Q1.

1 **(a)** Define gravitational potential.

....

.... [2]

(b) Explain why values of gravitational potential near to an isolated mass are all negative.

....

....

.... [3]

(c) The Earth may be assumed to be an isolated sphere of radius 6.4×10^3 km with its mass of 6.0×10^{24} kg concentrated at its centre. An object is projected vertically from the surface of the Earth so that it reaches an altitude of 1.3×10^4 km.

Calculate, for this object,

(i) the change in gravitational potential,

change in potential = ... J kg^{-1}

(ii) the speed of projection from the Earth's surface, assuming air resistance is negligible.

speed = ... $m s^{-1}$ [5]

(d) Suggest why the equation

$$v^2 = u^2 + 2as$$

is not appropriate for the calculation in **(c)(ii)**.

....

.... [1]

Q2.

3 A binary star consists of two stars that orbit about a fixed point C, as shown in Fig. 3.1.

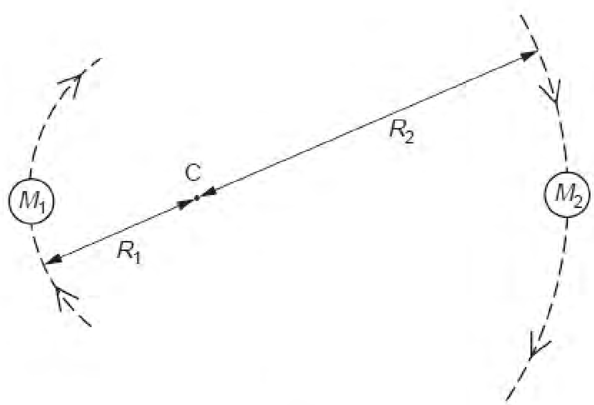

Fig. 3.1

The star of mass M_1 has a circular orbit of radius R_1 and the star of mass M_2 has a circular orbit of radius R_2. Both stars have the same angular speed ω, about C.

(a) State the formula, in terms of G, M_1, M_2, R_1, R_2 and ω for

(i) the gravitational force between the two stars,

....

(ii) the centripetal force on the star of mass M_1.

....

[2]

(b) The stars orbit each other in a time of 1.26×10^8 s (4.0 years). Calculate the angular speed ω for each star.

angular speed = ... rad s^{-1} [2]

(c) **(i)** Show that the ratio of the masses of the stars is given by the expression

$$\frac{M_1}{M_2} = \frac{R_2}{R_1}.$$

[2]

(ii) The ratio $\frac{M_1}{M_2}$ is equal to 3.0 and the separation of the stars is 3.2×10^{11} m.

Calculate the radii R_1 and R_2.

R_1 = ... m

R_2 = ... m
[2]

(d) **(i)** By equating the expressions you have given in **(a)** and using the data calculated in **(b)** and **(c)**, determine the mass of one of the stars.

mass of star = ... kg

(ii) State whether the answer in **(i)** is for the more massive or for the less massive star.

....
[4]

Q3.

1 The orbit of the Earth, mass 6.0×10^{24} kg, may be assumed to be a circle of radius 1.5×10^{11} m with the Sun at its centre, as illustrated in Fig. 1.1.

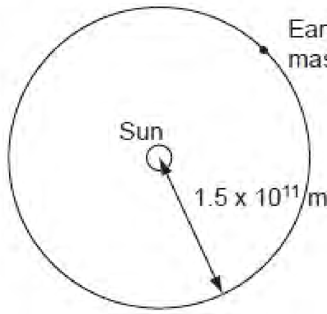

Fig. 1.1

The time taken for one orbit is 3.2×10^7 s.

(a) Calculate

(i) the magnitude of the angular velocity of the Earth about the Sun,

angular velocity = ... rad s^{-1} [2]

(ii) the magnitude of the centripetal force acting on the Earth.

force = ... N [2]

(b) **(i)** State the origin of the centripetal force calculated in **(a)(ii)**.

....

....[1]

(ii) Determine the mass of the Sun.

mass = ... kg [3]

Q4.

1 The Earth may be considered to be a uniform sphere with its mass M concentrated at its centre.

A satellite of mass m orbits the Earth such that the radius of the circular orbit is r.

(a) Show that the linear speed v of the satellite is given by the expression

$$v = \sqrt{\left(\frac{GM}{r}\right)}.$$

[2]

(b) For this satellite, write down expressions, in terms of G, M, m and r, for

(i) its kinetic energy,

kinetic energy = ... [1]

(ii) its gravitational potential energy,

potential energy = ... [1]

(iii) its total energy.

total energy = ... [2]

(c) The total energy of the satellite gradually decreases.

State and explain the effect of this decrease on

(i) the radius r of the orbit,

....

....

.... [2]

(ii) the linear speed v of the satellite.

....

....

.... [2]

Q5.

1 (a) Explain what is meant by a *gravitational field*.

....

.... [1]

(b) A spherical planet has mass M and radius R. The planet may be considered to have all its mass concentrated at its centre.
A rocket is launched from the surface of the planet such that the rocket moves radially away from the planet. The rocket engines are stopped when the rocket is at a height R above the surface of the planet, as shown in Fig. 1.1.

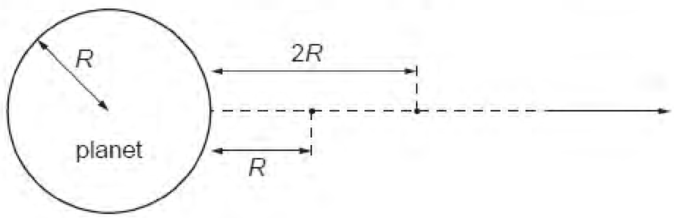

Fig. 1.1

The mass of the rocket, after its engines have been stopped, is m.

