M1.D

[1]

M2.C

[1]

M3.(a) (i) force per unit mass ✓
a vector quantity ✓
Accept force on 1 kg (or a unit mass).

2

(ii) force on body of mass *m* is given by $F = \frac{GMm}{(R+h)^2}$ ✓

gravitational field strength $g\left(=\frac{F}{m}\right) = \frac{GM}{(R+h)^2}$ ✓

For both marks to be awarded, correct symbols must be used for M and m.

2

(b) (i) $F\left(=\frac{GMm}{(R+h)^2}\right) = \frac{6.67\times10^{-11}\times5.98\times10^{24}\times2520}{\left((6.37\times10^{6})+(1.39\times10^{7})\right)^2}$ ✓

= 2.45 × 10^3 (N) ✓ to **3SF** ✓

1st mark: all substituted numbers must be to at least 3SF.
If 1.39 × 10^7 is used as the complete denominator, treat as AE with ECF available.
3rd mark: ***SF mark is independent.***

3

(ii) $F = m\omega^2 (R + h)$ gives $\omega^2 = \frac{2450}{2520 \times 2.03 \times 10^7}$ ✓

from which $\omega = 2.19 \times 10^{-4}$ (rad s^{-1}) ✓

time period $T\left(=\frac{2\pi}{\omega}\right)=\frac{2\pi}{2.19\times10^{-4}}$ **or** = 2.87 ✓ 10^4 s ✓

[**or** $F = \frac{mv^2}{R+h}$ gives $v^2 = \frac{2.45\times10^3 \times\left((6.37\times10^6)+(13.9\times10^6)\right)}{2520}$ ✓

from which v = 4.40 ✓ 10^3 (m s-1) ✓

time period $T\left(=\frac{2\pi(R+h))}{v}\right)=\frac{2\pi\times2.03\times10^7}{4.40\times10^3}$ **or** = 2.87 × 10^4 s ✓]

[**or** $T^2 = \frac{4\pi^2(R+h)^3}{GM}$ ✓

$= \frac{4\pi^2((6.37\times10^6)+(13.9\times10^6))^3}{6.67\times10^{-11}\times5.98\times10^{24}}$ ✓

gives time period T = 2.87 × 10^4s ✓]

$= \frac{2.87\times10^4}{3600}$ = 7.97 (hours) ✓

number of transits in 1 day = $\frac{24}{7.97}$ = 3.01 (≈ 3) ✓

Allow ECF from wrong F value in (i) but mark to max 4 (because final answer won't agree with value to be shown).

First 3 marks are for determining time period (or frequency). Last 2 marks are for relating this to the number of transits.

Determination of f = 3.46 × 10^{-5} (s^{-1}) is equivalent to finding T by any of the methods.

5

(c) acceptable use ✓
satisfactory explanation ✓
e.g. monitoring weather **or** surveillance:
whole Earth may be scanned **or** Earth rotates under orbit
or information can be updated regularly
or communications: limited by intermittent contact
or gps: several satellites needed to fix position on Earth

Any reference to equatorial satellite should be awarded 0 marks.

2

[14]

M4.A

[1]

M5.(a) (i) Use of $F = GMm/r^2$

C1

Allow 1 for
-correct formula quoted but forgetting square in substitution

Correct substitution of data

M1

-missing m in substitution

491 (490)N

A1

-substutution with incorrect powers of 10
Condone 492 N,

(ii) Up and down vectors shown (arrows at end) with labels

B1

allow W, mg (not gravity); R
allow if slightly out of line / two vectors shown at feet

up and down arrows of equal lengths

B1

condone if colinear but not shown acting on body
In relation to surface W ≤ R (by eye) to allow for weight vector starting in middle of the body
Must be colinear unless two arrows shown in which case R vectors ½ W vector(by eye)

(b) (i) Speed = $2\pi r / T$

B1

Max 2 if not easy to follow

$2\pi 6370000 / (24 \times 60 \times 60)$

B1

463 m s^{-1}

B1

Must be 3sf or more

(ii) Use of $F = mv^2/r$

C1

Allow 1 for use of $F = mr\omega^2$ with $\omega = 460$

1.7 (1.66 – 1.68) N

A1

(iii) Correct direction shown
(Perpendicular to and toward the axis of rotation)
NB – not towards the centre of the earth

B1

(c) Force on scales decreases / apparent weight decreases
Appreciates scale reading = reaction force

C1

The reading would become 489 (489.3)N or reduced by 1.7 N)

A1

Some of the gravitational force provides the necessary centripetal force

B1

or $R = mg - mv^2/r$

[14]

M6. A

[1]

M7. B

[1]

M8. D

[1]

M9. C

[1]

M10. A

[1]

M11. A

[1]

M12. B

[1]

M13. C

[1]

M14. A

[1]