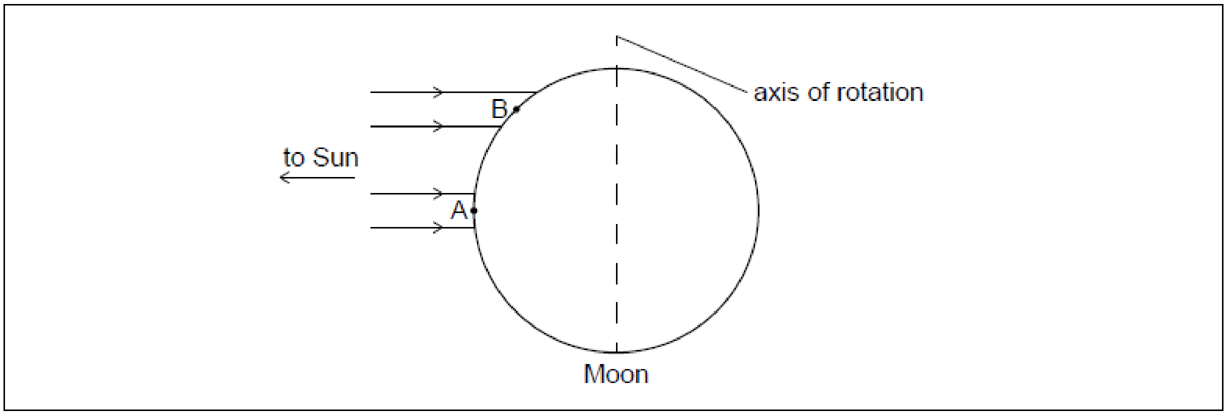
# Circular-practice-1a-ShortA

*[183 marks]*

The Moon has no atmosphere and orbits the Earth. The diagram shows the Moon with rays of light from the Sun that are incident at 90° to the axis of rotation of the Moon.




1a. A black body is on the Moon’s surface at point A. Show that the maximum temperature that this body can reach is 400 K. Assume that the Earth and the Moon are the same distance from the Sun. *[2 marks]*

1b. Another black body is on the Moon’s surface at point B. *[2 marks]*

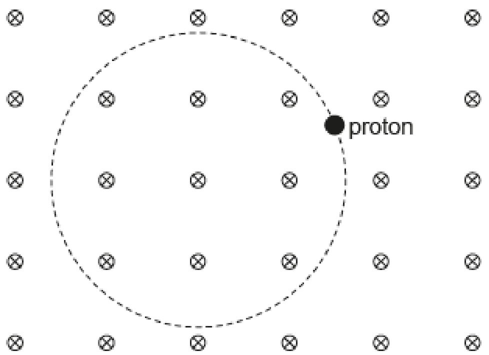
Outline, without calculation, why the aximum temperature of the black body at point B is less than at point A.

1c. The albedo of the Earth’s atmosphere is 0.28. Outline why the maximum temperature of a black body on the Earth when the Sun is overhead is less than that at point A on the Moon. *[1 mark]*

1d. Outline why a force acts on the Moon. *[1 mark]*

1e. Outline why this force does no work on the Moon. *[1 mark]*

A proton moves along a circular path in a region of a uniform magnetic field. The magnetic field is directed into the plane of the page.

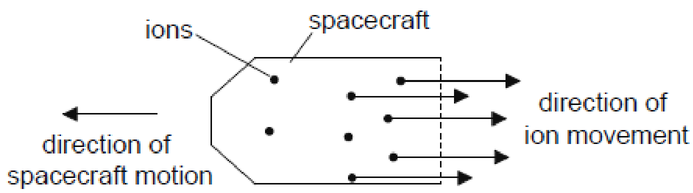



2a. Label with arrows on the diagram the magnetic force *F* on the proton. *[1 mark]*

2b. Label with arrows on the velocity vector *v* of the proton. *[1 mark]*

2c. The speed of the proton is $2.16 \times 10^{6}$ m s$^{-1}$ and the magnetic field strength is 0.042 T. For this proton, determine, in m, the radius of the circular path. Give your answer to an appropriate number of significant figures. *[3 marks]*

Ion-thrust engines can power spacecraft. In this type of engine, ions are created in a chamber and expelled from the spacecraft. The spacecraft is in outer space when the propulsion system is turned on. The spacecraft starts from rest.




The mass of ions ejected each second is $6.6 \times 10^{-6}$ kg and the speed of each ion is $5.2 \times 10^{4}$ m s$^{-1}$. The initial total mass of the spacecraft and its fuel is 740 kg. Assume that the ions travel away from the spacecraft parallel to its direction of motion.

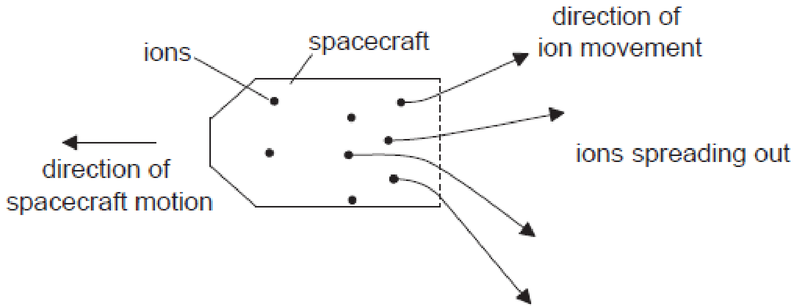
3a. Determine the initial acceleration of the spacecraft. *[2 marks]*

An initial mass of 60 kg of fuel is in the spacecraft for a journey to a planet. Half of the fuel will be required to slow down the spacecraft before arrival at the destination planet.