(i) Show that, for the rocket to travel from a height R to a height $2R$ above the planet's surface, the change ΔE_P in the magnitude of the gravitational potential energy of the rocket is given by the expression

$$\Delta E_P = \frac{GMm}{6R}.$$

[2]

(ii) During the ascent from a height R to a height $2R$, the speed of the rocket changes from 7600 m s^{-1} to 7320 m s^{-1}. Show that, in SI units, the change ΔE_K in the kinetic energy of the rocket is given by the expression

$$\Delta E_K = (2.09 \times 10^6)m.$$

[1]

(c) The planet has a radius of 3.40×10^6 m.

(i) Use the expressions in **(b)** to determine a value for the mass M of the planet.

M = ... kg [2]

(ii) State one assumption made in the determination in **(i)**.

....

.... [1]

Q6.

1 **(a)** Define *gravitational field strength*.

....

.... [1]

(b) A spherical planet has diameter 1.2×10^4 km. The gravitational field strength at the surface of the planet is $8.6\,\text{N kg}^{-1}$.
The planet may be assumed to be isolated in space and to have its mass concentrated at its centre.
Calculate the mass of the planet.

mass = ... kg [3]

(c) The gravitational potential at a point X above the surface of the planet in **(b)** is $-5.3 \times 10^7\,\text{J kg}^{-1}$.
For point Y above the surface of the planet, the gravitational potential is $-6.8 \times 10^7\,\text{J kg}^{-1}$.

(i) State, with a reason, whether point X or point Y is nearer to the planet.

....

....

.... [2]

(ii) A rock falls radially from rest towards the planet from one point to the other.
Calculate the final speed of the rock.

speed = ... m s^{-1} [2]

Q7.

1 **(a)** Define *gravitational potential* at a point.

....

....

.... [2]

(b) The Earth may be considered to be an isolated sphere of radius R with its mass concentrated at its centre.
The variation of the gravitational potential ϕ with distance x from the centre of the Earth is shown in Fig. 1.1.

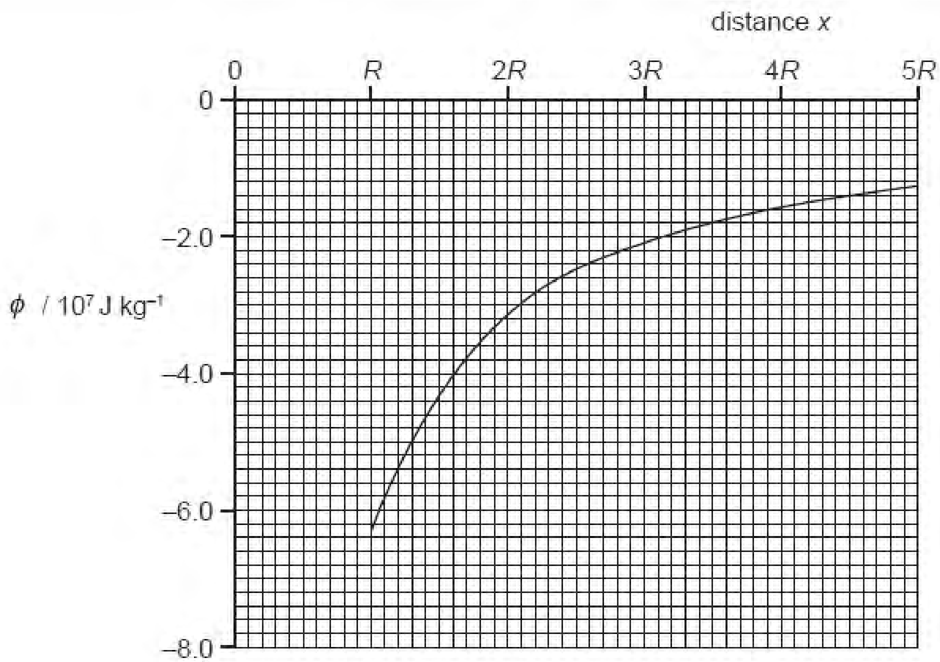

Fig. 1.1

The radius R of the Earth is 6.4×10^6 m.

(i) By considering the gravitational potential at the Earth's surface, determine a value for the mass of the Earth.

mass = ... kg [3]

(ii) A meteorite is at rest at infinity. The meteorite travels from infinity towards the Earth.

Calculate the speed of the meteorite when it is at a distance of $2R$ above the Earth's surface. Explain your working.

speed = ... m s^{-1} [4]

(iii) In practice, the Earth is not an isolated sphere because it is orbited by the Moon, as illustrated in Fig. 1.2.

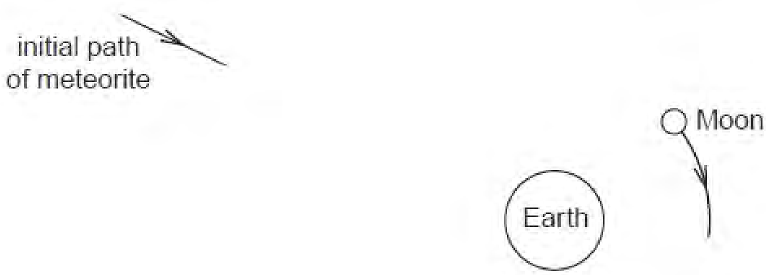

Fig. 1.2 (not to scale)

The initial path of the meteorite is also shown.

Suggest two changes to the motion of the meteorite caused by the Moon.

1. ....

....

2. ....

....
[2]

Q8.

1 (a) Newton's law of gravitation applies to point masses.

(i) State Newton's law of gravitation.

....

....

....[2]

(ii) Explain why, although the planets and the Sun are not point masses, the law also applies to planets orbiting the Sun.

....

....[1]

(b) Gravitational fields and electric fields show certain similarities and certain differences. State one aspect of gravitational and electric fields where there is

(i) a similarity,

....

....[1]

(ii) a difference.

