R1-2002 Q1(f)

R1-2003 Q1(h)

R1-2004 Q1(g)

R1-2004 Q1(k)

R1-2005 Q1(k)

R1-2007 Q1(k)

R1-2010 Q1(g)

R1-2012 Q1(g)

R1-2003 Q6

R1-2003 Q8(d)

R1-2005 Q2(b)

R1-2005 Q2(c)

R1-2005 Q8

R1-2007 Q7

R1-2008 Q3

R1-2009 Q8

R1-2010 Q8

R1-2009 Q9

R1-2011 Q8

R1-2012 Q7

R1-2013 Q3

R1-2013 Q7

R1-2002 Q1(f)

f) (i) Where are geostationary satellites located?

(ii) The square of the orbital period of a body in circular orbit around a planet is proportional to the cube of its orbital radius. Determine the orbital radius *R* of a geostationary satellite by applying this result to a geostationary satellite and the Moon.

(iii) Why is it difficult to receive satellite television programmes when living at latitudes close to the poles?

[12]

R1-2003 Q1(h)

h) Two stations on the equator, diametrically opposite each other, communicate by sending, and receiving, radio signals that are tangential to the Earth via two geostationary satellites in circular orbits at 3.59×10^4 km above the Earth's surface. Calculate the time delay between sending and receiving a signal.

[10]

R1-2004 Q1(g)

g)

Figure 1.3

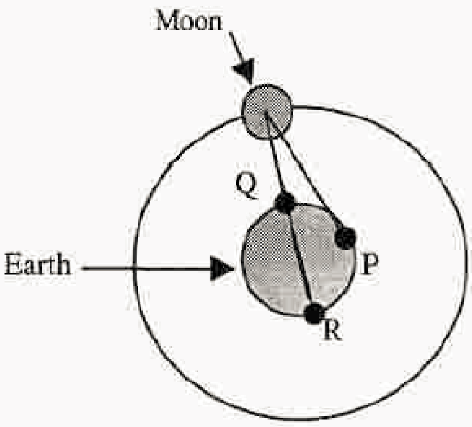


Figure 1.3 shows the Moon orbiting the Earth. Why do most sea ports experience two high tides every 24 hours? Explain which sea ports, of those indicated by Q,P, and R, have a high tide and which have a low tide. [6]

R1-2004 Q1(k)

k)

Figure 1.4 

Figure 1.4 shows the Moon seen against the dark sky on a clear winter night. A narrow crescent of the Moon shines brightly, the rest of the Moon can just be seen.

(i) Why is the crescent bright?
(ii) How is it that the rest of the Moon can just be seen?
(iii) What factors determine the ratio of the brightness of the crescent to that of the rest of the Moon?

[6]

R1-2005 Q1(k)

k) The mass and radius of Mars are 0.1074 M_E and 0.5326 R_E, where M_E is the mass of the Earth and R_E is its radius. Determine the escape velocity from the surface of Mars in terms of its value on Earth, v_E. [3]

R1-2007 Q1(k)

(k) Calculate the *mass* of electrons, M_e, in terms of the fraction of the Earth's mass, M_E, that is required to be taken from the Earth to the Moon in order to double the force of attraction between these two bodies. Assume M_e is much less than M_E. The mass of the Moon is 0.0123 M_E.

[4]

R1-2010 Q1(g)

(g) Determine an expression for the escape velocity of a body of mass m from a planet of mass M and radius R. Why do some planets possess an atmosphere and others do not?

[4]

R1-2012 Q1(g)

(g) An exoplanet is discovered by the Kepler mission. It has a mass M with angular velocity ω. A small moon of mass m and radius a orbits the planet at a centre to centre distance of r. What is the condition for this circular orbit?

If R is the reaction force on a loose rock on the moon's surface, write down the equation for the 'equilibrium' of the rock on the moon's surface. Assume that the moon orbits the planet always keeping the same face towards the planet. Deduce the condition, independent of ω, to be satisfied by M/m, for the rock to be lifted off the moon by the planet's gravitational attraction.