3b. Estimate the maximum speed of the spacecraft. *[2 marks]*

3c. Outline why scientists sometimes use estimates in making calculations. *[1 mark]*

In practice, the ions leave the spacecraft at a range of angles as shown.




3d. Outline why the ions are likely to spread out. *[2 marks]*

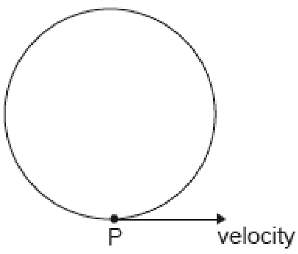
3e. Explain what effect, if any, this spreading of the ions has on the acceleration of the spacecraft. *[2 marks]*

On arrival at the planet, the spacecraft goes into orbit as it comes into the gravitational field of the planet.

3f. Outline what is meant by the gravitational field strength at a point. *[2 marks]*

3g. Newton's law of gravitation applies to point masses. Suggest why the law can be applied to a satellite orbiting a spherical planet of uniform density. *[1 mark]*

An electron moves in circular motion in a uniform magnetic field.




The velocity of the electron at point P is $6.8 \times 10^5$ m $s^{-1}$ in the direction shown.

The magnitude of the magnetic field is 8.5 T.

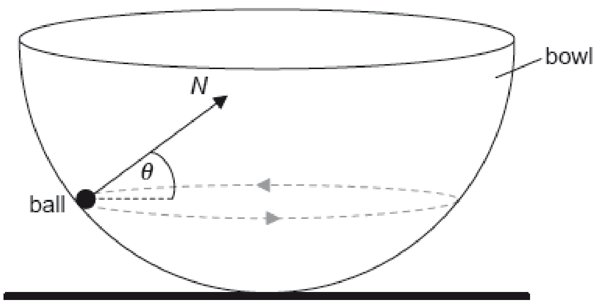
4a. State the direction of the magnetic field. *[1 mark]*

4b. Calculate, in N, the magnitude of the magnetic force acting on the electron. *[1 mark]*

4c. Explain why the electron moves at constant speed. *[1 mark]*

4d. Explain why the electron moves on a circular path. *[2 marks]*

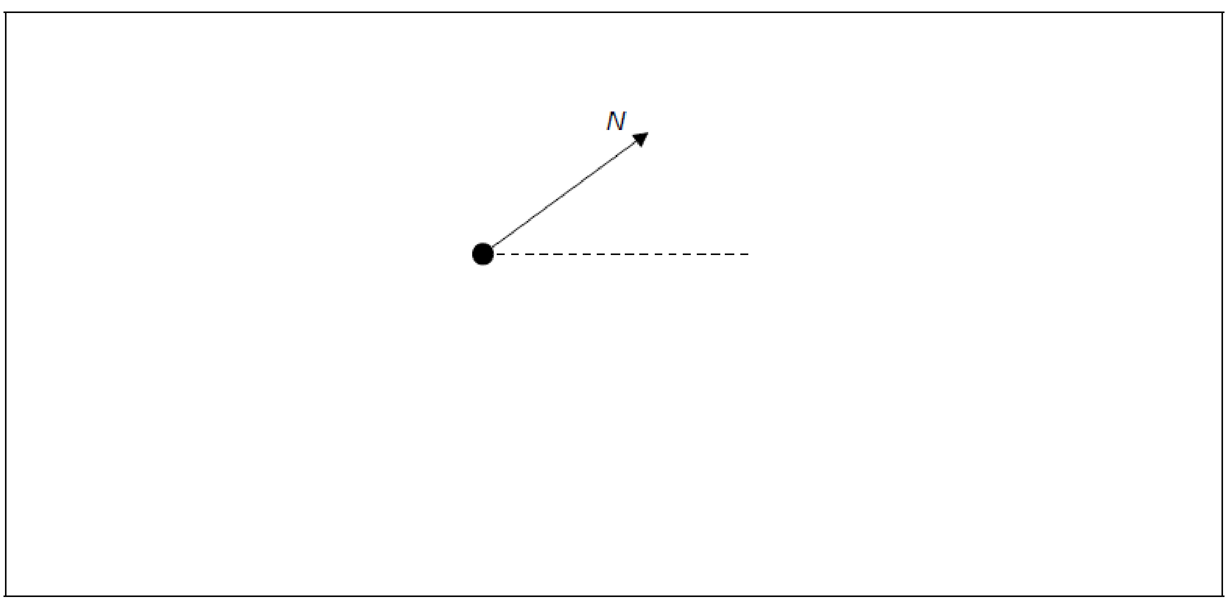
A small ball of mass $m$ is moving in a horizontal circle on the inside surface of a frictionless hemispherical bowl.




The normal reaction force $N$ makes an angle $\theta$ to the horizontal.

5a. State the direction of the resultant force on the ball. *[1 mark]*

5b. On the diagram, construct an arrow of the correct length to represent the weight of the ball. *[2 marks]*



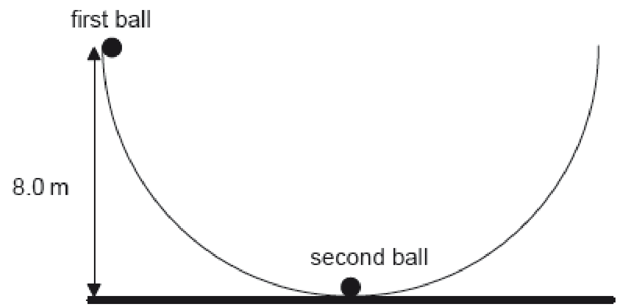

5c. Show that the magnitude of the net force $F$ on the ball is given by the following equation. *[3 marks]*

$$F = \frac{mg}{\tan\theta}$$

5d. The radius of the bowl is 8.0 m and $\theta = 22°$. Determine the speed of the ball. *[4 marks]*