....

....

....[2]

Q9.

1 **(a)** State what is meant by a *field of force*.

....

.... [1]

(b) Gravitational fields and electric fields are two examples of fields of force.
State one similarity and one difference between these two fields of force.

similarity: ....

....

difference: ....

....

....
[3]

(c) Two protons are isolated in space. Their centres are separated by a distance *R*.
Each proton may be considered to be a point mass with point charge.
Determine the magnitude of the ratio

$$\frac{\text{force between protons due to electric field}}{\text{force between protons due to gravitational field}}.$$

ratio = ... [3]

Q10.

1 **(a)** Define *gravitational potential* at a point.

....

.... [1]

(b) The gravitational potential ϕ at distance r from point mass M is given by the expression

$$\phi = -\frac{GM}{r}$$

where G is the gravitational constant.

Explain the significance of the negative sign in this expression.

....

....

.... [2]

(c) A spherical planet may be assumed to be an isolated point mass with its mass concentrated at its centre. A small mass m is moving near to, and normal to, the surface of the planet. The mass moves away from the planet through a short distance h.

State and explain why the change in gravitational potential energy ΔE_P of the mass is given by the expression

$$\Delta E_P = mgh$$

where g is the acceleration of free fall.

....

....

....

....

....

.... [4]

(d) The planet in **(c)** has mass M and diameter 6.8×10^3 km. The product GM for this planet is $4.3 \times 10^{13}\,\mathrm{N\,m^2\,kg^{-1}}$.

For Examin Use

A rock, initially at rest a long distance from the planet, accelerates towards the planet. Assuming that the planet has negligible atmosphere, calculate the speed of the rock as it hits the surface of the planet.

speed = ... $\mathrm{m\,s^{-1}}$ [3]

Q11.

1 **(a)** State Newton's law of gravitation.

....

....

....[2]

(b) The Earth and the Moon may be considered to be isolated in space with their masses concentrated at their centres.
The orbit of the Moon around the Earth is circular with a radius of 3.84×10^5 km. The period of the orbit is 27.3 days.

Show that

(i) the angular speed of the Moon in its orbit around the Earth is $2.66 \times 10^{-6}\,\mathrm{rad\,s^{-1}}$,

[1]

(ii) the mass of the Earth is 6.0×10^{24} kg.

[2]

(c) The mass of the Moon is 7.4×10^{22} kg.

Exa

(i) Using data from **(b)**, determine the gravitational force between the Earth and the Moon.

force = ... N [2]

(ii) Tidal action on the Earth's surface causes the radius of the orbit of the Moon to increase by 4.0 cm each year.

Use your answer in **(i)** to determine the change, in one year, of the gravitational potential energy of the Moon. Explain your working.

energy change = ... J [3]

Q12.

1 **(a)** State what is meant by a *gravitational field*.

....

....

.... [2]

(b) In the Solar System, the planets may be assumed to be in circular orbits about the Sun. Data for the radii of the orbits of the Earth and Jupiter about the Sun are given in Fig. 1.1.

	radius of orbit / km
Earth	1.50×10^8
Jupiter	7.78×10^8

Fig. 1.1

(i) State Newton's law of gravitation.

....

....

....

.... [3]

(ii) Use Newton's law to determine the ratio

$$\frac{\text{gravitational field strength due to the Sun at orbit of Earth}}{\text{gravitational field strength due to the Sun at orbit of Jupiter}}.$$

ratio = ... [3]

(c) The orbital period of the Earth about the Sun is T.

(i) Use ideas about circular motion to show that the mass M of the Sun is given by

$$M = \frac{4\pi^2 R^3}{GT^2}$$

where R is the radius of the Earth's orbit about the Sun and G is the gravitational constant.
Explain your working.

[3]

(ii) The orbital period T of the Earth about the Sun is 3.16×10^7 s.
The radius of the Earth's orbit is given in Fig. 1.1.
Use the expression in **(i)** to determine the mass of the Sun.

mass = ... kg [2]

Q13.

1 **(a)** Explain what is meant by a *geostationary orbit*.

....

....

....

.... [3]

(b) A satellite of mass m is in a circular orbit about a planet.
The mass M of the planet may be considered to be concentrated at its centre.
Show that the radius R of the orbit of the satellite is given by the expression

$$R^3 = \left(\frac{GMT^2}{4\pi^2}\right)$$

where T is the period of the orbit of the satellite and G is the gravitational constant.
Explain your working.

[4]

(c) The Earth has mass 6.0×10^{24} kg. Use the expression given in **(b)** to determine the radius of the geostationary orbit about the Earth.

radius = ... m [3]

Q14.

Use

4 If an object is projected vertically upwards from the surface of a planet at a fast enough speed, it can escape the planet's gravitational field. This means that the object can arrive at infinity where it has zero kinetic energy. The speed that is just enough for this to happen is known as the escape speed.

(a) (i) By equating the kinetic energy of the object at the planet's surface to its total gain of potential energy in going to infinity, show that the escape speed v is given by

$$v^2 = \frac{2GM}{R},$$

where R is the radius of the planet and M is its mass.

(ii) Hence show that

$$v^2 = 2Rg,$$

where g is the acceleration of free fall at the planet's surface.

[3]

Use

(b) The mean kinetic energy E_k of an atom of an ideal gas is given by

$$E_k = \tfrac{3}{2}kT,$$

where k is the Boltzmann constant and T is the thermodynamic temperature.

Using the equation in **(a)(ii)**, estimate the temperature at the Earth's surface such that helium atoms of mass 6.6×10^{-27} kg could escape to infinity.

You may assume that helium gas behaves as an ideal gas and that the radius of Earth is 6.4×10^{6} m.

temperature = ... K [4]

Q15.

1 (a) (i) On Fig. 1.1, draw lines to represent the gravitational field outside an isolated uniform sphere.

