19 Marking scheme: Worksheet (A2)

1 Gravitational field strength at a point, g, is the force experienced per unit mass at that point. [1]

2 $F = -\dfrac{GMm}{r^2}$ [1]

Therefore: $G = \dfrac{Fr^2}{Mm} \rightarrow \left[\dfrac{\text{N m}^2}{\text{kg}^2}\right] \rightarrow [\text{N m}^2\ \text{kg}^{-2}]$ [1]

3 $g = \dfrac{F}{m}$

$F = mg = 80 \times 1.6$ [1]

$F = 128$ N ≈ 130 N (F is the 'weight' of the astronaut.) [1]

4 **a** $F = \dfrac{GMm}{r^2}$ [1]

$F = \dfrac{6.67\times10^{-11}\times1.7\times10^{-27}\times1.7\times10^{-27}}{(5.0\times10^{-14})^2}$ [1]

$F \approx 7.7 \times 10^{-38}$ N [1]

b $F = \dfrac{6.67\times10^{-11}\times5.0\times10^{28}\times5.0\times10^{28}}{(8.0\times10^{12})^2}$ [1]

$F = 2.61 \times 10^{21}$ N $\approx 2.6 \times 10^{21}$ N [1]

c $F = \dfrac{6.67\times10^{-11}\times1500^2}{2.0^2}$ [1]

$F = 6.00 \times 10^{-6}$ N $\approx 6.00 \times 10^{-6}$ N [1]

5 **a** $g = -\dfrac{GM}{r^2}$ [1]

b The field strength obeys an inverse square law with distance ($g \propto \dfrac{1}{r^2}$). [1]

Doubling the distance decreases the field strength by a factor of four. [1]

c ratio $= \dfrac{GM/(5R)^2}{GM/(59R)^2}$ [1]

ratio $= \dfrac{59^2}{5^2} = \left(\dfrac{59}{5}\right)^2$ [1]

ratio ≈ 140 [1]

6 $g = -\dfrac{GM}{r^2}$ [1]

$g = \dfrac{6.67\times10^{-11}\times1.0\times10^{26}}{(2.2\times10^{7})^2}$ (magnitude only) [1]

$g = 13.8$ N kg^{-1} ≈ 14 N kg^{-1} [1]

7 $g = -\dfrac{GM}{r^2}$ [1]

$r^2 = \dfrac{GM}{g} = \dfrac{6.67\times10^{-11}\times5.0\times10^{23}}{4.0} = 8.34 \times 10^{12}$ m^2 [1]

$r = \sqrt{8.34\times10^{12}} \approx 2.9 \times 10^{6}$ m [1]

8 a $F = -\dfrac{GMm}{r^2}$ [1]

$F = \dfrac{6.67\times10^{-11}\times1800\times6.0\times10^{24}}{\left(3.9\times10^{10}\right)^2}$ $\left(r = \dfrac{7.8\times10^{10}}{2} = 3.9\times10^{10}\text{ m}\right)$ [1]

$F = 4.74 \times 10^{-4}$ N $\approx 4.7 \times 10^{-4}$ N [1]

b $F = -\dfrac{GMm}{r^2}$

$F = \dfrac{6.67\times10^{-11}\times1800\times6.4\times10^{23}}{\left(3.9\times10^{10}\right)^2}$ [1]

$F = 5.05 \times 10^{-5}$ N $\approx 5.1 \times 10^{-5}$ N [1]

c $a = \dfrac{F}{m}$ (F is the net force.) [1]

$a = \dfrac{4.74\times10^{-4} - 5.05\times10^{-5}}{1800}$ [1]

$a \approx 2.4 \times 10^{-7}$ m s^{-2} (towards the centre of the Earth) [1]

9 a $F = -\dfrac{GMm}{r^2}$ [1]

$F = \dfrac{6.67\times10^{-11}\times5000\times6.0\times10^{24}}{\left(6800\times10^{3}\right)^2}$ (r = 6400 + 400 = 6800 km) [1]

$F = 4.33 \times 10^{4}$ N $\approx 4.3 \times 10^{4}$ N [1]

b $a = \dfrac{F}{m} = \dfrac{4.33\times10^{4}}{5000}$ [1]

$a = 8.66 \approx 8.7$ m s^{-2} [1]

c $a = \dfrac{v^2}{r}$ [1]

$v^2 = ar = 8.66 \times 6800 \times 10^3$ [1]

$v = 7.67 \times 10^3$ m s^{-1} ≈ 7.7 km s^{-1} [1]

10 a The work done in bringing unit mass [1]
from infinity to the point [1]

b 0 J [1]

c $E_p = -\dfrac{6.67\times10^{-11}\times6.0\times10^{24}}{6.4\times10^{6}}$ ([1] mark only if minus sign missed) [2]

$= -6.25 \times 10^6$ J [1]

d 6.25×10^6 J [1]

11 a Gravitational force on planet = $\dfrac{GMm}{r^2}$ [1]

Centripetal force = $\dfrac{mv^2}{r}$ [1]

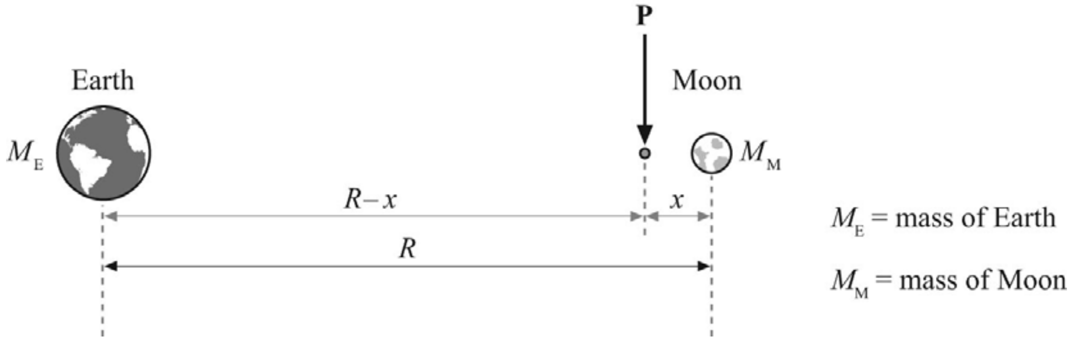
Equating these two forces, we have: $\dfrac{GMm}{r^2} = \dfrac{mv^2}{r}$ [1]

Therefore: $v^2 = \dfrac{GM}{r}$ or $v = \sqrt{\dfrac{GM}{r}}$ [1]

b $v = \sqrt{\dfrac{GM}{r}} = \sqrt{\dfrac{6.67\times10^{-11}\times2.0\times10^{30}}{1.5\times10^{11}}}$ [1]

$v = 2.98 \times 10^4\ \mathrm{m\ s^{-1}} \approx 30\ \mathrm{km\ s^{-1}}$ [1]

12 The field strengths are the same at point **P**.



$\dfrac{GM_M}{x^2} = \dfrac{GM_E}{(R-x)^2}$ [1]

$R - x = x \times \sqrt{\dfrac{M_E}{M_M}}$ [1]

$R - x = x \times \sqrt{81}$ so $R - x = 9x$ [1]

$10x = R$ so $x = \dfrac{R}{10}$ [1]