[5]

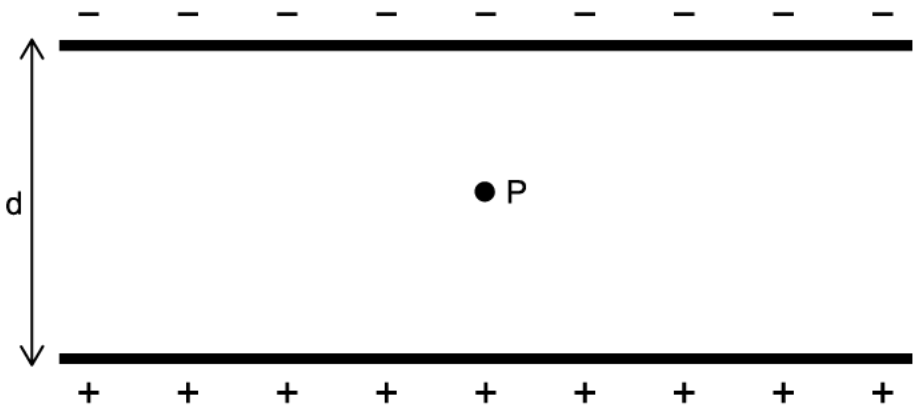
[5 marks]

Question 2a

This question is about forces and work done on objects held in fields. The first part is about charged oil drops in electric fields and the second part about space craft moving in gravitational fields.

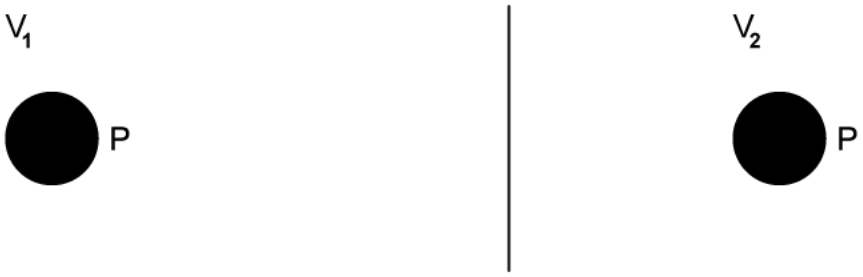
Two charged, horizontal, parallel metal plates are a distance *d* apart.

A small oil drop P is positioned between the plates such that when the potential difference between the plates is V_1, the drop is stationary. The potential difference is changed to V_2 and the drop moves upwards with a constant velocity *v*.



(a)
Complete the diagrams with the names, directions and relative magnitudes of the forces acting on the oil drop for the situations when pd = V_1 and pd = V_2.

[4]



[4 marks]

Question 2b

When a small, smooth sphere moves through a fluid such as air with low velocity v it experiences a resistive force. The force can be expressed in terms of a constant k so that:

$$resistive\ force = kv$$

The magnitude of the charge on the oil drop is q, and the distance between the plates is d.

(b)
Determine an expression which relates the velocity the oil drop moves upwards when the potential difference between the plates changes to the constant k.

[2]

[2 marks]

Question 2c

Work is done on the Soyuz spacecraft which is used to transport astronauts to the International Space Station (ISS). The ISS orbits the Earth at a height of 400 km above the Earth's surface. The Soyuz spacecraft has a mass of 7150 kg.

- Mass of the Earth = 5.97×10^{24} kg
- Mean radius of the Earth = 6.37×10^{6} m

(c)
For one trip from Earth to the ISS:

(i)
Calculate the work done in taking the Soyuz spacecraft from the Earth's surface to the ISS.

[3]

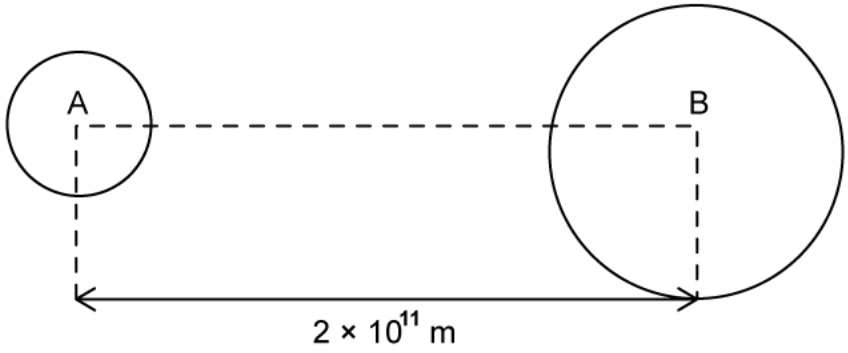
(ii)
State an assumption that was made in the calculation.

[1]

[4 marks]

Question 3a

A binary planet system consists of two stars, A and B.



A has a mass of mass 4.0×10^{30} kg and B has a mass of 8.0×10^{30} kg. The centres of the stars are separated by a distance of 2×10^{8} km.

(a)
Calculate the gravitational potential at the midpoint between the stars.