[8]

R1-2003 Q6

a) Explain, with suitable ray diagrams, the eclipses of the Sun and the Moon. Why do these eclipses not occur once a month? [5]

b) Assuming a circular orbit, show that the orbital period T of the Moon around the Earth is related to the radius R by

$$T^2 = \frac{4\pi^2}{GM_E} R^3, \quad [4]$$

where M_E is the mass of the Earth and $R = R_{EM}$, the distance between the centres of the Earth and the Moon.

c) This relation is valid for any possible elliptical orbit providing R is interpreted as the semi-major axis of the ellipse (half the major axis); a circle is a special case of an ellipse when both foci coincide at the centre of the ellipse.

In the limiting case of a "thin narrow' ellipse the foci are at the extremities of the ellipse. This corresponds to the Moon falling to Earth from an initial stationary position (the major axis being the distance between the centres of the Earth and the Moon); a conceivable possibility in the early formation of the solar system. Neglecting the radii of the Earth and the Moon, calculate:

(i) the time, τ, taken for the Moon to strike the Earth
(ii) the average speed of the Moon during its fall to Earth
(iii) the Moon's speed, V_M, at a distance equal to the radius of the Earth, R_E, from the centre of the Earth
(iv) the time taken for a stationery asteroid, at 2.00 AU from the Sun, to fall into the Sun; the stationary asteroid could result from a collision with another asteroid. [11]

R1-2003 Q8(d)

d) A pulsar is a rotating neutron star which emits a band of radio frequencies in short pulses. The frequency of the pulses is equal to the frequency of rotation of the star.

(i) The radius of a neutron star can contract. How could one detect this?

(ii) When a cloud of ionised gas passes in front of the star, the refractive index of the interstellar medium changes.
How could an observer detect this cloud? [6]

R1-2005 Q2

a) (i) Derive an expression for the acceleration due to gravity at a height h above the Earth's surface, g_h, in terms of g_0, the acceleration due to gravity at the surface, and R_E the radius of the Earth.
Assume the Earth is a sphere of uniform density.

(ii) Repeat the above calculation for a point below the Earth's surface at a distance r from the centre of the Earth.

(iii) Sketch a graph of the variation of the acceleration due to gravity with distance from the centre of the Earth.

(iv) Comment on the assumption that the Earth has a uniform density.

[9]

b) An Earth satellite, in a circular orbit, has a rotational period of 2.00 hours. It is in the plane of the Earth's equator, moving in the same rotational direction as the Earth.

(i) How far above the Earth's surface is the satellite ?

(ii) Calculate the angular velocity of the satellite relative to that of the Earth.

(iii) Determine the angle, measured about the centre of the Earth, through which the satellite will be visible to an observer at the equator. [9]

c) What limits the largest and smallest possible periods of an Earth satellite ?

[2]

R1-2005 Q8

a) Figure 8.1

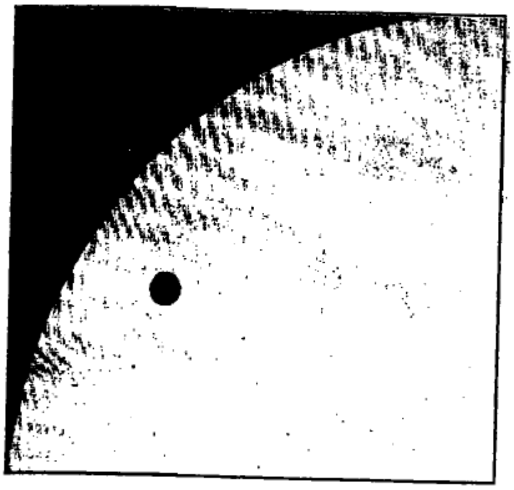
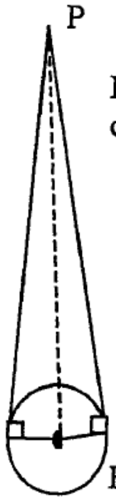


Figure 8.2



(i) Figure 8.1 is a photograph of the recent transit of Venus. The planet Venus is shown crossing the face of the Sun. Determine, by measurement, the ratio, λ, of the photographic area of the full face of the Sun to that produced by Venus. State the accuracy of the result.

(ii) Calculate λ, with the associated accuracy, using the data in the Table 8.1.

Body	Radius/m	Orbital period (round the Sun) /s	Distance from the Sun/m
Sun	6.96×10^8		
Venus	6.05×10^6	1.94×10^7	1.08×10^{11}
Earth	6.38×10^6	3.16×10^7	1.50×10^{11}

Table 8.1

[6]

b) Assume here that the orbits of the Earth and Venus are coplanar.

