Mark schemes

1 (a) technique one **(1)**

information derived from it **(1)**

technique two **(1)**

information derived from it **(1)**

4

(b) (i) gravitational **attraction** to …**(1)**

…centre of gravity(mass) of mountain **(1)**

(ii) cancellation of some systematic errors **(1)**

3

(c) (i) calculates volume of cone **(1)**

mass = density × volume seen **(1)**

2.2×10^{12} kg **(1)**

(ii) sideways force/mg = tan (0.0011) **(1)**

sideways force = Gm_{sch} $0.5/(1400)^2$ subst seen **(1)**

2.4×10^{24} kg **(1)**

(iii) his density estimate was too low **(1)**

or mean density of the Earth is higher than that of the mountain **(1)**

7

[14]

2 (a) attractive **force** between point masses **(1)**
proportional to (product of) the masses **(1)**
inversely proportional to square of separation/distance apart **(1)**

3

(b) $m\omega^2 R = (-)\frac{GMm}{R^2}\left(\text{or} = \frac{mv^2}{R}\right)$ **(1)**

(use of $T = \frac{2\pi}{\omega}$ gives) $\frac{4\pi^2}{T^2} = \frac{GM}{R^3}$ **(1)**

G and M are constants, hence $T^2 \propto R^3$ **(1)**

3

(c) (i) (use of $T^2 \propto R^3$ gives) $\frac{365^2}{(1.50 \times 10^{11})^3} = \frac{T_m^2}{(5.79 \times 10^{10})^3}$ **(1)**

T_m = 87(.5) days **(1)**

(ii) $\frac{1^2}{(1.50 \times 10^{11})^3} = \frac{165^2}{R_N^3}$ **(1)** (gives $R_N = 4.52 \times 10^{12}$ m)

ratio = $\frac{4.51 \times 10^{12}}{1.50 \times 10^{11}}$ = 30(.1) **(1)**

4

[10]

3 (a) work done/energy change (against the field) per unit mass **(1)**
when moved from infinity to the point **(1)**

2

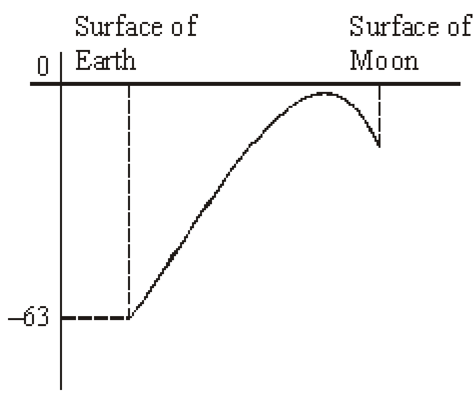
(b) $V_E = -\frac{GM_E}{R_E}$ and $V_M = -\frac{GM_M}{R_M}$ **(1)**

$V_M = -G \times \frac{M_E}{81} \times \frac{3.7}{R_E} = \frac{3.7}{81} V_E$ **(1)**

$= 4.57 \times 10^{-2} \times (-63) = -2.9$ MJ kg^{-1} **(1)** (2.88 MJ kg^{-1})

3

(c)



limiting values $(-63, -V_M)$ on correctly curving line **(1)**
rises to value close to but below zero **(1)**
falls to Moon **(1)**
from point much closer to M than E **(1)**

max 3

[8]

4 (a) (i) h (= ct) (= $3.0 \times 10^8 \times 68 \times 10^{-3}$) = $2.0(4) \times 10^7$ m **(1)**

(ii) $g = (-)\frac{GM}{r^2}$ **(1)**

r (= $6.4 \times 10^6 + 2.04 \times 10^7$) = 2.68×10^7 (m) **(1)**

(allow C.E. for value of h from (i) for first two marks, but not 3rd)

$g = \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{(2.68 \times 10^7)^2}$ **(1)** (= 0.56 N kg^{-1})

4

(b) (i) $g = \frac{v^2}{r}$ **(1)**

$v = [0.56 \times (2.68 \times 10^7)]^{½}$ **(1)**

= 3.9×10^3m s^{-1} **(1)** (3.87×10^3 m s^{-1})

(allow C.E. for value of r from a**(**ii**)**

[or $v^2 = \frac{GM}{r}$ = **(1)**

$v = \left(\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{2.68 \times 10^7}\right)^{1/2}$ **(1)**

