10.1 Describing Fields

Question Paper

Course	DP IB Physics
Section	10. Fields (HL only)
Topic	10.1 Describing Fields
Difficulty	Hard

Time allowed: 50

Score: /39

Percentage: /100

Question 1a

An object has a weight of 100 N at a distance of 200 km above the centre of a small planet.

(a)
Sketch a labelled graph to show the relationship between the gravitational force, *F*, between two masses and the distance, *r*, between them. Mark at least three points on the graph using the information provided in the question.

[3]

[3 marks]

Question 1b

The distance along the Earth's surface from the North Pole to the Equator is 1×10^7 m.

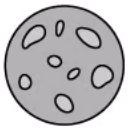
(b)
Calculate the mass of the Earth.

[2]

[2 marks]

Question 1c

A rocket is sent from the Earth to the moon. The moon has a radius of 1.74×10^6 m and the gravitational field strength on its surface is 1.62 N kg^{-1}. The radius of the Earth is 6370 km.



Moon

Rocket

Earth

The distance between the centre of the Earth and the centre of the moon is 385 000 km.

(c)
Calculate the distance above the Earth's surface where there is no resultant gravitational field strength acting on the rocket.

[4]

[4 marks]

Question 1d

The rocket will require a different amount of fuel to get to the moon than it will to return to the Earth.

(d)
Explain which journey will require the most fuel.

[2]

[2 marks]

Question 2a

A space shuttle of mass 2×10^6 kg is travelling from the Earth to the moon. It accelerates uniformly from launch at 5.25 m s^{-2}.It has enough propellant to provide thrust for the first 124 seconds.

The mass of the Earth is 5.97×10^{24} kg and the mean radius is 6.37×10^6 m.

(a)
Calculate the work done by the rocket during the first 124 seconds after launch. State any assumptions you have made.

[3]

[3 marks]

Question 2b

The Moon has a radius approximately 27% that of the Earth, and a mass of 1.2% that of the Earth.

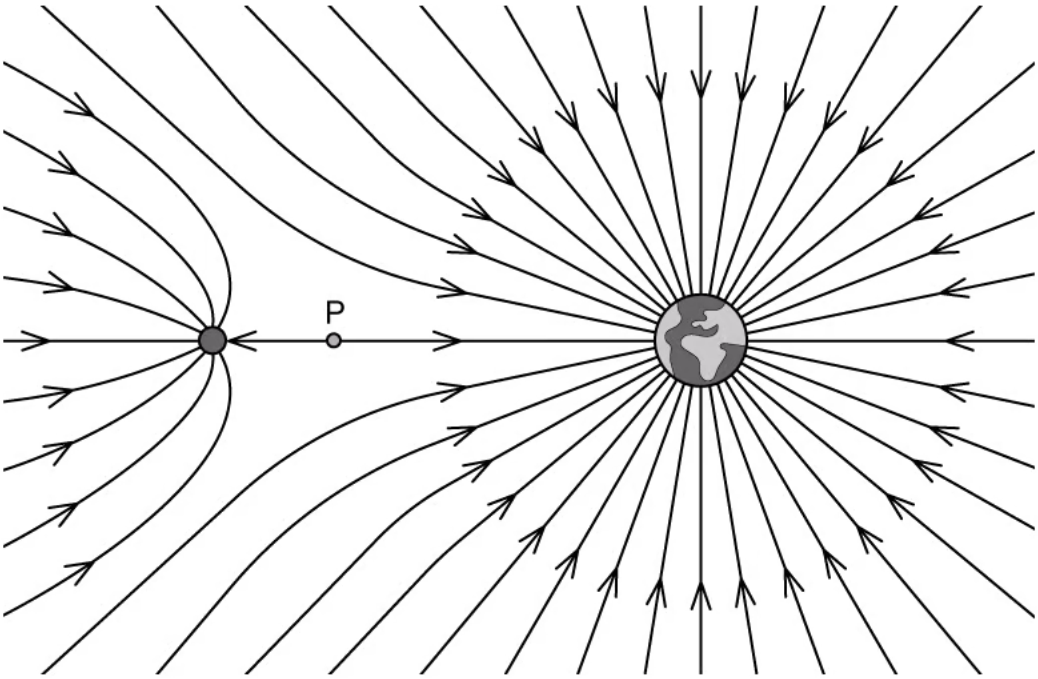
(b)
Calculate the gravitational potential at the surface of the moon in terms of the gravitational potential on the surface of the Earth.