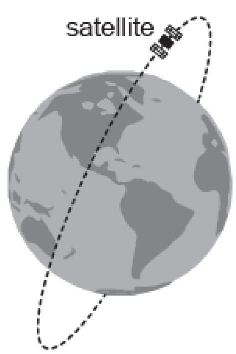
5e. Outline whether this ball can move on a horizontal circular path of radius equal to the radius of the bowl. *[2 marks]*

5f. A second identical ball is placed at the bottom of the bowl and the first ball is displaced so that its height from the horizontal is equal to 8.0 m. *[3 marks]*




The first ball is released and eventually strikes the second ball. The two balls remain in contact. Determine, in m, the maximum height reached by the two balls.

A satellite powered by solar cells directed towards the Sun is in a polar orbit about the Earth.




The satellite is orbiting the Earth at a distance of 6600 km from the centre of the Earth.

6a. Determine the orbital period for the satellite. *[3 marks]*

Mass of Earth = $6.0 \times 10^{24}$ kg

The satellite carries an experiment that measures the peak wavelength emitted by different objects. The Sun emits radiation that has a peak wavelength $\lambda_S$ of 509 nm. The peak wavelength $\lambda_E$ of the radiation emitted by the Earth is 10.1 µm.

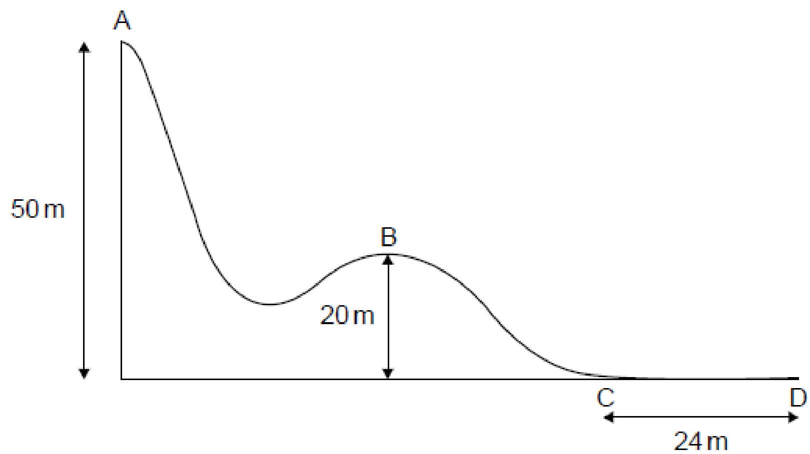
6b. Determine the mean temperature of the Earth. *[2 marks]*

6c. Suggest how the difference between $\lambda_S$ and $\lambda_E$ helps to account for the greenhouse effect. *[3 marks]*

6d. Not all scientists agree that global warming is caused by the activities of man. *[1 mark]*

Outline how scientists try to ensure agreement on a scientific issue.

The diagram below shows part of a downhill ski course which starts at point A, 50 m above level ground. Point B is 20 m above level ground.

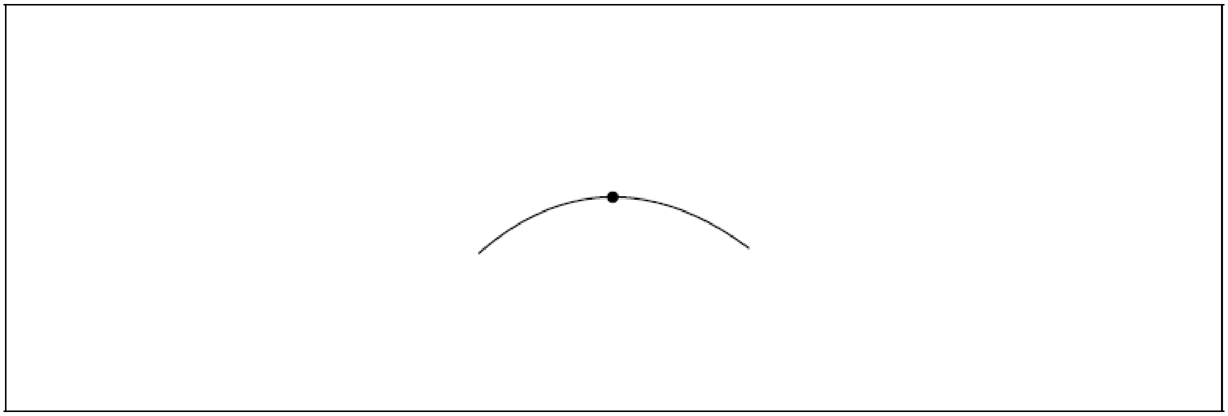



A skier of mass 65 kg starts from rest at point A and during the ski course some of the gravitational potential energy transferred to kinetic energy.

7a. From A to B, 24 % of the gravitational potential energy transferred to kinetic energy. Show that the velocity at B is 12 m $s^{-1}$. *[2 marks]*

7b. Some of the gravitational potential energy transferred into internal energy of the skis, slightly increasing their temperature. Distinguish between internal energy and temperature. *[2 marks]*

7c. The dot on the following diagram represents the skier as she passes point B. *[2 marks]*
Draw and label the vertical forces acting on the skier.