(i) Determine the interval, in years, between successive transits using data in Table 8.1. Comment on the result in the light of astronomical observations.

(ii) Calculate the transit time for Venus to complete a diameter of the Sun.

[7]

c) In the 18th century the transit of Venus was observed using two telescopes separated roughly by the diameter of the Earth. This enabled the distance between Venus and the Earth to be determined. Figure 8.2 illustrates the simplest placing of the telescopes.

(i) What is the angle between the telescopes?

(ii) Why was it essential that both telescopes observed the point when the image of Venus touched that of the edge of the Sun?

(iii) What were the difficulties associated with the timing of the measurements? [4]

d) Calculate the smallest velocity component, v_s, perpendicular to its orbit, required by Venus so that the next expected transit does not occur. [3]

R1-2007 Q7

(a) Assuming the planets are in circular motion around the Sun, with radius R and period T, use the data in Table 7.1 to test, graphically, the hypothesis that T is proportional to R^{α} , where α is a constant. Obtain from the graph:

(i) a value for α and give its accuracy

(ii) the constant of proportionality in SI units

[10]

PLANET	R / 10^8 km	T / days
Earth	1.49	365
Mars	2.28	687
Jupiter	7.78	4333
Uranus	28.7	30690

Table 7.1

(b) (i) Derive, using mechanics, the relation between T and R in terms of the mass of the Sun, M_S.

(ii) Determine M_S using the data in (a).

(iii) The distance of the Moon from the Earth is 3.8×10^5 km and its period is 27.3 days. Deduce the ratio (M_S/M_E), where M_E is the mass of the Earth.

[10]

R1-2008 Q3

(a) A double star consists of two stars, each with the same mass as our Sun, M_S, separated by a distance d. They are observed to complete a full rotation about their centre of mass in one week. Determine, to two significant figures, the ratio (d/R_{SE}), where R_{SE} is the Sun-Earth distance, without assuming the numerical value of M_S.

[6]

(b) In this calculation light may be considered as a stream of particles, photons, each having a mass ($h/\lambda c$) and energy (hc/λ), where λ is the wavelength of the light. Light with $\lambda = 500$ nm is emitted from the surface of the Sun, radius R_S, and received on Earth, radius R_E, slightly shifted in wavelength by $\Delta\lambda$ after travelling a distance R_{SE}.

(i) Give an algebraic expression for the change in the gravitational potential energy of the photon, ΔU.

(ii) Estimate the relative order of magnitude of each term in the expression for ΔU in (i). Indicate which term/s can be neglected for the result to be correct to 2 significant figures.

(iii) Calculate ($\Delta\lambda / \lambda$) to 2 significant figures. [11]

These calculations give identical results to those involving a more rigorous calculation.

(c) Explain why the value of g at the Earth's equator differs from its value at the poles. Which has the greater value?

[3]

R1-2009 Q8

Q8

(a)

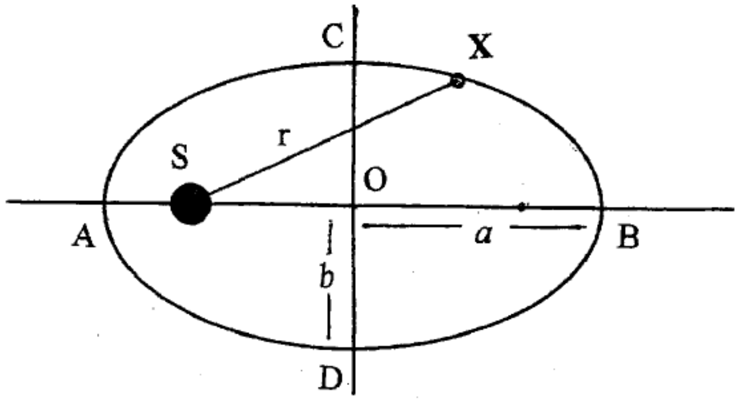


Figure 8.a

Planet X, mass *m*, is in an elliptical orbit, centre O, Figure 8.a, around a star S, mass *M*. It has a speed *v* when at a distance *r* from the centre of S. The lengths of the major and minor axes are *2a* and *2b*.

(i) Write down an algebraic expression for the total energy *E* of the planet.