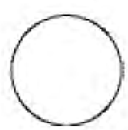

Fig. 1.1

(ii) A second sphere has the same mass but a smaller radius. Suggest what difference, if any, there is between the patterns of field lines for the two spheres.

....

....

[3]

(b) The Earth may be considered to be a uniform sphere of radius 6380 km with its mass of 5.98×10^{24} kg concentrated at its centre, as illustrated in Fig. 1.2.

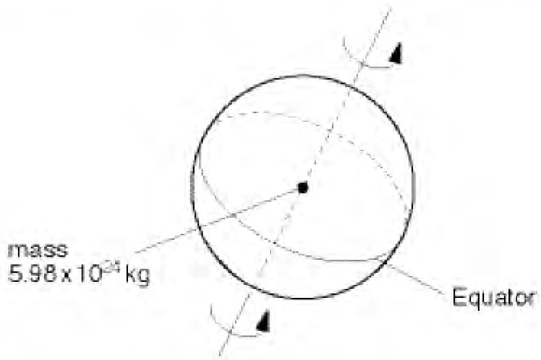

Fig. 1.2

A mass of 1.00 kg on the Equator rotates about the axis of the Earth with a period of 1.00 day (8.64×10^4 s).

Calculate, to three significant figures,

(i) the gravitational force F_G of attraction between the mass and the Earth,

F_G = ... N

(ii) the centripetal force F_C on the 1.00 kg mass,

F_C = ... N

(iii) the difference in magnitude of the forces.

difference = ... N
[6]

(c) By reference to your answers in **(b)**, suggest, with a reason, a value for the acceleration of free fall at the Equator.

....

....

.... [2]

Q16.

1 The Earth may be considered to be a sphere of radius 6.4×10^6 m with its mass of 6.0×10^{24} kg concentrated at its centre.
A satellite of mass 650 kg is to be launched from the Equator and put into geostationary orbit.

(a) Show that the radius of the geostationary orbit is 4.2×10^7 m.

[3]

(b) Determine the increase in gravitational potential energy of the satellite during its launch from the Earth's surface to the geostationary orbit.

energy = ... J [4]

(c) Suggest one advantage of launching satellites from the Equator in the direction of rotation of the Earth.

....

....[1]

Q17.

1 The definitions of electric potential and of gravitational potential at a point have some similarity.

(a) State one similarity between these two definitions.

....

.... [1]

(b) Explain why values of gravitational potential are always negative whereas values of electric potential may be positive or negative.

....

....

....

....

.... [4]

q18.

4 A rocket is launched from the surface of the Earth.

Fig. 4.1 gives data for the speed of the rocket at two heights above the Earth's surface, after the rocket engine has been switched off.

height / m	speed / m s^{-1}
$h_1 = 19.9 \times 10^6$	$v_1 = 5370$
$h_2 = 22.7 \times 10^6$	$v_2 = 5090$

Fig. 4.1

The Earth may be assumed to be a uniform sphere of radius $R = 6.38 \times 10^6$ m, with its mass M concentrated at its centre. The rocket, after the engine has been switched off, has mass m.

(a) Write down an expression in terms of

(i) G, M, m, h_1, h_2 and R for the change in gravitational potential energy of the rocket,

.... [1]

(ii) m, v_1 and v_2 for the change in kinetic energy of the rocket.

.... [1]

(b) Using the expressions in **(a)**, determine a value for the mass M of the Earth.

M = ... kg [3]

Q19.

1 A spherical planet has mass M and radius R.
The planet may be assumed to be isolated in space and to have its mass concentrated at its centre.
The planet spins on its axis with angular speed ω, as illustrated in Fig. 1.1.

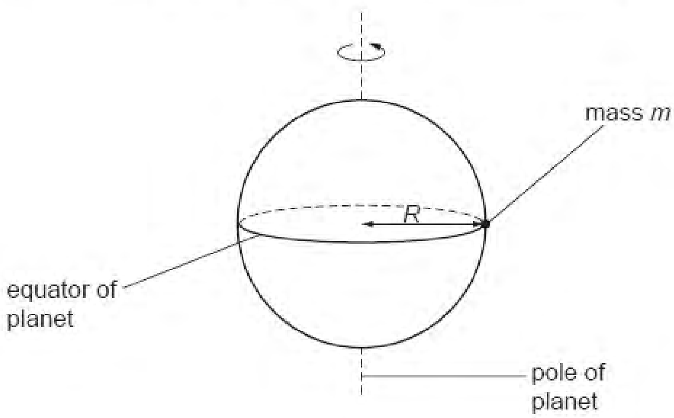

Fig. 1.1

A small object of mass m rests on the equator of the planet. The surface of the planet exerts a normal reaction force on the mass.

(a) State formulae, in terms of M, m, R and ω, for

(i) the gravitational force between the planet and the object,

.... [1]

(ii) the centripetal force required for circular motion of the small mass,

.... [1]

(iii) the normal reaction exerted by the planet on the mass.

.... [1]

(b) **(i)** Explain why the normal reaction on the mass will have different values at the equator and at the poles.

....

....

.... [2]

(ii) The radius of the planet is 6.4×10^6 m. It completes one revolution in 8.6×10^4 s. Calculate the magnitude of the centripetal acceleration at

For Examiner's Use

1. the equator,

acceleration = ... $\mathrm{m\,s^{-2}}$ [2]

2. one of the poles.

acceleration = ... $\mathrm{m\,s^{-2}}$ [1]

(c) Suggest two factors that could, in the case of a real planet, cause variations in the acceleration of free fall at its surface.

1. ....

....

2. ....

....
[2]

Q20.

1 **(a)** State Newton's law of gravitation.

....

....

.... [2]

(b) The Earth may be considered to be a uniform sphere of radius R equal to 6.4×10^{6} m.

A satellite is in a geostationary orbit.

