# Gravitational Fields

## Mark Scheme 3

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|---|---|
| **Level** | International A Level |
| **Subject** | Physics |
| **Exam Board** | CIE |
| **Topic** | Gravitational Fields |
| **Sub Topic** | |
| **Paper Type** | Theory |
| **Booklet** | Mark Scheme 3 |

**Time Allowed:** **69 minutes**

**Score:** **/57**

**Percentage:** **/100**

| A* | A | B | C | D | E | U |
|---|---|---|---|---|---|---|
| >85% | '77.5% | 70% | 62.5% | 57.5% | 45% | <45% |

| | | | | | |
|---|---|---|---|---|---|
| **1** | **(a** | **(i)** | force proportional to product of masses | B1 | |
| | | | force inversely proportional to square of separation | B1 | [2] |
| | | **(ii)** | separation <u>much</u> greater than radius / diameter of Sun / planet | B1 | [1] |
| | **(b)** | **(i)** | e.g. force or field strength $\propto 1 / r^2$ | | |
| | | | potential $\propto 1 / r$ | B1 | [1] |
| | | **(ii)** | e.g. gravitational force (always) attractive | B1 | |
| | | | electric force attractive or repulsive | B1 | [2] |

| | | | | | |
|---|---|---|---|---|---|
| 2 | **(a** | | force per unit mass (*ratio idea essential*) | B | [1] |
| | **(b)** | | graph: correct curvature | M1 | |
| | | | from $(R, 1.0\,g_S)$ & at least one other correct point | A1 | [2] |
| | **(c)** | **(i)** | fields of Earth and Moon are in opposite directions | M1 | |
| | | | *either* resultant field found by subtraction of the field strength | | |
| | | | *or* any other sensible comment | A1 | |
| | | | so there is a point where it is zero | A0 | [2] |
| | | | (*allow* $F_E = -F_M$ *for 2 marks*) | | |
| | | **(ii)** | $GM_E / x^2 = GM_M / (D - x)^2$ | C1 | |
| | | | $(6.0 \times 10^{24}) / (7.4 \times 10^{22}) = x^2 / (60R_E - x)^2$ | C1 | |
| | | | $x = 54\,R_E$ | A1 | [3] |
| | | **(iii)** | graph: $g = 0$ at least ⅔ distance to Moon | B1 | |
| | | | $g_E$ and $g_M$ in opposite directions | M1 | |
| | | | correct curvature (by eye) and $g_E > g_M$ at surface | A1 | [3] |

3 **(a)** work done moving <u>unit</u> mass — M1
from infinity to the point — A1 [2]

**(b) (i)** at $R$, $\phi = 6.3 \times 10^7$ J kg$^{-1}$ (allow $\pm$ 0.1 $\times 10^7$) — B
$\phi = GM / R$
$6.3 \times 10^7 = (6.67 \times 10^{-11} \times M) / (6.4 \times 10^6)$ — C
$M = 6.0 \times 10^{24}$ kg (allow 5.95 $\rightarrow$ 6.14) — A1 [3]
Maximum of 2/3 for any value chosen for $\phi$ not at $R$

**(ii)** change in potential = $2.1 \times 10^7$ J kg$^{-1}$ (allow $\pm$ 0.1 $\times 10^7$) — C
loss in potential energy = gain in kinetic energy — B1
$½ mv^2 = \phi m$ or $½ mv^2 = GM / 3R$ — C1
$½ v^2 = 2.1 \times 10^7$
$v = 6.5 \times 10^3$ m s$^{-1}$ ………………(allow 6.3 $\rightarrow$ 6.6) — A1 [4]
(answer $7.9 \times 10^3$ m s$^{-1}$, based on $x = 2R$, allow max 3 marks)

**(iii)** e.g. speed / velocity / acceleration would be greater — B1
deviates / bends from straight path — B1 [2]
(any sensible ideas, 1 each, max 2)

4 **(a** $F \propto Mm / R^2$ ……..(*words or explained symbols*) ................................................M1
*either* $M$ and $m$ are point masses
*or* $R$ >> diameter of masses …(*do not allow 'size'*) ...................................... A1 [2

**(b) (i)** equatorial orbit ........................................................................................ B1
period 24 hours / same angular speed ............................................................. B1
from west to east / same direction of rotation ..................................................... B1 [3]
(*allow one of the last two marks for 'always overhead' if 2nd or 3rd marks not scored*)

**(ii)** gravitational force provides centripetal force
/ gives rise to centripetal acceleration ….(*in 'words'*) ........................................ B1
$GM / x^2 = x\omega^2$ ........................................................................................M1
$g = GM / R^2$ ........................................................................................M1
to give $gR^2 = x^3\omega^2$ ........................................................................................ A0 [3]

**(iii)** $\omega = 2\pi / (24 \times 3600) = 7.27 \times 10^{-5}$ rad s$^{-1}$ ........................................................ C1
$9.81 \times (6.4 \times 10^6)^2 = x^3 \times (7.27 \times 10^{-5})^2$ ........................................................ C1
$x^3 = 7.6 \times 10^{22}$
$x = 4.2 \times 10^7$ m ........................................................................................ A1 [3]
(*use of $g$ = 10 m s$^{-2}$, loses 1 mark but once only in the Paper*)

**[Total: 11]**

5 **(a)** **(i)** force per (unit) mass ……(*ratio idea essential*) ................................................ B1 [1]

**(ii)** $g = GM / R^2$ ................................................ C1

$9.81 = (6.67 \times 10^{-11} \times M) / (6.38 \times 10^6)^2$ ……(*all 3 s.f*) ................................................ M1

$M = 5.99 \times 10^{24}$ kg ................................................ A0 [2]

**(b)** **(i)** *either* $GM = \omega^2 r^3$ *or* $gR^2 = \omega^2 r^3$ ................................................ C1

*either* $6.67 \times 10^{-11} \times 5.99 \times 10^{24} = \omega^2 \times (2.86 \times 10^7)^3$

*or* $9.81 \times (6.38 \times 10^6)^2 = \omega^2 \times (2.86 \times 10^7)^3$ ................................................ C1

$\omega = 1.3 \times 10^{-4}$ rad s$^{-1}$ ................................................ A1 [3]

(*use of $r = 2.22 \times 10^7$m scores max 2 marks*)

**(ii)** period of orbit = $2\pi / \omega$ ................................................ C1

$= 4.8 \times 10^4$ s (= 13.4 hours) ................................................ A1

period for geostationary satellite is 24 hours (= $8.6 \times 10^4$ s) ................................................ A1

so no ................................................ A0 [3]

**(c)** satellite can then provide cover at Poles ................................................ B1 [1]

**[Total: 10]**

6 **(a)** force per unit mass *(ratio idea essential)* B1 [1]

**(b)** $g = GM / R^2$ C1

$8.6 \times (0.6 \times 10^7)^2 = M \times 6.67 \times 10^{-11}$ C1

$M = 4.6 \times 10^{24}$ kg [3]

**(c)** **(i)** *either* potential decreases as distance from planet decreases

*or* potential zero at infinity and X is closer to zero

*or* potential $\alpha\, -1/r$ and Y more negative M1

so point Y is closer to planet. A1 [2]

**(ii)** idea of $\Delta\phi = ½v^2$ C1

$(6.8 - 5.3) \times 10^7 = ½v^2$

$v = 5.5 \times 10^3$ ms$^{-1}$ A1 [2]