(ii) Deduce from (i) the point/s in the orbit where *v* is a maximum and a minimum.

(iii) Comment on the time to travel, clockwise, from C to D and D to C.

Kepler's Third Law states that the period *T* for elliptical motion is related to *a* by $T^2 = ka^3$, where *k* is a constant, for a planet, or smaller body, about a star.

(iv) Determine, in the most convenient units, *k* for the circular motion of the Earth about the Sun using the known values of *T* and *a*; here $a = b$ and S is at O.

(v) Halley's comet orbits the Sun about every 76 years . Calculate the length of its major axis. [10]

(b)

Kepler's Second Law states that for a body in elliptical motion about a more massive body , as in Figure 8.a, the radius vector sweeps out an area proportional to the time taken by the body to travel from one point to another in the orbit.

A space capsule is launched from a spherical planet, radius *R*, with no atmosphere, at L and returns to the planet at T. The angular separation between the launch point L and the termination point T, with respect to the centre of the planet O, is 2θ. The minor axis of this elliptical path is along TL, and the major axis has length *2R* , Figure 8.b.

(i) How long does the flight of the capsule take if the period for the 'complete' elliptical path is T_0?

(ii) Does the result in (i) apply to the limiting case of $\theta = 0$? Explain.

The area of an ellipse with major and minor axes of lengths *2a* and *2b,* respectively, is πab.
$\sin(2\theta) = 2\sin\theta\cos\theta$.

[10]

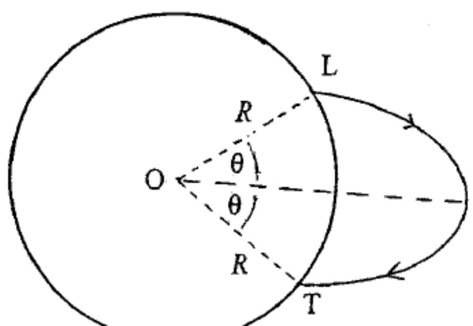


Figure 8.b

R1-2010 Q8

(a) Calculate the numerical value of the acceleration due to free fall, g, at the surface of the Earth by applying Newton's law of gravitation. Neglect rotational effects and assume a spherical Earth of mass M_E and radius R_E.

[3]

(b) If the Earth's crust, density 2.7×10^3 kgm^{-3} , is assumed to be 30 km deep, what is the fractional change in g would occur upon descending to a depth of 15 km ? Indicate if g increased or decreased .

[7]

(c) A spherical deposit of iron, density 7.9×10^3 kgm^{-3}, has a diameter of 5.0 km and lies just beneath the Earth's surface. Determine the fractional change in g, measured at the Earth's surface immediately above the deposit, due to this deposit.

[6]

(d) If the iron in (c) is mined, leaving a cavity, determine the fractional change in g.

[4]

R1-2010 Q9

A rocket carrying a 1,000 kg satellite is to be launched from Earth with a velocity such that the combined vehicle has *just sufficient* energy to reach the Moon. At a height of 20 km above the lunar surface, the satellite is detached. Its velocity is altered, and redirected by its internal motors, so as to place it in a stable orbit 10 km above the lunar surface. The rocket's speed is not affected by the freeing of the satellite and it is allowed to continue on its flight until it crashes into the Moon. It can be assumed that the rocket has constant mass and there is no relative motion between the Earth and the Moon.

(a) Determine the distances, R_{MF} and R_{MP} respectively, measured from the centre of the Moon, at which the magnitude of (i) the gravitational forces, F, and (ii) the gravitational potential energies, P, of the Moon and Earth on the combined vehicle are equal in magnitude.

[6]

(b) Derive an *algebraic* expression, using the symbols in the table below, for the velocity at which the rocket would impact on the lunar surface if it did not detach the satellite.

[5]

(c) Obtain the speed of the satellite in orbit at 10 km above the Moon's surface.

[4]

(d) Determine the energy, E_m, required to be extracted from the satellite, in orbit 10 km above the Moon's surface, in order to achieve a soft landing on the lunar surface.