[2]

[2 marks]

Question 2c

The gravitational field strength lines between the Earth and the moon can be drawn on a diagram.



Point P is the neutral point between the Earth and the moon where there is no resultant gravitational field.

(c)
Sketch the equipotential lines between the Earth and the moon on the diagram.

[3]

[3 marks]

Question 3a

Imagine that it was possible to construct a tunnel through the centre of the earth, connecting a point on the surface to the diametrically opposite point. Assume that the earth is perfectly spherical with an evenly distributed mass and that the mass and volume of the tunnel, air resistance and friction are negligible.

(a)
Describe the variation in gravitational field strength and how speed of travel would vary if a person were to jump into the hole.

[2]

[2 marks]

Question 3b

Within a hollow sphere of uniform density, the gravitational field strength is zero.

(b)
Using this information, derive an expression for the gravitational field strength at any point in the tunnel in terms of:

- The distance from the centre of the earth = r
- The radius of the earth = R_e
- The gravitational field strength on the surface of the earth = g_{surf}

[3]

[3 marks]

Question 3c

This case is analogous to a mass bouncing on a spring where $F = ma = -kx$, and where in this situation $k = \frac{mg_{surf}}{R_e}$.

The time period for a mass on a spring, *T*, is equal to $2\pi\sqrt{\frac{m}{k}}$. For a satellite in orbit at a distance *r*, from the centre of a large body with mass *M*, the orbital speed can be obtained as $v = \sqrt{\frac{GM}{r}}$.

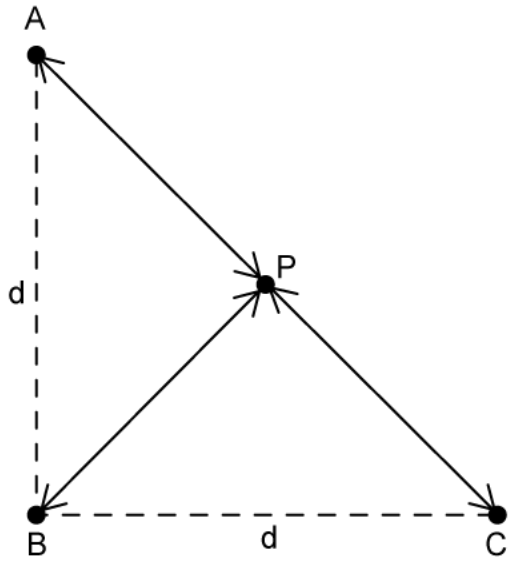
(c)
Using this information, show that the time for a traveller to reach the other end of the tunnel is the same as the time taken for a satellite in orbit just above the surface of the Earth to travel through half its orbit.

[2]

[1 mark]

Question 4a

Three charges are fixed at the corners of a right-angled triangle.



The length of both the horizontal and vertical sides is *d*.

(a)

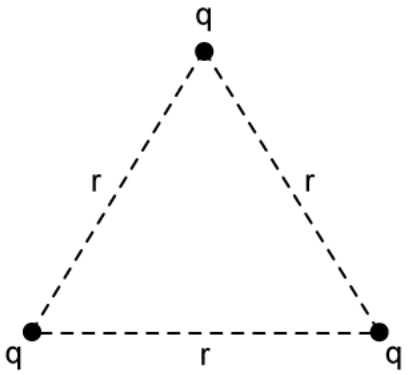
Show that the electric potential at point P, halfway between the –2Q and –6Q charge is given by $-\frac{2Q}{\sqrt{2}\pi\varepsilon_0 d}$.