(i) Describe what is meant by a *geostationary orbit*.

....

....

....

.... [3]

(ii) Show that the radius x of the geostationary orbit is given by the expression

$$gR^2 = x^3\omega^2$$

where g is the acceleration of free fall at the Earth's surface and ω is the angular speed of the satellite about the centre of the Earth.

[3]

(iii) Determine the radius x of the geostationary orbit.

radius = ... m [3]

Q21.

1 **(a)** The Earth may be considered to be a uniform sphere of radius 6.38×10^3 km, with its mass concentrated at its centre.

(i) Define *gravitational field strength*.

....

.... [1]

(ii) By considering the gravitational field strength at the surface of the Earth, show that the mass of the Earth is 5.99×10^{24} kg.

[2]

(b) The Global Positioning System (GPS) is a navigation system that can be used anywhere on Earth. It uses a number of satellites that orbit the Earth in circular orbits at a distance of 2.22×10^4 km above its surface.

(i) Use data from **(a)** to calculate the angular speed of a GPS satellite in its orbit.

angular speed = ... rad s^{-1} [3]

(ii) Use your answer in **(i)** to show that the satellites are not in geostationary orbits.

For Examiner Use

[3]

(c) The planes of the orbits of the GPS satellites in **(b)** are inclined at an angle of 55° to the Equator.

Suggest why the satellites are not in equatorial orbits.

....

.... [1]

Q22.

1 (a) Define *gravitational field strength*.

....

....[1]

(b) An isolated star has radius R. The mass of the star may be considered to be a point mass at the centre of the star.
The gravitational field strength at the surface of the star is g_s.

On Fig. 1.1, sketch a graph to show the variation of the gravitational field strength of the star with distance from its centre. You should consider distances in the range R to $4R$.

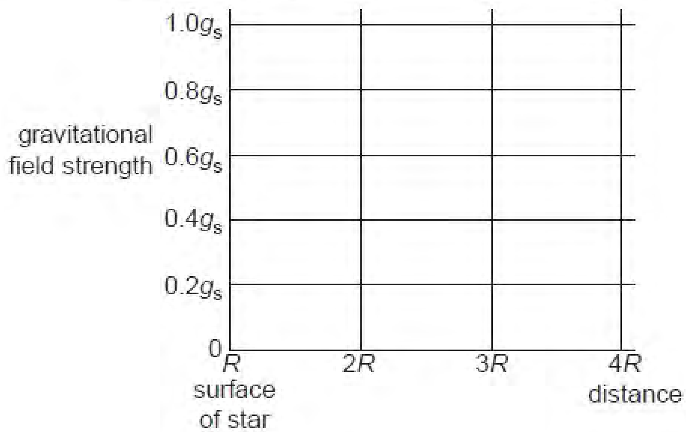

Fig. 1.1

[2]

(c) The Earth and the Moon may be considered to be spheres that are isolated in space with their masses concentrated at their centres.
The masses of the Earth and the Moon are 6.00×10^{24} kg and 7.40×10^{22} kg respectively.
The radius of the Earth is R_E and the separation of the centres of the Earth and the Moon is $60 R_E$, as illustrated in Fig. 1.2.

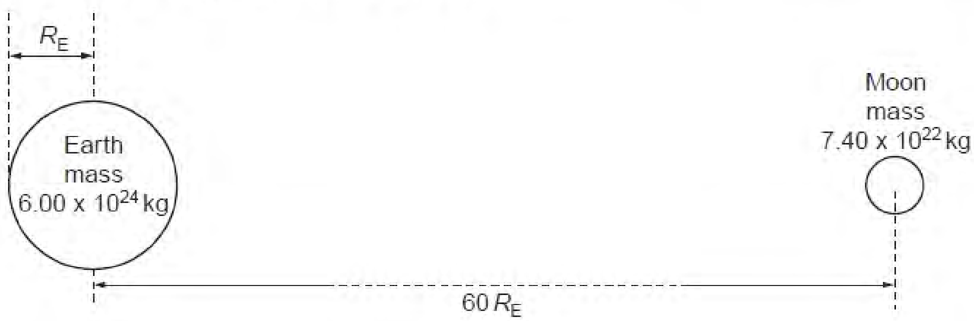

Fig. 1.2 (not to scale)

(i) Explain why there is a point between the Earth and the Moon at which the gravitational field strength is zero.

....

....

....[2]

(ii) Determine the distance, in terms of R_E, from the centre of the Earth at which the gravitational field strength is zero.

distance = ... R_E [3]

(iii) On the axes of Fig. 1.3, sketch a graph to show the variation of the gravitational field strength with position between the surface of the Earth and the surface of the Moon.

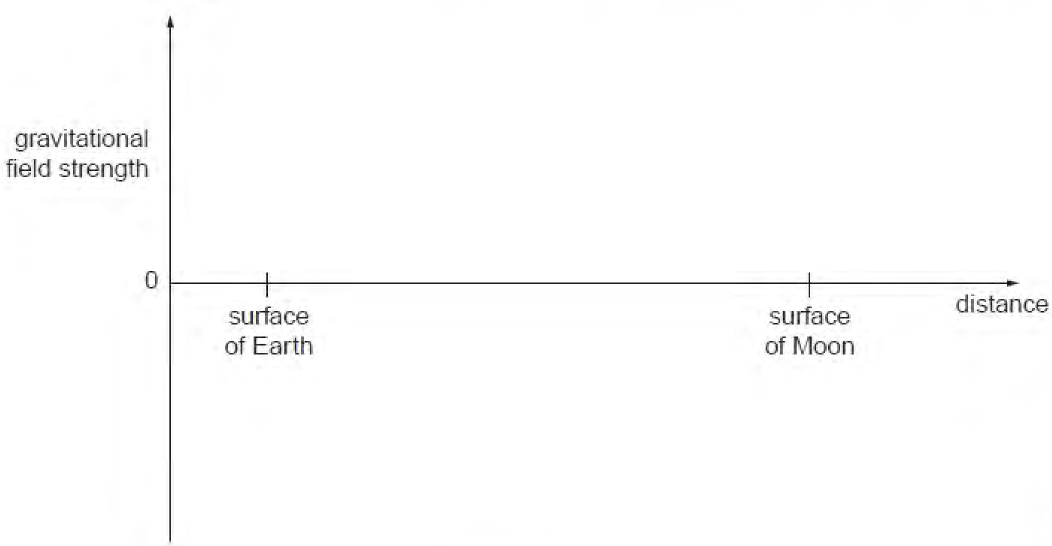

Fig. 1.3

[3]

Q23.

