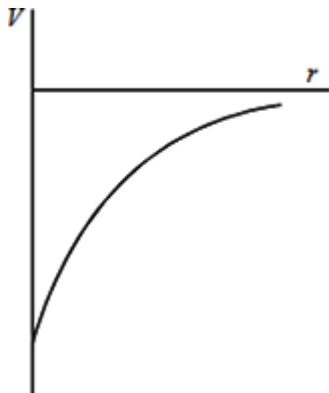
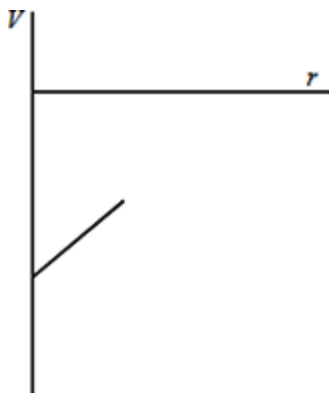


Mark schemes

1	A	[1]
2	A	[1]
3	A	[1]
4	D	[1]
5	C	[1]
6	C	[1]
7	A	[1]
8	C	[1]
9	B	[1]
10	B	[1]
11	D	[1]
12	A	[1]

13gradient decreases as r increases **(1)** V increases as r increases **(1)**only negative values of V shown **(1)**constant gradient **(1)** V increases as r increases **(1)****[max 4]****14**

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

2

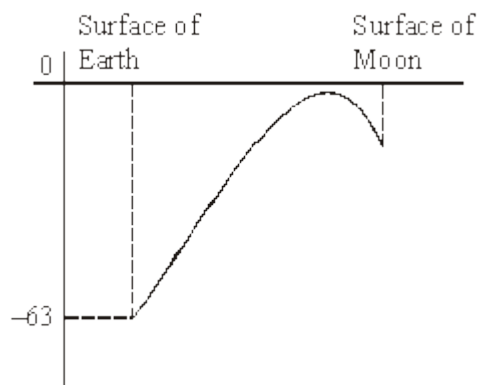
(b) $V_E = -\frac{GM_E}{R_E}$ and $V_M = -\frac{GM_M}{R_M}$ **(1)**

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

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

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]

15

(a) zero potential at infinity (a long way away)

B1

energy input needed to move to infinity (from the point)
 work done by the field moving object from infinity
 potential energy falls as object moves from infinity

B1

2

(b) Any pair of coordinates read correctly

C1

 $\pm 1/2$ square

Use of E_p or $V = (-)\frac{GM}{r}$

C1

Rearrange for M

 $6.4 (\pm 0.5) \times 10^{23} \text{ kg}$

A1

3

- (c) Reads correct potential at surface of Mars = -12.6 (MJ)

C1

or reads radius of mars correctly (3.5×10^6)

equates to $\frac{1}{2} v^2$ (condone power of 10 in MJ)

C1

use of $v = \sqrt{2GM/r}$ with wrong radius

$5000 \pm 20 \text{ m s}^{-1}$ (condone 1sf e.g. 5 km s^{-1})

A1

e.c.f. value of M from (b) may be outside range for other method $6.2 \times 10^{-9} \times \sqrt{\text{their } M}$

3

- (d) Attempts 1 calculation of V_r

B1

*Many values give 4.2.... so allow mark is for reading and using correct coordinates but allow minor differences in readings
Ignore powers of 10 but consistent*

Two correct calculation of V_r

B1

Three correct calculations with conclusion

B1

3

[11]

16

- (a) (centripetal) force = $m r (2\pi / T)^2$ Or $m r (\omega)^2$
(is given by the gravitational) force = $G m M / r^2$ ✓ (mark for both equations)
(equating both expressions and substituting for ω if required) $T^2 = (4\pi^2 / GM) r^3$ ✓ ($4\pi^2 / GM$ is constant, the constants may be on either side of equation but T and r must be numerators)

*First mark is for two equations (gravitational and centripetal)
The second mark is for combining.*