7d. The hill at point B has a circular shape with a radius of 20 m. Determine whether the skier will lose contact with the ground at point B. *[3 marks]*

7e. The skier reaches point C with a speed of 8.2 m $s^{-1}$. She stops after a distance of 24 m at point D. *[3 marks]*

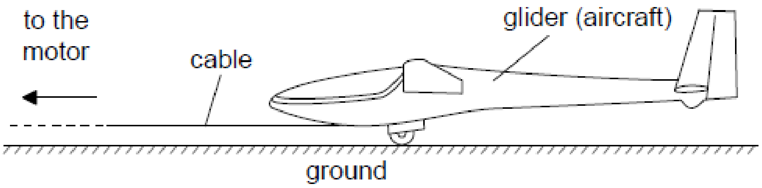
Determine the coefficient of dynamic friction between the base of the skis and the snow. Assume that the frictional force is constant and that air resistance can be neglected.

At the side of the course flexible safety nets are used. Another skier of mass 76 kg falls normally into the safety net with speed 9.6 m $s^{-1}$.

7f. Calculate the impulse required from the net to stop the skier and state an appropriate unit for your answer. *[2 marks]*

7g. Explain, with reference to change in momentum, why a flexible safety net is less likely to harm the skier than a rigid barrier. *[2 marks]*

A glider is an aircraft with no engine. To be launched, a glider is uniformly accelerated from rest by a cable pulled by a motor that exerts a horizontal force on the glider throughout the launch.



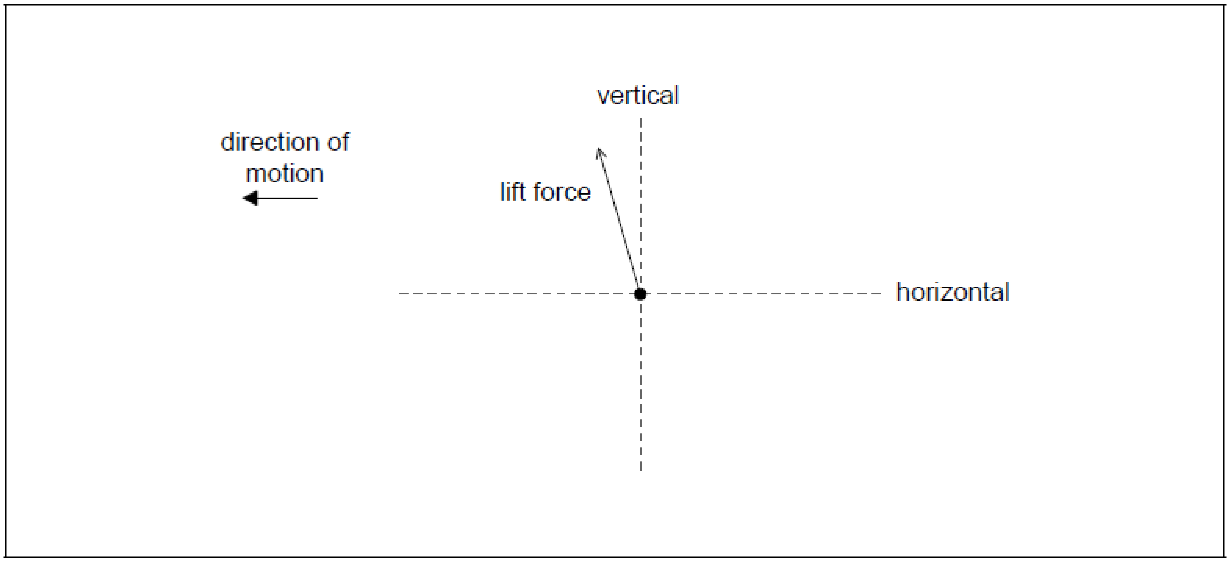

8a. The glider reaches its launch speed of 27.0 m s$^{-1}$ after accelerating for 11.0 s. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground. *[2 marks]*

8b. The glider and pilot have a total mass of 492 kg. During the acceleration the glider is subject to an average resistive force of 160 N. Determine the average tension in the cable as the glider accelerates. *[3 marks]*

8c. The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %. Determine the average power input to the motor. *[3 marks]*

8d. The cable is wound onto a cylinder of diameter 1.2 m. Calculate the angular velocity of the cylinder at the instant when the glider has a speed of 27 m s$^{-1}$. Include an appropriate unit for your answer. *[2 marks]*

8e. After takeoff the cable is released and the unpowered glider moves horizontally at constant speed. The wings of the glider provide a lift force. The diagram shows the lift force acting on the glider and the direction of motion of the glider. *[2 marks]*




Draw the forces acting on the glider to complete the free-body diagram. The dotted lines show the horizontal and vertical directions.

8f. Explain, using appropriate laws of motion, how the forces acting on the glider maintain it in level flight. *[2 marks]*

8g. At a particular instant in the flight the glider is losing 1.00 m of vertical height for every 6.00 m that it goes forward horizontally. At this instant, the horizontal speed of the glider is 12.5 m $s^{-1}$. Calculate the **velocity** of the glider. Give your answer to an appropriate number of significant figures. *[3 marks]*