1 A planet of mass m is in a circular orbit of radius r about the Sun of mass M, as illustrated in Fig. 1.1.

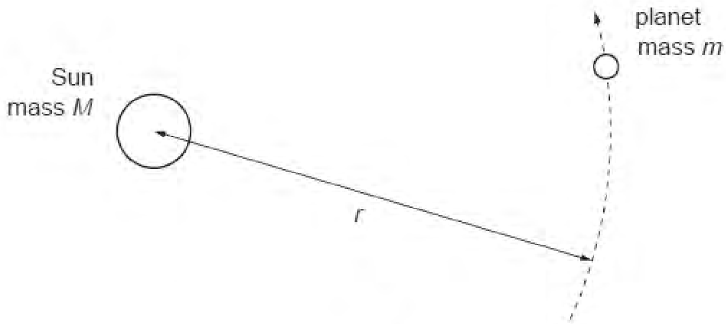

Fig. 1.1

The magnitude of the angular velocity and the period of revolution of the planet about the Sun are ω and T respectively.

(a) State

(i) what is meant by *angular velocity*,

....

....

.... [2]

(ii) the relation between ω and T.

.... [1]

(b) Show that, for a planet in a circular orbit of radius r, the period T of the orbit is given by the expression

$$T^2 = cr^3$$

where c is a constant. Explain your working.

[4]

(c) Data for the planets Venus and Neptune are given in Fig. 1.2.

planet	r / 10^8 km	T / years
Venus	1.08	0.615
Neptune	45.0	

Fig. 1.2

Assume that the orbits of both planets are circular.

(i) Use the expression in **(b)** to calculate the value of T for Neptune.

T = ... years [2]

(ii) Determine the linear speed of Venus in its orbit.

speed = ... km s^{-1} [2]

Q24.

1 **(a)** A moon is in a circular orbit of radius r about a planet. The angular speed of the moon in its orbit is ω. The planet and its moon may be considered to be point masses that are isolated in space.

Show that r and ω are related by the expression

$$r^3\omega^2 = \text{constant}.$$

Explain your working.

[3]

(b) Phobos and Deimos are moons that are in circular orbits about the planet Mars. Data for Phobos and Deimos are shown in Fig. 1.1.

moon	radius of orbit / m	period of rotation about Mars / hours
Phobos	9.39×10^6	7.65
Deimos	1.99×10^7	

Fig. 1.1

(i) Use data from Fig. 1.1 to determine

For Examiner's Use

1. the mass of Mars,

mass = ... kg [3]

2. the period of Deimos in its orbit about Mars.

period = ... hours [3]

(ii) The period of rotation of Mars about its axis is 24.6 hours.
Deimos is in an equatorial orbit, orbiting in the same direction as the spin of Mars about its axis.

Use your answer in **(i)** to comment on the orbit of Deimos.

....

....[1]

Q25.

1 The planet Mars may be considered to be an isolated sphere of diameter 6.79×10^6 m with its mass of 6.42×10^{23} kg concentrated at its centre.
A rock of mass 1.40 kg rests on the surface of Mars.

For this rock,

(a) **(i)** determine its weight,

weight = ... N [3]

(ii) show that its gravitational potential energy is -1.77×10^7 J.

[2]

(b) Use the information in **(a)(ii)** to determine the speed at which the rock must leave the surface of Mars so that it will escape the gravitational attraction of the planet.

speed = ... m s^{-1} [3]

Q26.

1 **(a)** State Newton's law of gravitation.

....

....

.... [2]

(b) A satellite of mass m is in a circular orbit of radius r about a planet of mass M.
For this planet, the product GM is $4.00 \times 10^{14}\,\mathrm{N\,m^2\,kg^{-1}}$, where G is the gravitational constant.
The planet may be assumed to be isolated in space.

(i) By considering the gravitational force on the satellite and the centripetal force, show that the kinetic energy E_K of the satellite is given by the expression

$$E_K = \frac{GMm}{2r}.$$

[2]

(ii) The satellite has mass 620 kg and is initially in a circular orbit of radius 7.34×10^6 m, as illustrated in Fig. 1.1.

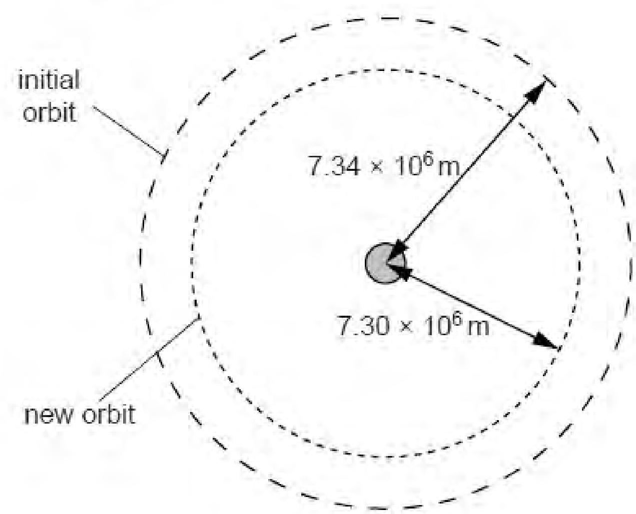

Fig. 1.1 (not to scale)

Resistive forces cause the satellite to move into a new orbit of radius 7.30×10^6 m.