2

- (b) (use of $T^2 \propto r^3$ so $(T_P / T_E)^2 = (r_P / r_E)^3$)
 $(T_P / 1.00)^2 = (5.91 \times 10^9 / 1.50 \times 10^8)^3$ ✓ (mark is for substitution of given data into any equation that corresponds to the proportional equation given above)
 $(T_P)^2 = 61163$
 $T_P = 250$ (yr) ✓ (247 yr)

Answer only gains both marks

The calculation may be performed using data for the Sun in $T^2 = (4\pi^2 / GM) r^3$ easily spotted from $M_s = 1.99 \times 10^{30}$ kg giving a similar answer 247 – 252 yr.

2

- (c) using $M (= g r^2 / G) = 0.617 \times (1.19 \times 10^6)^2 / 6.67 \times 10^{-11}$ ✓
 $M = 1.31 \times 10^{22}$ kg ✓
 answer to 3 sig fig ✓ (this mark stands alone)

The last mark may be given from an incorrect calculation but not lone wrong answer.

3

- (d) Initial KE = $\frac{1}{2} (m) 1400^2 = 9.8 \times 10^5$ (m) J ✓
 Energy needed to escape = 7.4×10^5 (m) J ✓
 So sufficient energy to escape. ✓

OR For object on surface escape speed given by $7.4 \times 10^5 = \frac{1}{2} v^2$
 ✓

escape speed = 1200 m s^{-1} ✓ (if correct equation is shown the previous mark is awarded without substitution)
 So sufficient (initial) speed to escape. ✓

OR escape velocity = $\sqrt{\frac{2GM}{R}}$ substituting M from part (c) ✓

escape speed = 1200 m s^{-1} ✓ (1210 m s^{-1})
 So sufficient (initial) speed to escape. ✓

OR escape velocity = $\sqrt{2Rg}$ substituting from data in (c) ✓

Third alternative may come from a CE from (c)

$(1.06 \times 10^{-8} \times (1.06 \times 10^{-8} \times \sqrt{\text{answer(c)}}))$

Conclusion must be explicit for third mark and cannot be awarded from a CE

3

[10]

17

- (a) force is proportional to the product of the two masses

B1

force is inversely proportional to the square of their separation
(condone radius between masses)

or

equation M0 : masses defined A1 separation defined A1

B1

2

- (b) (i) appreciation that potential $\times$ distance from centre of sun = constant

or calculation of Vr for two sets of values (1.33×10^{20})

or uses distance ratio to calculate new V or r

C1

calculation of all three + conclusion

or uses distance ratios twice+ conclusion

conclusion must be more than 'numbers are same'

(condone 'signs' and no use of powers of 10)

A1

2

- (ii) $V = GM/r$ and $g = GM/r^2$

or

$g = V/r$ (no mark for E or $g = V/d$ or $E = V/r$)

B1

substitution of one set of data to obtain GM (1.33×10^{20})

or $19 \times 10^{10}/7 \times 10^8$ seen

B1

$271 \text{ N kg}^{-1} (\text{m s}^{-2}) (\text{J kg}^{-1} \text{ m}^{-1})$

B1

3

- (iii) potential energy of the Earth = $(-)GMm/r$
 or potential difference formula + $r^2 = \infty$
 or potential at position of Earth = $-8.87 \times 10^8 \text{ J kg}^{-1}$
 (from $Vr = 1.33 \times 10^{20}$)

C1

correct substitution (allow ecf for GM from (ii))
 or
 potential energy = potential x mass of Earth

C1

change in PE = $5.32 \times 10^{33} \text{ J}$ (cnao)
 Fd approach is PE so 0 marks

A1

3

- (iv) speed of Earth round Sun = $2\pi r/T$ or $\sqrt{\frac{GM}{r}}$
 or $3.0 \times 10^4 \text{ m s}^{-1}$

or $KE = \frac{GMm}{2r}$

B1

KE of Earth = $\frac{1}{2} 6 \times 10^{24} \times \text{their } v^2$ ($2.68 \times 10^{33} \text{ J}$)