= 3.9×10^3 m s^{-1} **(1)**]

(ii) $T\left(= \frac{2\pi r}{v}\right) = \frac{2\pi \times 2.68 \times 10^7}{3.87 \times 10^3}$ **(1)**

= $4.3(5) \times 10^4$s **(1)** (12.**(1)** hours)

(use of $v = 3.9 \times 10^3$ gives T = 4.3**(1)** × 10^4 s = 12.0 hours)

(allow C.E. for value of v from (I)

[alternative for (b):

(i) $v\left(\frac{2\pi r}{T}\right) = \frac{2\pi \times 2.68 \times 10^7}{4.36 \times 10^4}$ **(1)**

$= 3.8(6) \times 10^3$ m s^{-1} **(1)**]

(allow C.E. for value of *r* from (a)(ii) and value of *T*)

(ii) $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$ **(1)**

$\left(= \frac{4\pi^2}{6.67 \times 10^{-11} \times 6.0 \times 10^{24}} \times (2.68 \times 10^7)^3\right) = (1.90 \times 10^9$ **(**s^2**) (1)**

$T = 4.3(6) \times 10^4$ s **(1)**

5

[9]

5 (a)

quantity	**SI unit**	
(gravitational potential)	J kg^{-1} or N m kg $^{-1}$	scalar
(electric field strength)	N C^{-1} or V m^{-1}	vector
(magnetic flux density	T or Wb m^{-2} or N A^{-1} m^{-1}	vector

6 entries correct **(1) (1) (1)**
4 or 5 entries correct **(1) (1)**
2 or 3 entries correct **(1)**

3

(b) (i) $mg = EQ$ **(1)**

$E\left(\frac{mg}{Q} = \frac{4.3 \times 10^{-9} \times 9.81}{3.2 \times 10^{-12}}\right) = 1.32 \times 10^4$ (V m^{-1}) **(1)**

(ii) positive **(1)**

3

[6]

6 (a) period = 24 hours or equals period of Earth's rotation **(1)**
remains in fixed position relative to surface of Earth **(1)**
equatorial orbit **(1)**
same angular speed as Earth or equatorial surface **(1)**

max 2

(b) (i) $\frac{GMm}{r^2} = m\omega^2 r$ **(1)**

$T = \frac{2\pi}{\omega}$ **(1)**

$r\left(= \frac{GMT^2}{4\pi^2}\right)^{1/3} = \left(\frac{6.67\times10^{-11}\times6\times10^{24}\times(24\times3600)^2}{4\pi^2}\right)^{1/3}$ **(1)**

(gives $r = 42.3 \times 10^3$ km)

(ii) $\Delta V = GM\left(\frac{1}{R} - \frac{1}{r}\right)$ **(1)**

$= 6.67 \times 10^{-11} \times 6 \times 10^{24} \times \left(\frac{1}{6.4\times10^6} - \frac{1}{4.23\times10^7}\right)$

$= 5.31 \times 10^7$ (J kg^{-1}) **(1)**

$\Delta E_p = m\Delta V$ (= $750 \times 5.31 \times 10^7$) = 3.98×10^{10} J **(1)**

(allow C.E. for value of ΔV)

[alternatives:

calculation of $\frac{GM}{R}$ (6.25×10^7) or $\frac{GM}{r}$ (9.46×10^6) **(1)**

or calculation of $\frac{GMm}{R}$ (4.69×10^{10}) or $\frac{GMm}{r}$ (7.10×10^9) **(1)**

calculation of both potential energy values **(1)**
subtraction of values or use of $m\Delta V$ with correct answer **(1)**]

6

[8]

7 D

[1]

8 B

[1]

9 A

[1]

10 C

[1]

11 B

[1]

Examiner reports

2 It was rare for all three marks to be awarded in part (a). Most answers made at least some reference to the proportionality and inverse proportionality involved in Newton's law, but references to point masses or to the attractive nature of the force were scarce.
The essential starting point in part (b) was a correct statement equating the gravitational force with $m\omega^2 R$; the more able candidates had little difficulty in then applying $T = 2\pi/\omega$ to derive the required result, and three marks were usually obtained by them.