9a. (i) Define *gravitational field strength.* *[2 marks]*

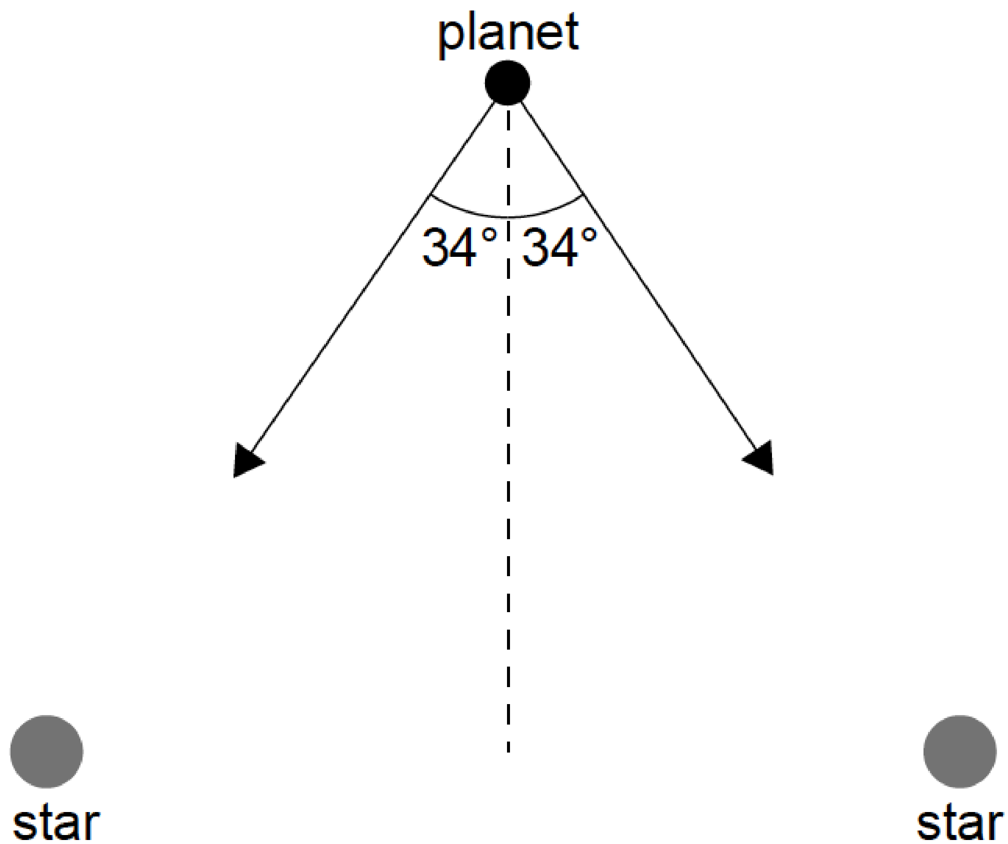
(ii) State the SI unit for gravitational field strength.

9b. A planet orbits the Sun in a circular orbit with orbital period *T* and orbital radius *R*. The mass of the Sun is *M*. *[4 marks]*

(i) Show that $T = \sqrt{\frac{4\pi^2 R^3}{GM}}$.

(ii) The Earth’s orbit around the Sun is almost circular with radius $1.5\times10^{11}$ m. Estimate the mass of the Sun.

The two arrows in the diagram show the gravitational field strength vectors at the position of a planet due to each of two stars of equal mass *M*.




Each star has mass $M = 2.0 \times 10^{30}$ kg. The planet is at a distance of $6.0 \times 10^{11}$ m from each star.

10a. Show that the gravitational field strength at the position of the planet due to **one** of the stars is $g = 3.7 \times 10^{-4}$ N kg$^{-1}$. *[1 mark]*

10b. Calculate the magnitude of the resultant gravitational field strength at the position of the planet. *[2 marks]*

This question is about gravitation and uniform circular motion.

Phobos, a moon of Mars, has an orbital period of 7.7 hours and an orbital radius of $9.4 \times 10^3$ km.

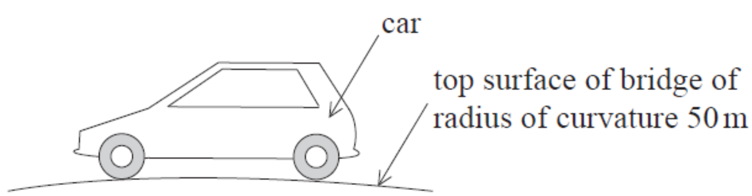
11a. Outline why Phobos moves with uniform circular motion. *[3 marks]*

11b. Show that the orbital speed of Phobos is about $2 \text{ km s}^{-1}$. *[2 marks]*

11c. Deduce the mass of Mars. *[3 marks]*

This question is about circular motion.

The diagram shows a car moving at a constant speed over a curved bridge. At the position shown, the top surface of the bridge has a radius of curvature of 50 m.




12a. Explain why the car is accelerating even though it is moving with a constant speed. *[2 marks]*

12b. On the diagram, draw and label the vertical forces acting on the car in the position shown. *[2 marks]*

12c. Calculate the maximum speed at which the car will stay in contact with the bridge. *[3 marks]*

This question is in two parts. **Part 1** is about electric charge and electric circuits. **Part 2** is about momentum.

**Part 1** Electric charge and electric circuits

13a. State Coulomb’s law. *[2 marks]*

13b. In a simple model of the hydrogen atom, the electron can be regarded as being in a circular orbit about the proton. The radius of the orbit is $2.0 \times 10^{-10}$ m. *[7 marks]*

(i) Determine the magnitude of the electric force between the proton and the electron.

(ii) Calculate the magnitude of the electric field strength *E* and state the direction of the electric field due to the proton at a distance of $2.0 \times 10^{-10}$ m from the proton.

(iii) The magnitude of the gravitational field due to the proton at a distance of $2.0 \times 10^{-10}$ m from the proton is *H.*
Show that the ratio $\frac{H}{E}$ is of the order $10^{-28}$C $kg^{-1}$.

(iv) The orbital electron is transferred from its orbit to a point where the potential is zero. The gain in potential energy of the electron is $5.4 \times 10^{-19}$J. Calculate the value of the potential difference through which the electron is moved.