[2]

[2 marks]

Question 3b

The amount of energy required to send a space probe of mass 1800 kg from the surface of star A to the midpoint between stars A and B is 4.2×10^{11} J.

(b)
Calculate the gravitational field strength on the surface of star A.

[4]

[4 marks]

Question 3c

The two stars are drifting apart.

(c)
Calculate how far star A will have drifted at the point where its gravitational potential energy has decreased by 10 %.

[3]

[3 marks]

Question 4a

The orbits of the Earth and Jupiter are very nearly circular, with radii of 150×10^9 m and 778×10^9 m respectively. It takes Jupiter 11.8 years to complete a full orbit of the Sun.

(a)
Show that the values in this question are consistent with Kepler's third law.

[2]

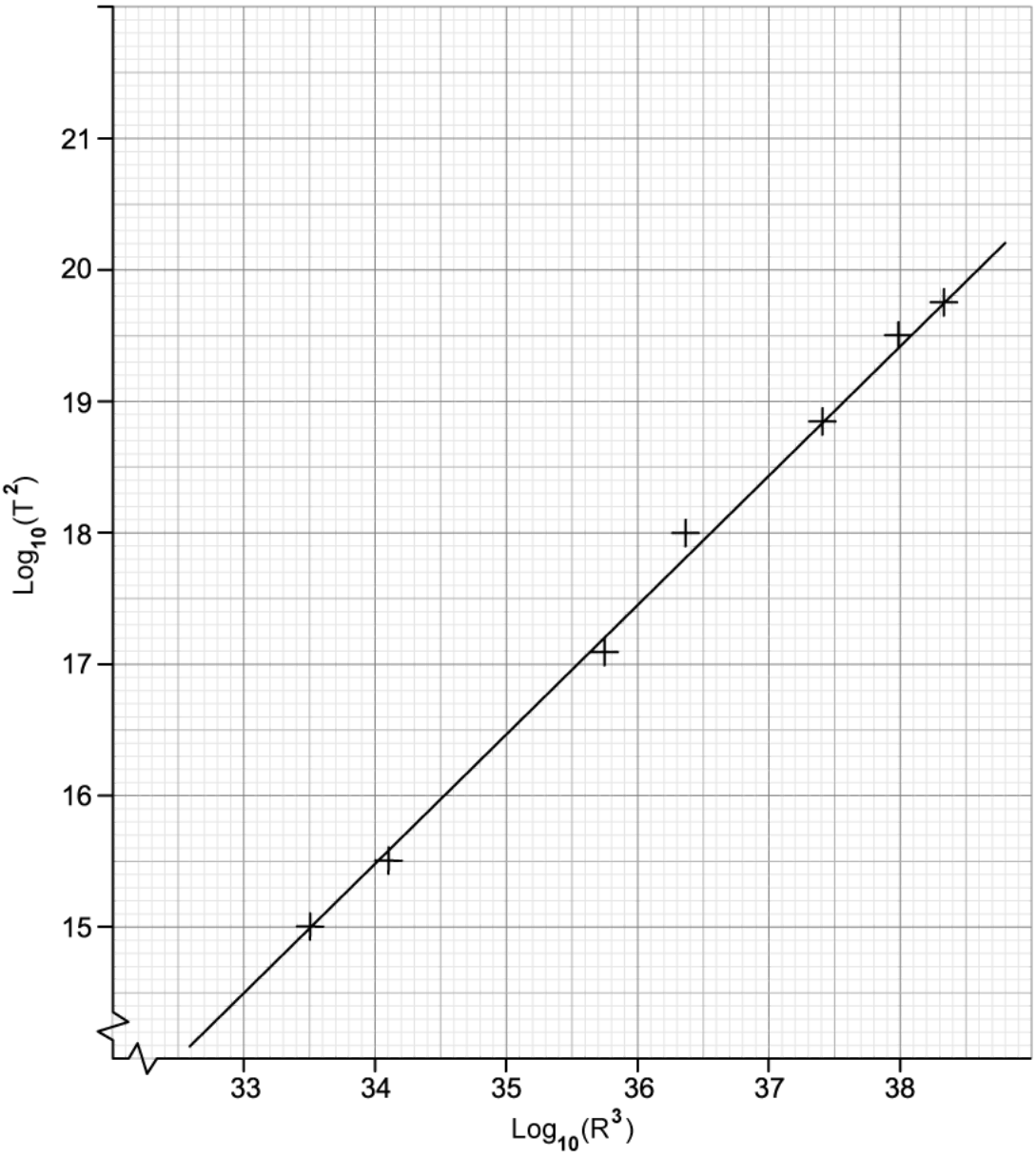
[2 marks]

Question 4b

Data from the orbits of different planets around our Sun is plotted in a graph of $\log(T^2)$ against $\log(R^3)$ as shown in the graph below, where T is the orbital period and R is the radius of the planet's orbit.

The values of T and R have been squared and cubed respectively due to Kepler's Third Law stating that:

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



(b)
Calculate the percentage error for the mass of the Sun obtained from the graph.

[4]

[4 marks]