Both halves of part (c) followed directly from the $T^2 \propto R^3$ result in part (b), and the candidates who realised this usually made excellent progress. Unfortunately, a large proportion tried to go back to first principles and tied themselves in knots with the algebra and/or arithmetic, often getting nowhere. Confusion over which unit of time to employ in the different parts caused much difficulty, especially for candidates who had calculated a constant of proportionality in part (i). Some very elegant solutions to part (ii) were seen, where the result emerged swiftly from $(165)^{2/3}$. The most absurd efforts came from candidates who made the implicit assumption that the Earth, Mercury and Neptune all travel at the same speed in their orbits, leading to wrong answers of 141 days and 165 respectively.

3 Acceptable responses in part (a) were dependent on knowledge of the definition of gravitational potential. Roughly half of the candidates were able to make some progress with this. The principal omission was *per unit* in "work done per unit mass"; "work done on a small mass" was sometimes written. To satisfy the definition, the movement has to be from infinity to the point being considered; inevitably some candidates gave this the wrong way round.

Part (b) instructed candidates to "use the following data", and many were able to arrive at the correct answer by using the data in the question alone. Those who also resorted to the data sheet, from which values for G, M_{Earth} and R_{Earth} could be extracted, were allowed two of the three marks. Either way, the negative sign was considered to be essential in final answers.

The graphs drawn in part (c) were often good, showing clear understanding of the general V µ –(1/r) relationship. When the curve started at the surface of the Earth and stopped short of zero potential this usually gained two marks. Some curves were started carelessly at the vertical axis. Most candidates overlooked the final part of the curve (the effect caused by the Moon's own gravitational potential); for full credit this last section had to be shown.

4 Most candidates scored the mark in part (a) (i) and went to use their answer correctly in part (ii). A small number of candidates however, failed to add the height calculated in part (i) to the Earth's radius or added the radius in km to the height in m. They were usually able to gain some credit for knowing the correct equation to use.

In part (b) (i), many candidates gave a clear and correct expression, using either the expressions for centripetal acceleration or the speed in terms of the mass of the Earth. Weaker candidates confused the symbols for speed and gravitational potential on the data sheet and attempted to calculate the speed using the expression for gravitational potential. Most candidates who completed part (i) went on to complete part (ii) successfully, although some lost the final mark as a result of giving the answer to too many significant figures. Some candidates in part (ii) successfully related the time period to the radius of orbit and thus gained full credit. A small minority of candidates gained no credit as a result of misreading part (b), attempting to provide answers based on a time period of 24 hours.

5 Units of the various physical quantities related to fields and the scalar/vector nature of them, are generally not well known by the candidates. Part (a) showed that the 2004 cohort were no better than their predecessors. Six correct entries in the table were required for three marks, and it was very rare for all three to be awarded. The unit of N m kg^{-1} was accepted as an alternative to J kg^{-1} for gravitational potential, but candidates regularly put N kg^{-1} in the table. The unit of electric field strength was known better, and that of magnetic flux density was usually shown correctly. Candidates often resorted to guesswork when completing the second column of the table. Many did not appreciate that the concept of potential arises from energy considerations and that it is therefore a scalar quantity, whilst the other two quantities are force-related and therefore vectors.

Completely correct answers to part (b) were encountered in many of the scripts. Since the unit of E had already been tested in the table in part (a), no penalty was imposed for wrong or missing units in the answer to part (b)(i). A worrying error, made by a significant minority of the candidates, was to equate the electric force on the particle to its mass, rather than to its weight.

6 Two appropriate features of a geo-synchronous orbit were usually given by the candidates in part (a), but the marks for them were often the last that could be awarded in this question. The required radius in part (b)(i) came readily to the candidates who correctly equated the gravitational force on the satellite with $m\omega^2 r$, applied $T = 2\pi/\omega$, and completed the calculation by substituting T = 24 hours and the values given in the question. Other candidates commonly presented a tangled mass of unrelated algebra in part (b)(i), from which the examiners could rescue nothing worthy of credit.

In part (b)(ii) an incredible proportion of the candidates assumed that it was possible to calculate the increase in the potential energy by the use of mg Δh, in spite of the fact that the satellite had be raised vertically through almost 36,000 km. These attempts gained no marks. Other efforts started promisingly by the use of $V = -GM / r$, but made the crucial error of using $(4.23 \times 10^7 - 6.4 \times 10^6)$ as r in the denominator. Some credit was available to candidates who made progress with a partial solution that proceeded along the correct lines, such as evaluating the gravitational potential at a point in the orbit of the satellite. Confusion between the mass of the Earth and the mass of the satellite was common when doing this.