13c. An electric cell is a device that is used to transfer energy to electrons in a circuit. A particular circuit consists of a cell of emf $\varepsilon$ and internal resistance *r* connected in series with a resistor of resistance 5.0 Ω. *[6 marks]*

(i) Define *emf of a cell.*

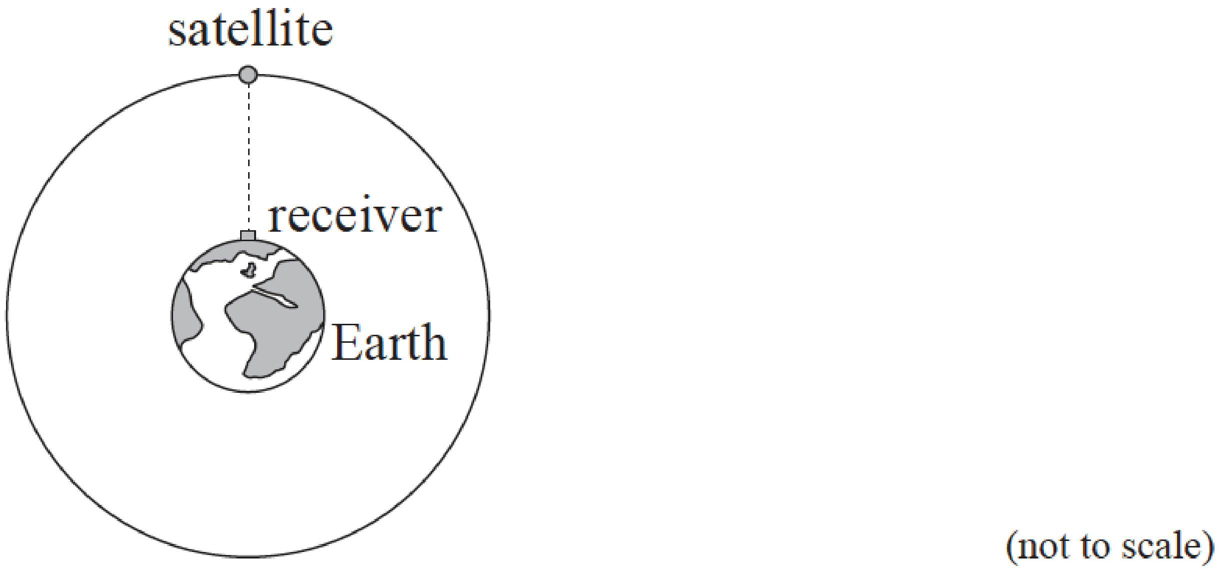
(ii) The energy supplied by the cell to one electron in transferring it around the circuit is $5.1 \times 10^{-19}$J. Show that the emf of the cell is 3.2V.

(iii) Each electron in the circuit transfers an energy of $4.0 \times 10^{-19}$ J to the 5.0 Ω resistor. Determine the value of the internal resistance *r.*

**Part 2** Satellite

14a. State, in words, Newton’s universal law of gravitation. *[2 marks]*

14b. 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. *[3 marks]*




When the satellite is directly overhead, the microwave signal reaches the receiver 67ms after it leaves the satellite.

(i) State the order of magnitude of the wavelength of microwaves.

(ii) Calculate the height of the satellite above the surface of the Earth

14c. (i) Explain why the satellite is accelerating towards the centre of the Earth even though its orbital speed is constant. *[8 marks]*

(ii) Calculate the gravitational field strength due to the Earth at the position of the satellite.

Mass of Earth = $6.0\times10^{24}$kg
Radius of Earth = $6.4\times10^{6}$m

(iii) Determine the orbital speed of the satellite.

(iv) Determine, in hours, the orbital period of the satellite.

**Part 2** Gravitational fields

15a. State Newton’s universal law of gravitation. *[3 marks]*

15b. Deduce that the gravitational field strength $g$ at the surface of a spherical planet of uniform density is given by *[2 marks]*

$$g = \frac{GM}{R^2}$$

where $M$ is the mass of the planet, $R$ is its radius and $G$ is the gravitational constant. You can assume that spherical objects of uniform density act as point masses.

15c. The gravitational field strength at the surface of Mars $g_M$ is related to the gravitational field strength at the surface of the Earth $g_E$ by *[2 marks]*