For Examiner's Use

Determine, for the satellite, the change in

1. kinetic energy,

change in kinetic energy = ... J [2]

2. gravitational potential energy.

change in potential energy = ... J [2]

(iii) Use your answers in **(ii)** to explain whether the linear speed of the satellite increases, decreases or remains unchanged when the radius of the orbit decreases.

....

....

.... [2]

Q27.

1 **(a)** Define *gravitational potential* at a point.

....

....

.... [2]

(b) The Moon may be considered to be an isolated sphere of radius 1.74×10^3 km with its mass of 7.35×10^{22} kg concentrated at its centre.

(i) A rock of mass 4.50 kg is situated on the surface of the Moon. Show that the change in gravitational potential energy of the rock in moving it from the Moon's surface to infinity is 1.27×10^7 J.

[1]

(ii) The escape speed of the rock is the minimum speed that the rock must be given when it is on the Moon's surface so that it can escape to infinity.
Use the answer in **(i)** to determine the escape speed. Explain your working.

speed = ... $m s^{-1}$ [2]

(c) The Moon in **(b)** is assumed to be isolated in space. The Moon does, in fact, orbit the Earth.
State and explain whether the minimum speed for the rock to reach the Earth from the surface of the Moon is different from the escape speed calculated in **(b)**.

....

....

.... [2]

Q28.

1 **(a)** State Newton's law of gravitation.

....

....

.... [2]

(b) A star and a planet are isolated in space. The planet orbits the star in a circular orbit of radius R, as illustrated in Fig. 1.1.

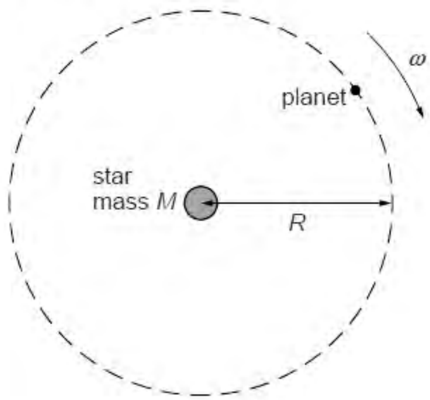

Fig. 1.1

The angular speed of the planet about the star is ω.
By considering the circular motion of the planet about the star of mass M, show that ω and R are related by the expression

$$R^3\omega^2 = GM$$

where G is the gravitational constant. Explain your working.

[3]

(c) The Earth orbits the Sun in a circular orbit of radius 1.5×10^8 km. The mass of the Sun is 2.0×10^{30} kg.
A distant star is found to have a planet that has a circular orbit about the star. The radius of the orbit is 6.0×10^8 km and the period of the orbit is 2.0 years.

For Examiner's Use

Use the expression in **(b)** to calculate the mass of the star.

mass = ... kg [3]

Q29.

1 **(a)** Define *gravitational potential* at a point.

....

....

.... [2]

(b) A stone of mass m has gravitational potential energy E_P at a point X in a gravitational field. The magnitude of the gravitational potential at X is ϕ.

State the relation between m, E_P and ϕ.

.... [1]

(c) An isolated spherical planet of radius R may be assumed to have all its mass concentrated at its centre. The gravitational potential at the surface of the planet is $-6.30 \times 10^7\,\mathrm{J\,kg^{-1}}$.

A stone of mass 1.30 kg is travelling towards the planet such that its distance from the centre of the planet changes from $6R$ to $5R$.

Calculate the change in gravitational potential energy of the stone.

change in energy = ... J [4]

Q30.

1 The mass *M* of a spherical planet may be assumed to be a point mass at the centre of the planet.

(a) A stone, travelling at speed *v*, is in a circular orbit of radius *r* about the planet, as illustrated in Fig. 1.1.

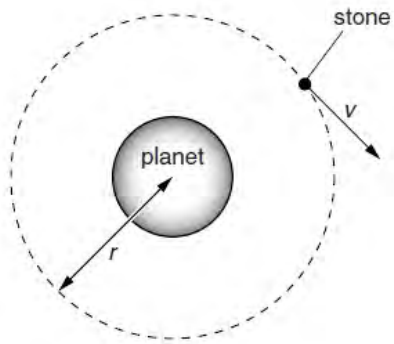

Fig. 1.1

Show that the speed *v* is given by the expression

$$v = \sqrt{\left(\frac{GM}{r}\right)}$$

where *G* is the gravitational constant.
Explain your working.

[2]

(b) A second stone, initially at rest at infinity, travels towards the planet, as illustrated in Fig. 1.2.

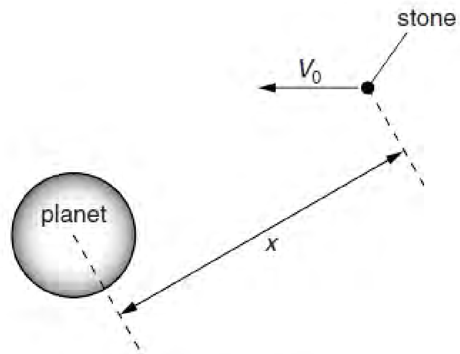

Fig. 1.2 (not to scale)

The stone does not hit the surface of the planet.

(i) Determine, in terms of the gravitational constant G and the mass M of the planet, the speed V_0 of the stone at a distance x from the centre of the planet. Explain your working. You may assume that the gravitational attraction on the stone is due only to the planet.

[3]

(ii) Use your answer in **(i)** and the expression in **(a)** to explain whether this stone could enter a circular orbit about the planet.

....

....

....

.... [2]

Q31.