[2]

[2 marks]

Question 4b

Before the discovery of quarks, scientists speculated that the subatomic particles might be made up of smaller particles.
If an electron was made up of three smaller, identical particles with charge *q*, which are brought in from an infinite distance to the vertices of an equilateral triangle, it would have this arrangement.



The radius of an electron is 2.82 fm.

(b)
Show that the work done in forming an electron consisting of 3 identical particles in this arrangement is given by:

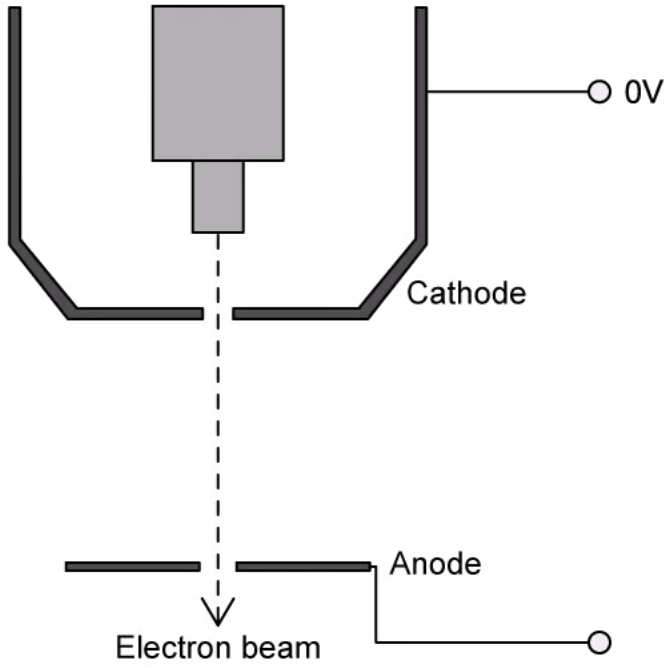
$$\frac{e^2}{12\pi\varepsilon_0 r}$$

[5]

[5 marks]

Question 4c

In an electron gun, electrons are released from a cathode and accelerated towards an anode. The electrons leave the electron gun at 10% of the speed of light.



(c)
Calculate the potential difference between the cathode and the anode.

[2]

[2 marks]

Question 5a

A science fiction film director is planning for a battle scene between two spacecrafts. The first spacecraft uses an electron gun to fire a beam of electrons at the second spacecraft from close range. The electron beam is created by accelerating electrons from rest between electrodes with a potential difference of 120 V.

To shield against the attack, the second aircraft creates a uniform electric field around itself and the electrons are stopped after 85 m. The director wishes to calculate the strength of the electric field, but is not aware of the equation $E = -\frac{\Delta V_e}{\Delta r}$.

(a)
Calculate the strength of the electric field without the use of this equation.

[2]

[1 mark]

Question 5b

After the failure of the first spacecraft to break through the electric shield of the second spacecraft a new weapon is to be designed. Instead of firing electrons, research is carried out to see if firing negatively charged ions with a charge of –2e and a mass of 2.26×10^{-26} kg would be more effective. The second spacecraft uses the same electric field as in part (a) to shield itself and that the electric field is uniform.

(b)
Calculate the magnitude of the minimum velocity at which these ions would need to be fired if they are to strike the second spacecraft from a distance of 1 km.

[2]

[2 marks]

Question 5c

Another option to attack the second spacecraft is to create a superweapon which can be fired from the aliens' home planet. As this weapon will fired from such a long way away from the second spacecraft, the spaceship and shield can be modelled as a charged particle carrying a charge of –130 C. The electrons fired by the superweapon have a kinetic energy of 12 MeV.

(c)
Calculate how close the electrons will come to the second spacecraft before they are stopped by the shield.

[2]

[2 marks]