[5]

Mass of the Earth	$M_E = 5.97 \times 10^{24}$	kg
Mass of the Moon	$M_M = 7.35 \times 10^{22}$	kg
Radius of the Earth	$R_E = 6.38 \times 10^{3}$	km
Radius of the Moon	$R_M = 1.74 \times 10^{3}$	km
Earth – Moon, centre to centre, distance	$R_{EM} = 3.84 \times 10^{5}$	km

R1-2011 Q8

a) A satellite of mass $m = 500$ kg is in a circular orbit at an altitude of $l = 600$ km above the Earth's surface . The satellite returns to Earth as a result of the frictional forces and impacts with a speed of $v = 2.00$ kms^{-1}. How much energy was absorbed by the atmosphere?

[6]

b) A rocket, mass M_R , is launched from the Earth. Its motors are used only near the Earth's surface in order to give the rocket *just* sufficient energy to reach the Moon. Once the fuel is exhausted the rocket has initial velocity v. Assume no relative motion of the Earth – Moon system.

Determine:

(i) the distance from the Earth's centre, d_E , at which the velocity of the rocket is least.

(ii) the initial velocity of the rocket, v, justifying any approximations you may make.

[14]

Mass of the Earth	M_E	$= 5.97 \times 10^{24}$	kg
Mass of the Moon	M_M	$= 7.35 \times 10^{22}$	kg
Radius of the Earth	R_E	$= 6.38 \times 10^{3}$	km
Radius of the Moon	R_M	$= 1.74 \times 10^{3}$	km
Earth – Moon distance, measured from their centres	R_{EM}	$= 3.84 \times 10^{5}$	km

R1-2012 Q7

In order to send a space vehicle to the Moon, the vehicle is first placed in a 'parking orbit' near the Earth.

(a) Calculate the speed v of the vehicle when it is in the parking orbit close to the Earth (you may neglect the height of the orbit compared to the radius of the earth).

[3]

(b) Explain how the rotation of the Earth affects the initial energy required to launch the vehicle from the surface of the Earth.

[3]

(c) When the vehicle is in the parking orbit close to the Earth, in the outer layers of the Earth's atmosphere, friction causes a gradual reduction in its total energy. However it is observed that the vehicle increases its speed. How is this explained using Newtonian mechanics?

[7]

(d) A star, with mass equal to that of our Sun, is located near the outer edge of a spherical galaxy, 3×10^4 ly from the centre. (1 ly is the distance light travels in 1 year.). Its orbital speed around the centre of the galaxy is 250 km s^{-1}.

Estimate, stating any assumptions made, the order of magnitude of:

(i) the mass of the galaxy.
(ii) the number of stars in the galaxy.

[7]

R1-2013 Q3

(a) The Earth can be approximated by a perfect homogeneous stationary solid sphere, radius R_E. A straight smooth tunnel is drilled along a diameter. Show that a particle, mass *m*, released from the entrance, will perform simple harmonic motion. Determine its period, T_1, in terms of RE and *g*. Hence evaluate T_1.

$$R_E = 6.38 \times 10^3 \text{ km}$$

[8]

(b) A straight smooth tunnel is drilled through the Earth, in any direction, from any point on the Earth's surface, not passing through the centre of the Earth. Determine the motion of a particle released from the entrance and obtain its period of oscillation, T_2.

[5]

(c) Compare the period of a satellite orbit, T_S, in very close Earth orbit, with T_2.

[5]

(d) If the particle is given an increased velocity, when in the middle of the tunnel, what can be deduced about its trajectory when it emerges from the tunnel into space?

[2]

R1-2013 Q7

(a) If the radius of the Earth R_E = 6.38 x 10^3 km and g = 9.81 ms^{-2} is the acceleration of free fall, obtain an expression for the minimum launch speed required to put a satellite into polar orbit, over the poles, and calculate its magnitude.

[4]

(b) What is the ratio of the minimum launch speed required to put a satellite into polar orbit, over the poles, to the minimum launch speed for an equatorial orbit, around the equator, when they are in close Earth orbits?

[4]

(c) What minimum initial speed must a space probe have if it is to leave the gravitational field of the Earth?

[4]

(d) What minimum launch speed is required for a probe to hit the Sun? Neglect the Earth's gravitational field.

[4]

(e) Ignoring the Earth's gravitational field, what minimum launch speed is required for a probe to leave the solar system?

[4]

Distance of the Earth from the Sun, R_{ES} = 1.50 x 10^8 km

Mass of the Sun, M_S = 1.99 x 10^{30} kg

Mass of the Earth, M_E = 5.98 x 10^{24} kg