# 13. Gravitational Fields

## 13.3 Gravitational field of a point mass

## Paper 4

Marking Scheme

## Q1.

| | | |
|---|---|---|
| (b)(iii) | field strength at X: $\Phi / 4R$ | **A1** |
| | field strength at Y: $4\Phi / R$ | **A1** |
| | potential energy at X: $-M\Phi$ | **A1** |
| | potential energy at Y: $-8M\Phi$ | **A1** |

## Q2.

| | | |
|---|---|---|
| (b)(i) | $g = GM / x^2$ | **C1** |
| | $= (6.67 \times 10^{-11} \times 1.99 \times 10^{30}) / (1.47 \times 10^{11})^2$<br>$= 6.14 \times 10^{-3}$ N kg$^{-1}$ | **A1** |

## Q3.

| | | |
|---|---|---|
| (b)(i) | $g = GM / r^2$ | **M1** |
| | $E = Q / 4\pi\varepsilon_0 r^2$ | **M1** |
| | algebra showing the elimination of $r$ leading to $M / Q = (1 / 4\pi G\varepsilon_0) (g / E)$ | **A1** |

## Q4.

| | | |
|---|---|---|
| (a)(ii) | change in height negligible compared with radius (of Earth) | **B1** |
| | (so) field lines are (effectively) parallel | **B1** |
| (b)(i) | $Y = GM / R^2$ | **M1** |
| | $G$ is the gravitational constant | **A1** |
| (b)(iii) | sketch: smooth curve with decreasing positive gradient, starting at $(R, -Y)$ and reaching $3R$ with $g$ still negative<br>**or**<br>smooth curve with increasing positive gradient, ending at $(-R, Y)$ and reaching $-3R$ with $g$ still positive | **B1** |
| | both of the above curves, in correct quadrants | **B1** |
| | curve passing through $(\pm 2R, \pm 0.25Y)$ and $(\pm 3R, \pm 0.11Y)$ | **B1** |

## Q5.

| | | |
|---|---|---|
| (a)(ii) | $g = F / m$ | **C1** |
| | $F = GMm / r^2$<br>and so<br>$g = [GMm / r^2] / m = GM / r^2$ | **A1** |
| (b)(i) | $g = (6.67 \times 10^{-11} \times 7.35 \times 10^{22}) / (1.74 \times 10^6)^2 = 1.62$ N kg$^{-1}$ | **A1** |
| (b)(ii) | fields (due to Earth and the Moon) have equal magnitudes | **B1** |
| | fields (due to Earth and the Moon) are in opposite directions | **B1** |
| (b)(iii) | distance of X from Earth $= (3.84 \times 10^8 - x)$ | **C1** |
| | $(G \times) 7.35 \times 10^{22} / x^2 = (G \times) 5.98 \times 10^{24} / (3.84 \times 10^8 - x)^2$ | **C1** |
| | $x = 3.8 \times 10^7$ m | **A1** |

## Q6.

| | | |
|---|---|---|
| (b)(i) | $g = GM / r^2$ | **C1** |
| | $= (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (3.39 \times 10^6)^2$<br>$= 3.73$ N kg$^{-1}$ | **A1** |

## Q7.

| | | |
|---|---|---|
| (b)(i) | (gravitational) fields from the Earth and Moon are in opposite directions | **B1** |
| | (resultant is zero where gravitational) fields are equal (in magnitude) | **B1** |
| (b)(ii) | $g \propto M / r^2$ | **C1** |
| | $5.98 \times 10^{24} / x^2 = 7.35 \times 10^{22} / (3.84 \times 10^8 - x)^2$<br>leading to $x = 3.5 \times 10^8$ (m) | **A1** |

## Q8.

| | | |
|---|---|---|
| (b)(iii) | sketch: one curve, starting with gradient of decreasing magnitude at $2R$ and finishing with gradient of increasing magnitude at $D - R$ | **B1** |
| | field strength shown as zero (only) near the point of maximum potential | **B1** |
| | negative field strength near one sphere and positive field strength near the other | **B1** |

## Q9.

| | | |
|---|---|---|
| (b) | $g = GM / R^2$ | **C1** |
| | $= (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (3.39 \times 10^6)^2$ | **C1** |
| | $= 3.73$ N kg$^{-1}$ | **A1** |
| (c) | $0.99 \times 3.73 = (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / r^2$ | **C1** |
| | $r = 3.41 \times 10^6$ (m) | **C1** |
| | height $= (r - R)$<br>$= 2 \times 10^4$ m | **A1** |
| | **or** | |
| | $0.99 \times 3.73 = (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (R + h)^2$<br>$(R + h)^2 = 1.1596 \times 10^{13}$ | **(C1)** |
| | $R + h = 3.41 \times 10^6$ (m) | **(C1)** |
| | $h = 2 \times 10^4$ m | **(A1)** |
| | **or** | |
| | $0.99 = (3.39 \times 10^6)^2 / r^2$ | **(C1)** |
| | $r = 3.41 \times 10^6$ (m) | **(C1)** |
| | height $= 2 \times 10^4$ m | **(A1)** |

## Q10.

| | | |
|---|---|---|
| (a)(ii) | (at surface,) lines (of force) are radial | **B1** |
| | Earth has large radius/height above surface is small<br>so lines are (approximately) parallel | **B1** |
| | parallel lines → constant field strength | **B1** |

**Q11.**

| | | |
|---|---|---|
| (b) | smooth curve between $R$ and $4R$ with negative gradient of decreasing magnitude | **B1** |
| | line passing through ($R$, 1.00$g$) and ($2R$, 0.25$g$) | **B1** |
| | line ending at ($4R$, 0.0625$g$) | **B1** |
| (c) | $M = (4/3 \times \pi R^3)\rho$ | **C1** |
| | $g = GM/(2R)^2$ | **C1** |
| | $g = ⅓ \times 6.67 \times 10^{-11} \times \pi \times 3.4 \times 10^6 \times 4.0 \times 10^3$<br>$= 0.95\,\text{m s}^{-2}$ | **A1** |