1 An isolated spherical planet has a diameter of 6.8×10^6 m. Its mass of 6.4×10^{23} kg may be assumed to be a point mass at the centre of the planet.

(a) Show that the gravitational field strength at the surface of the planet is 3.7 N kg^{-1}.

[2]

(b) A stone of mass 2.4 kg is raised from the surface of the planet through a vertical height of 1800 m.
Use the value of field strength given in **(a)** to determine the change in gravitational potential energy of the stone.
Explain your working.

change in energy = ... J [3]

(c) A rock, initially at rest at infinity, moves towards the planet. At point P, its height above the surface of the planet is 3.5 *D*, where *D* is the diameter of the planet, as shown in Fig. 1.1.

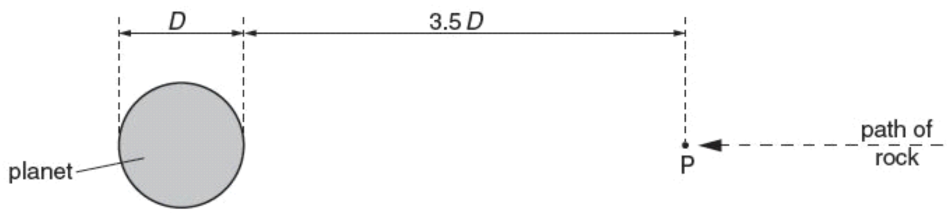

Fig. 1.1

Calculate the speed of the rock at point P, assuming that the change in gravitational potential energy is all transferred to kinetic energy.

speed = ... m s^{-1} [4]

Q32.

2 (a) On the axes of Fig. 2.1, sketch the variation with distance from a point mass of the gravitational field strength due to the mass.

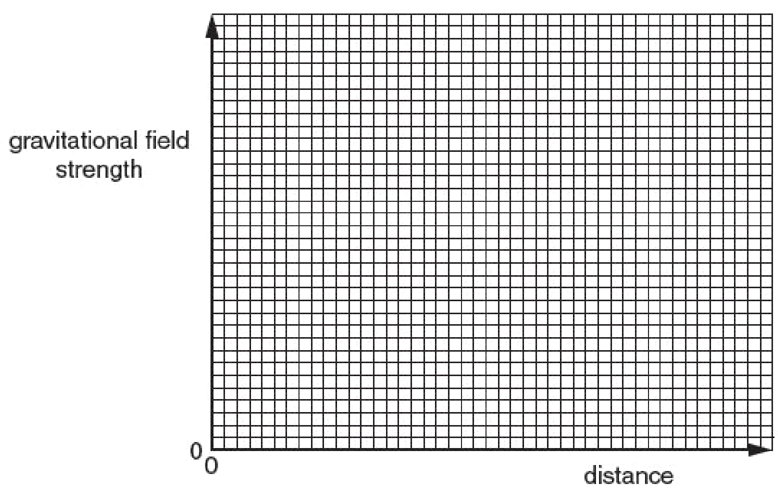

Fig. 2.1

[2]

(b) On the axes of Fig. 2.2, sketch the variation with speed of the magnitude of the force on a charged particle moving at right-angles to a uniform magnetic field.

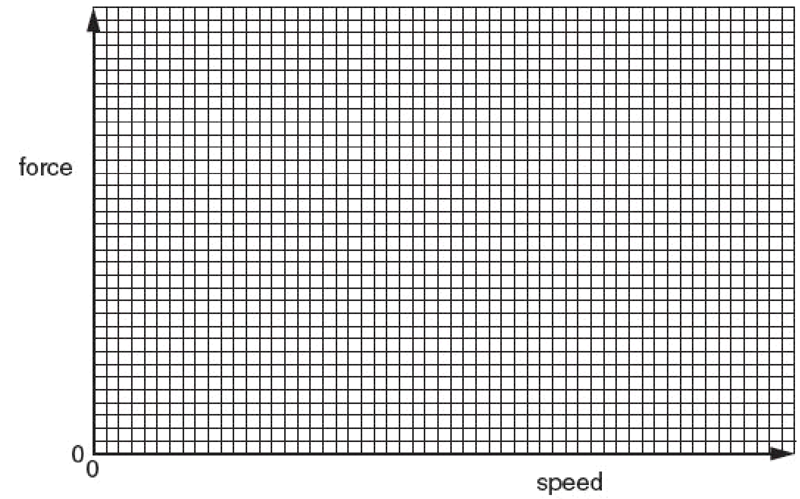

Fig. 2.2

[2]

(c) On the axes of Fig. 2.3, sketch the variation with time of the power dissipated in a resistor by a sinusoidal alternating current during two cycles of the current.

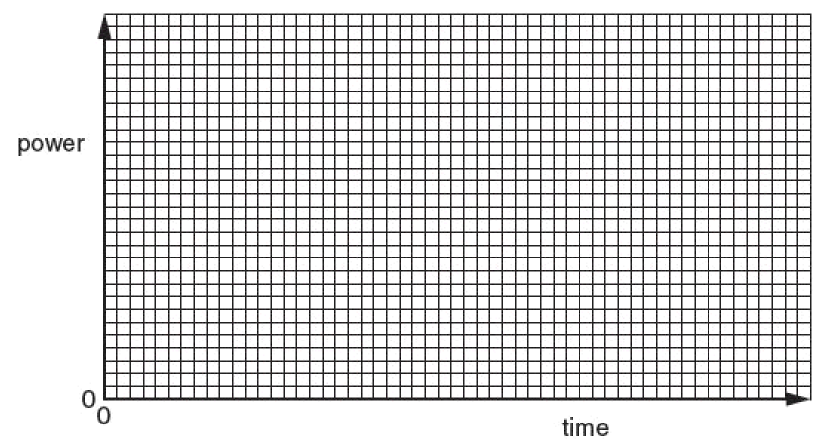

Fig. 2.3

[3]