IB PHYSICS: Gravitational Forces Markscheme

1. (a) attractive force is proportional to the product of the point masses;
and inversely proportional to the square of the separation; 2

*Award **[1]** if the response is not clear that they are point masses or if the force is attractive. Award **[0]** for quoting the formula from data booklet without any further explanation.*

(b) use of $g = \frac{GM}{r^2}$;

appropriate substitution: $g = \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{(6.4 \times 10^6)^2} = 9.77 \approx 10 \text{ N kg}^{-1}$; 2

(c) (i) point marked on Earth's surface that is nearest to Moon;
since force of attraction from Moon greatest; 2

Accept other sensible comment.

(ii) same point as above; (*accept point on directly opposite side of Earth*)
explanation of why the resultant field is a minimum at this point
e.g. forces from Earth and Moon are in opposite directions; 2

(iii) each relevant point;
e.g. Earth is rotating;
Moon orbits the Earth *etc.*;
position of Sun also affects resultant field *etc.*; 2 max

[10]

2. (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) $M = \frac{gR_2}{G}$;

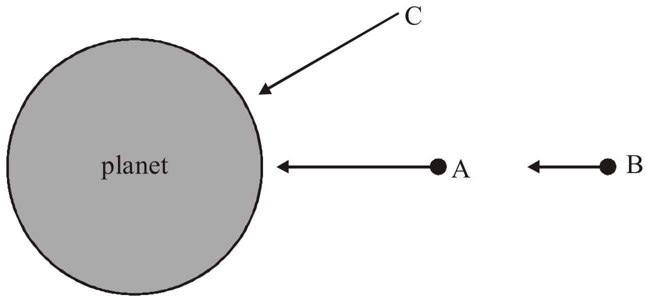
substitute to get $M = 1.9 \times 10^{27}$; 2

[6]

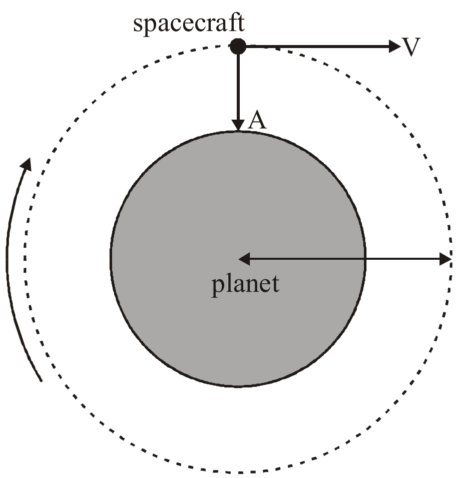
3. (a) $g = \frac{F}{m}$

F is the gravitational force;
exerted on/experienced by a small/point/infinitesimal mass m; 2

(b) *Award **[1]** for each correct arrow. The one at B points in the same direction as that at A and is shorter. The one at C has the same length as that at A and points toward the centre of the planet.* 2



(c)



(i) velocity is tangent to path; 1

(ii) acceleration is normal to velocity toward centre; 1

(d) for realizing that $g = a$;

$a = \frac{v^2}{r} = \frac{(6.5 \times 10^3)^2}{7.5 \times 10^6}$ N kg^{-1};

$g = 5.6$ N kg^{-1}; 3

[9]

4. (a) (i) $V_{surface} = -6.3\ (\pm 0.3) \times 10^7$ J kg^{-1} 1 max

(ii) V_h is at $R = 42 \times 10^6$ m;
$= -1.0\ (\pm 0.2) \times 10^7$ J kg^{-1}; 2 max
*Watch for $R = 3.6 \times 10^7$ m being used. If so award **[1]** and use ECF.*

(b) $\Delta V = 5.3\ (\pm 0.5) \times 10^7$ J kg^{-1};
Energy = $m\Delta V$;
$= 5.3\ (\pm 0.5) \times 10^{11}$ J; 3 max
*Award **[2]** if they calculate the PE of the satellite (10^{11} J).*

(c) *Any **two** of the following **[1]** each.*
the satellite has to be given a horizontal velocity (or has to have KE) to go into orbit;
rockets motors lifting rocket not 100 % efficient;
air resistance in initial stages of launch; 2 max

[8]

5. C+D

[1]

6. B

[1]

7. B

[1]

8. (a) (i) speed of object at Earth's surface;
so that it will escape from the gravitational field / travel to infinity; 2

(ii) gravitational potential energy at Earth's surface = (–) $\frac{GMn}{R_e}$;
this must be provided for probe to escape;
energy is less than this <u>hence</u> not escape; 3

(b) (i) change = $GMm\left(\frac{1}{R_e} - \frac{1}{R}\right)$; 1

Accept $GMm\left(\frac{1}{R} - \frac{1}{R_e}\right)$.

(ii) in orbit, $\frac{mv^2}{r} = \frac{GMm}{r^2}$;

$\frac{1}{2}mv^2 = \frac{GMm}{2R}$; 2

(c) idea of equating energies;

$$\frac{3GMm}{4R_e} = \frac{GMm}{2R} + \frac{GMm}{R_e} - \frac{GMm}{R}$$

$$\frac{1}{4R_e} = \frac{1}{2R}$$

$R = 2R_e$;
height above surface = R_e; 4 max

(d) (i) probe collides with air molecules;
giving them kinetic energy and so losing energy itself; 2
Accept answers in terms of frictional forces.

(ii) greater density, more molecules of air with which to collide;
higher speed, higher rebound speed for air molecules; 2
Accept answers in terms of magnitude of frictional force.

(iii) height becomes less;
and speed increases; 2

[18]

9. C

[1]