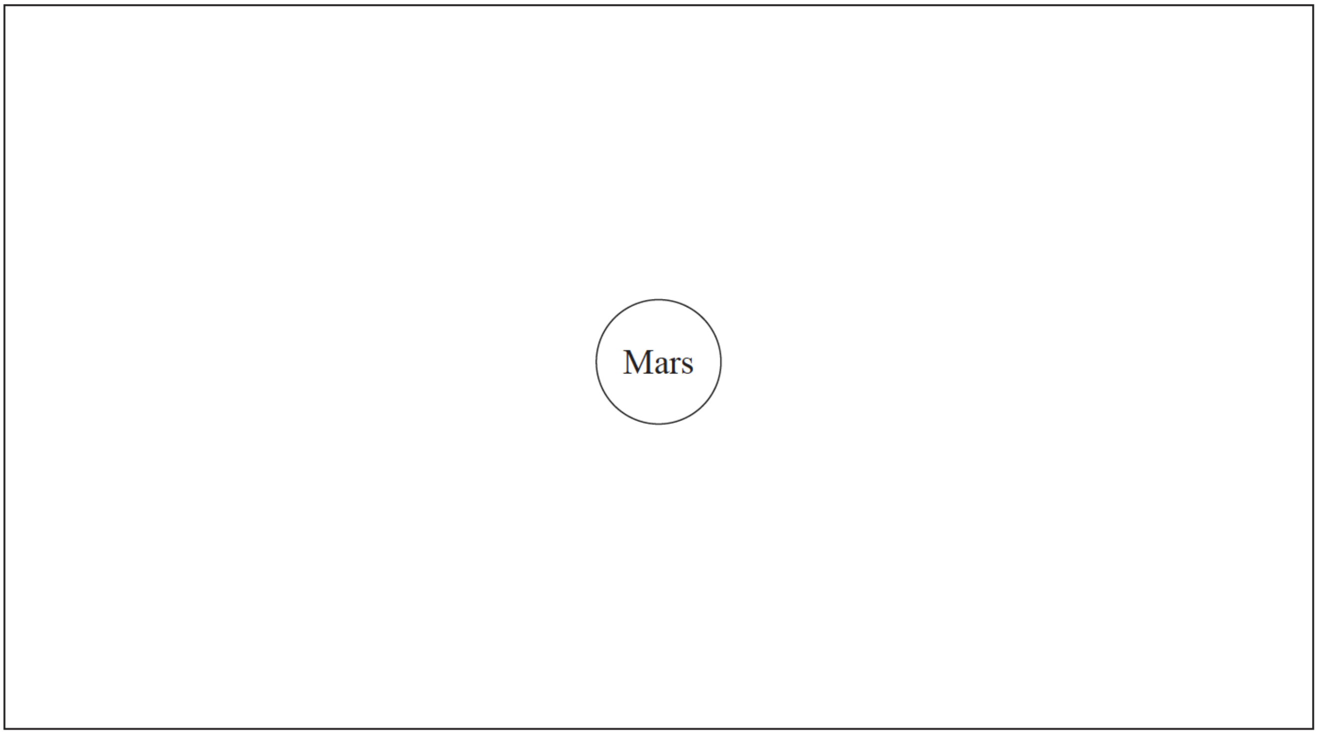
$g_M = 0.38 \times g_E$.

The radius of Mars $R_M$ is related to the radius of the Earth $R_E$ by

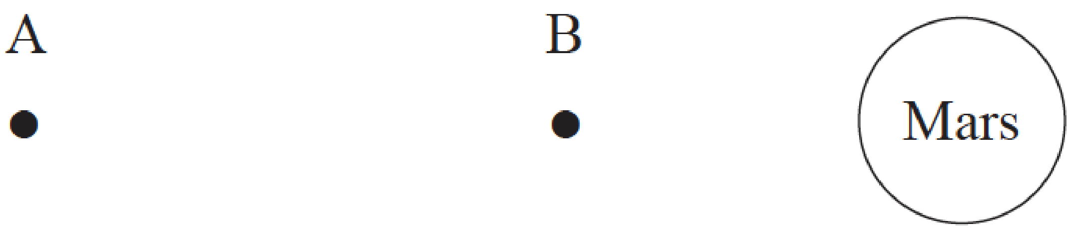
$R_M = 0.53 \times R_E$.

Determine the mass of Mars $M_M$ in terms of the mass of the Earth $M_E$.

15d. (i) On the diagram below, draw lines to represent the gravitational field *[3 marks]* around the planet Mars.




(ii) An object falls freely in a straight line from point A to point B in time $t$. The speed of the object at A is $u$ and the speed at B is $v$. A student suggests using the equation $v = u + g_M t$ to calculate $v$. Suggest **two** reasons why it is not appropriate to use this equation.



**Part 2** Gravitational fields and electric fields

16. The magnitude of gravitational field strength *g* is defined from the equation shown below. *[4 marks]*

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

The magnitude of electric field strength *E* is defined from the equation shown below.

$$E = \frac{F_E}{q}$$

For each of these defining equations, state the meaning of the symbols

(i) $F_g$.

(ii) $F_E$.

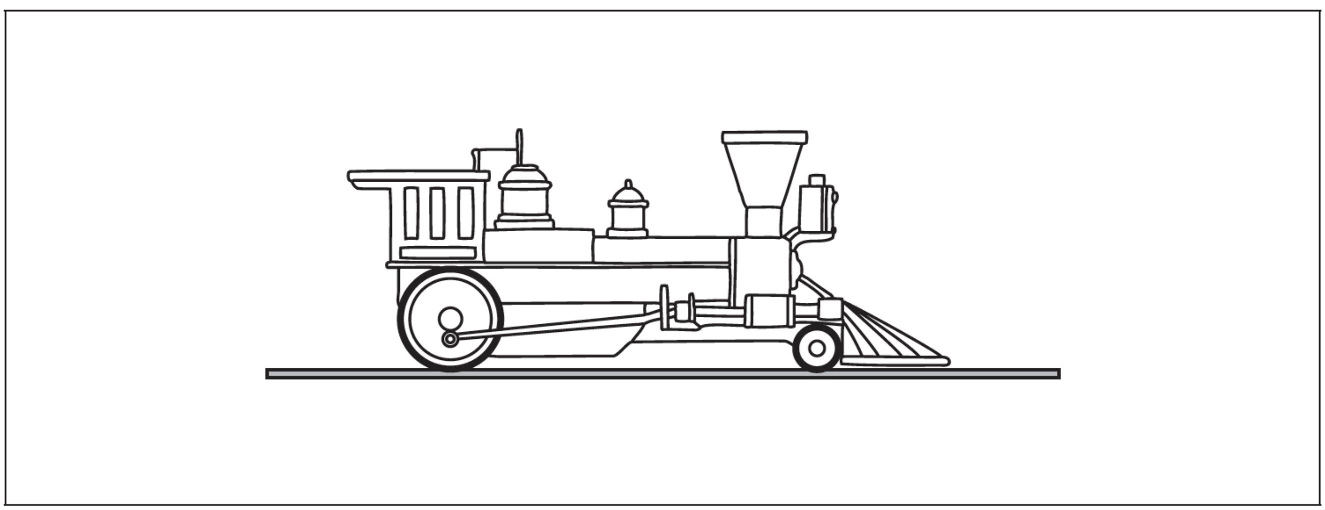
(iii) $m$.

