Gravitation …. Markscheme

1. A **1]**

2. C **[1]**

3. B **[1]**

4. C+D **[1]**

5. C **[1]**

6. B **[1]**

7. A **[1]**

8. B **[1]**

9. C **[1]**

10. B **[1]**

11. A **[1]**

12. (a) the force exerted per unit mass;
on a point (small) mass; 2

(b) (i) use of $g = \frac{F}{m}$ and $F = G\frac{Mm}{R^2}$;

combine to get $g = G\frac{M}{R^2}$; 2

(ii) $M = \frac{gR^2}{G}$;

substitute to get $M = 1.9 \times 10^{27}$ kg; 2

[6]

13. **Kepler's third law**

(a) (i) the orbits are elliptical / not circular; 1
Do not accept "because R changes".

(ii) gravity / gravitational; 1

(iii) $F = G\frac{M_s m}{R^2}$; 1

Same symbols as in question must be used to receive the mark.

(iv) let v = the speed of planet, the acceleration is then = $\frac{v^2}{R}$

from Newton 2, $F = G\frac{M_s m}{R^2} = \frac{mv^2}{R}$; { *Some reference to Newton 2 is required to receive this mark.*

$v = \frac{2\pi R}{T}$;

therefore, = $G\frac{M_s m}{R^2} = \frac{4\pi^2 mR^2}{T^2}$;

therefore, $T^2 = \frac{4\pi^2}{GM_s}R^3$; 4

so $K = \frac{4\pi^2}{GM_s}$

Be aware of the many simple variants of this eg
using $a = \omega^2 R = \frac{4\pi^2 R}{T^2}$.

(b) (i) recognize that gravitational field strength = $\frac{v^2}{R} = \frac{4\pi^2 R}{T^2}$;

$= \frac{40 \times 1.1 \times 10^9}{(6.2 \times 10^5)^2}$;

= 0.1Nkg^{-1} 2

(ii) $T^2 = \frac{4\pi^2}{GM_s}R^3$ therefore, $M_{jup} = \frac{4\pi^2 R^3}{GT^2}$;

$M_{jup} = \frac{4\pi^2 \times (1.1)^3 \times 10^{27}}{6.7 \times 10^{-11} \times (6.2 \times 10^5)^2}$;

$\approx 2.0 \times 10^{27}$ kg;

Or

$0.1 = \frac{GM}{R^2}$;

$M = \frac{0.1R^2}{G}$;

$= \frac{0.1 \times (1.1 \times 10^9)^2}{6.7 \times 10^{-11}}$

$\approx 2.0 \times 10^{27}$ kg; 3

[12]

14. (a) change in potential energy per unit mass / work done per unit mass;
in moving small / point mass from infinity to the point; 2
Do not allow "from a long distance away".

(b) (i) asymptotic at large r <u>and</u> in negative gravitational potential region;
line stops at surface line; 2
Do not allow asymptotic to y-axis.

(ii) loss of gravitational potential = $6.67 \times 10^{-11} \times \frac{m_{\text{Moon}}}{r_{\text{Moon}}}$;

equates loss of gravitational potential to $\frac{1}{2}v^2$;

$v = 2.4$ kms^{-1}; 3

(iii) meteorite may have initial speed / velocity <u>towards</u> Moon / contribution of Earth's gravity; 1

(c) (i) constant; 1

(ii) decreasing; 1

15. Gravitational potential

(a) the work done per unit mass;
in bringing a small / point mass;
from infinity to the point (in the gravitational field); 3

(b) from the graph $V_0 = 3.9\ (\pm 0.2) \times 10^7$ J kg^{-1};

$g_0 = \frac{V_0}{R_0} = \frac{39}{5}$;

$= 7.8(\pm 2)$N kg^{-1}; 3

(c) 2.0×10^7 m above surface is 2.5×10^7 m from centre;

ΔV between surface and 2.5×10^7m $= (3.9 - 0.80) \times 10^7$
$= 3.1(\pm 0.2) \times 10^7$ J kg^{-1};

$v = \sqrt{\frac{2m\Delta V}{m}} = \sqrt{2\Delta V}$;

$= \sqrt{6.2 \times 10^7} = 7.9(\pm 0.2) \times 10^3$ ms^{-1}; 4

*Award **[3 max]** if the candidate forgets that the distances are from the centre (answer 3.2×10^3 ms^{-1}), ie the candidate must show ΔV.*

[10]

16. (a) (i) direction is changing and so there is an acceleration;
there must be a resultant force on the satellite / force is provided by gravitational attraction; 2

(ii) object and satellite have the same acceleration;
acceleration is towards centre of planet;
so no reaction force between object and satellite; 3

(b) (i) potential energy $\frac{-(GMm)}{(R+h)}$; 1

(ii) in orbit, $\frac{mv^2}{(R+h)} = \frac{(GMm)}{(R+h)^2}$ **or** expressed in words;

use of $E_K = \frac{1}{2}mv^2$;

$E_K = \frac{\frac{1}{2}(GMm)}{(R+h)}$; 3

(c) (total energy = potential energy + kinetic energy)
total energy is $\frac{-(GMm)}{2(R+h)}$;

as total energy is reduced, $\frac{(GMm)}{2(R+h)}$ increases;

hence h decreases;
Do not award if there is no reasoning or reasoning is fallacious or misleading.
E_K increases and v increases; 4

(d) friction reduces the total energy of the satellite;
causing height to decrease and speed to increase;
less height, greater frictional force;
because atmosphere denser;
frictional force causes heating effect;
as height decreases heating effect increases / heats up more;
if satellite small, sufficient heating to cause destruction; 4 max
Do not allow "heats up as height decreases".

]