B1

energy needed = difference between (iii) and orbital KE
 ($2.64 \times 10^{33} \text{ J}$)

or KE in orbit = half total energy needed to
 escape (-1 for AE)

B1

3

[13]

18

- (a) mass depends only on the amount of matter present

B1

weight is force between body and Earth/depends on g/mg /gravitational field strength or answers in terms of Newton's gravitational law

B1

g (etc) varies at different points on and above the Earth or is different on different planets etc

B1

3

- (b) (i) reference is 'infinity' where potential is 0

B1

energy has to be put in/work has to be done to move mass to infinity or a body's energy/PE decreases as a body moves from infinity towards the Earth

B1

2

- (ii) need to show V_r to be constant, clear from algebra or final statement

B1

two sets of data used correctly

B1

all three sets of data used correctly (4.02, 4.025, 4.028)

B1

3

- (iii) energy change per kg = $(5.36 - 3.22) \times 10^7$ (J)

B1

total change = 963 (960) $\times 10^7$ J

B1

2

(c) (i) $GMm/r^2 = mv^2/r$ or $v = (GM/r)$

C1

$$v^2 = 3.2 \times 10^7 \text{ m}^2 \text{ s}^{-2} \text{ or } v = 5670 \text{ ms}^{-1}$$

C1

use of $\text{KE} = \frac{1}{2} mv^2$ using their v

C1

7.2 GJ

A1

4

(ii) KE changes by 4.8 GJ (allow ecf, 12 – their ci)

B1

1

(iii) total energy (supplied) = (4.8) GJ (cnao)

(allow 5.2 GJ using 10 GJ for change in E_p)
(allow variations due to rounding off if physics
is correct in previous parts)

B1

1

[16]**19**

(a) work done per unit mass in bringing object from infinity to point

B1

potential at infinity zero by definition

B1

work has been done by the field so potential at all points closer than
infinity negative

B1

3

- (b) use of point on graph allow within $\pm$ small square

C1

substitution into $V = -\frac{GM}{r}$

C1

range from $590 - 6.90 \times 10^{24}$ (kg)

A1

3

(c) (i) $\Delta E_p = -\frac{GMm}{R_E + h} + \frac{GMm}{R_E}$

C1

addition of radius of Earth to give 7.25×10^6 (m)

C1

1.54×10^{10} (J)

A1

3

(ii) equates $\frac{mv^2}{r}$ and $G\frac{mM}{r^2}$

C1

to give $\Delta E_k = G\frac{mM}{2} \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$

C1

1.25×10^9 J

A1

positive or increase

B1

4

(iii) (lower altitude so) gpe decreases ke increases

C1

loss of gpe is twice gain in ke

A1

2

[15]

20

(a) the work done per unit mass ✓

in moving from infinity to the point ✓

2

(b) Gravitational potential is defined as zero at ∞ ✓

(Forces attractive) so work must be done (on a mass) to reach ∞ (hence negative) ✓

2

(c) $V = -GM/r = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / 6.37 \times 10^6$ ✓

$= -6.25 \times 10^7 \text{ J kg}^{-1}$ ✓

2

(d) in the plane of the equator

always above the same location on the earth

having the same period as the earth / 24 hours

✓✓any two lines

2

(e) $V = -GM/r = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / 4.23 \times 10^7 = -9.41 \times 10^6 \text{ J kg}^{-1}$ ✓

$E_p = \Delta V \times m = (6.26 - 0.94) \times 10^7 \times 1200$ ✓

$= 6.38 \times 10^{10} \text{ J}$ ✓

3

(f) radius must increase ✓

velocity gets smaller ✓

reference to R^3 is proportional to T^2 ✓

reference (from circular motion) v^2 is proportional to $1/r$ ✓

4

[15]