M1.C

[1]

M2.(a) (i) (Minimum) Speed (given at the Earth's surface) that will allow an object to leave / escape the (Earth's) gravitational field (with no further energy input)

Not gravity

Condone gravitational pull / attraction

B1

1

(ii) $\frac{1}{2} mv^2 = \frac{GMm}{r}$

B1

Evidence of correct manipulation

At least one other step before answer

B1

2

(iii) Substitutes data and obtains $M = 7.33 \times 10^{22}$(kg)

or

Volume = $(1.33 \times 3.14 \times (1.74 \times 10^6)^3$ or 2.2×10^{19}

or $\rho = \frac{3v^2}{8\pi G r^2}$

C1

3300 (kg m^{-3})

A1

2

(b) (Not given all their KE at Earth's surface) energy continually added in flight / continuous thrust provided / can use fuel (continuously)

B1

Less energy needed to achieve orbit than to escape from Earth's gravitational field / it is not leaving the gravitational field

B1

2

[7]

M3. C

[1]

M4. A

[1]

M5. A

[1]

M6. C

[1]

M7. B

[1]

M8. (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

±1/2 square

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

C1

Rearrange for M

6.4 (±0.5) × 10^{23} 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 ½ v^2 (condone power of 10 in MJ)

C1

use of v = √(2GM/r) with wrong radius

5000 ± *20* 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 × 10^{-9}x √their M

3

(d) Attempts 1 calculation of *Vr*

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 *Vr*

B1

Three correct calculations with conclusion

B1

3

[11]

M9. D

[1]

M10. B

[1]

M11. D

[1]

M12. (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 ± small square

C1

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

C1

range from 590 – 6.90 × 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]

M13. A

[1]