(iv) $q$.

This question is in two parts. **Part 1** is about forces. **Part 2** is about internal energy.

**Part 1** Forces

A railway engine is travelling along a horizontal track at a constant velocity.



17a. On the diagram above, draw labelled arrows to represent the vertical forces that act on the railway engine. *[3 marks]*

17b. Explain, with reference to Newton's laws of motion, why the velocity of the railway engine is constant. *[2 marks]*

17c. The constant horizontal velocity of the railway engine is 16 $ms^{-1}$. A total horizontal resistive force of 76 kN acts on the railway engine. *[2 marks]*

Calculate the useful power output of the railway engine.

17d. The power driving the railway engine is switched off. The railway engine stops, from its speed of 16 $ms^{-1}$, without braking in a distance of 1.1 km. A student hypothesizes that the horizontal resistive force is constant. *[2 marks]*

Based on this hypothesis, calculate the mass of the railway engine.

17e. Another hypothesis is that the horizontal force in (c) consists of two components. One component is a constant frictional force of 19 kN. The other component is a resistive force $F$ that varies with speed $v$ where $F$ is proportional to $v^3$. *[5 marks]*

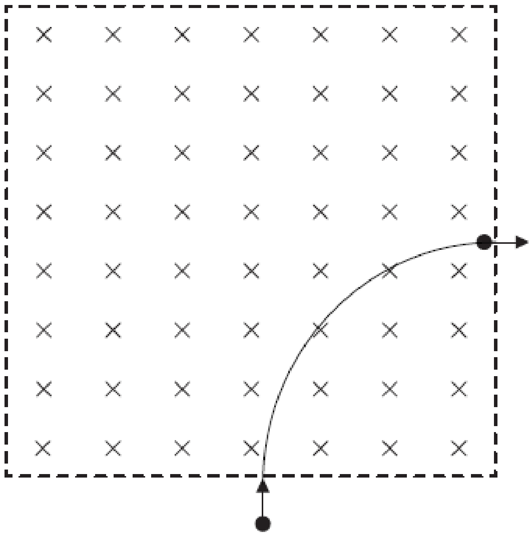
(i) State the value of the magnitude of $F$ when the railway engine is travelling at 16 $ms^{-1}$.

(ii) Determine the **total** horizontal resistive force when the railway engine is travelling at 8.0 $ms^{-1}$.

17f. On its journey, the railway engine now travels around a curved track at constant speed. Explain whether or not the railway engine is accelerating. *[3 marks]*

This question is about motion in a magnetic field.

An electron, that has been accelerated from rest by a potential difference of 250 V, enters a region of magnetic field of strength 0.12 T that is directed into the plane of the page.

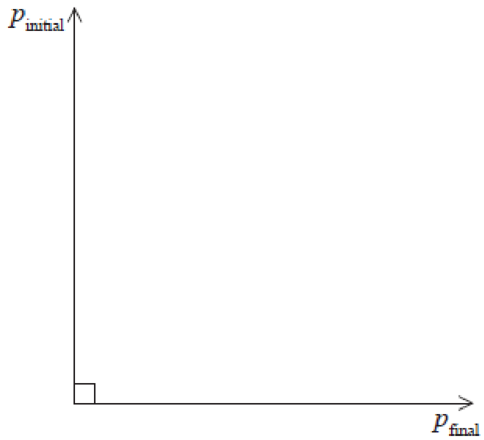


18a. The electron's path while in the region of magnetic field is a quarter circle. Show that the *[4 marks]*

(i) speed of the electron after acceleration is $9.4\times10^{6}\,ms^{-1}$.

(ii) radius of the path is $4.5\times10^{-4}$m.

18b. The diagram below shows the momentum of the electron as it enters and leaves the region of magnetic field. The magnitude of the initial momentum and of the final momentum is $8.6\times10^{-24}$Ns. *[3 marks]*



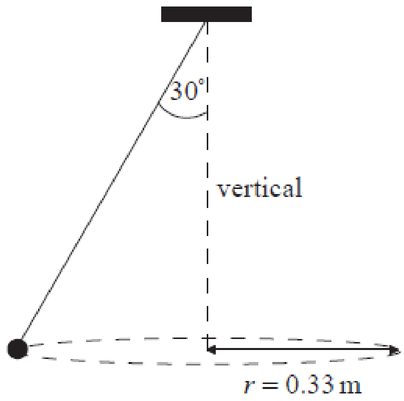

(i) On the diagram above, draw an arrow to indicate the vector representing the change in the momentum of the electron.

(ii) Show that the magnitude of the change in the momentum of the electron is $1.2\times10^{-23}$Ns.

(iii) The time the electron spends in the region of magnetic field is $7.5\times10^{-11}$s. Estimate the magnitude of the average force on the electron.

This question is about circular motion.

A ball of mass 0.25 kg is attached to a string and is made to rotate with constant speed *v* along a horizontal circle of radius *r* = 0.33m. The string is attached to the ceiling and makes an angle of 30° with the vertical.




19a. (i) On the diagram above, draw and label arrows to represent the forces on the ball in the position shown. *[4 marks]*

(ii) State and explain whether the ball is in equilibrium.

19b. Determine the speed of rotation of the ball. *[3 marks]*