

|           |                                                                                             |
|-----------|---------------------------------------------------------------------------------------------|
| 3(a)      | force per unit mass                                                                         |
| 3(b)(i)   | $F = GMm / x^2$                                                                             |
|           | $g = F / m$                                                                                 |
|           | $g = [GMm / x^2] / m = GM / x^2$ <b>and</b> $G$ = gravitational constant                    |
| 3(b)(ii)  | arrow drawn at P pointing directly towards the point mass                                   |
| 3(b)(iii) | fields are in opposite directions                                                           |
|           | field strength at Q is four times the field strength at P                                   |
| 3(c)      | line starting at $(R, -g_0)$ and ending at $(L - R, +g_0)$                                  |
|           | line passing through $(L / 2, 0)$                                                           |
|           | curve becoming shallower from $R$ to $(L / 2)$ and then steeper from $(L / 2)$ to $(L - R)$ |

|          |                                                                                                                        |
|----------|------------------------------------------------------------------------------------------------------------------------|
| 1(a)     | work done per unit mass                                                                                                |
|          | work (done in) moving mass from infinity (to the point)                                                                |
| 1(b)(i)  | evidence of addition of $3.4 \times 10^6$ to $1.7 \times 10^6$ <b>or</b> $6.8 \times 10^6$                             |
|          | $GM \times 122 / (5.1 \times 10^6)$ <b>or</b> $GM \times 122 / (10.2 \times 10^6)$                                     |
|          | $6.67 \times 10^{-11} \times M \times 122 \times [(5.1 \times 10^6)^{-1} - (10.2 \times 10^6)^{-1}] = 5.1 \times 10^8$ |
|          | leading to $M = 6.4 \times 10^{23}$ kg                                                                                 |
| 1(b)(ii) | $\phi = (-) (6.67 \times 10^{-11} \times 6.4 \times 10^{23}) / (3.4 \times 10^6)$                                      |
|          | $= -1.3 \times 10^7 \text{ J kg}^{-1}$                                                                                 |
| 1(c)(i)  | Mars takes (just under) 25 hours to rotate once on its axis                                                            |
| 1(c)(ii) | orbit is equatorial<br><b>or</b><br>orbit is in same direction as direction of rotation of Mars                        |

|          |                                                                                                                    |
|----------|--------------------------------------------------------------------------------------------------------------------|
| 1(a)     | force per unit mass                                                                                                |
| 1(b)(i)  | radial                                                                                                             |
|          | towards (centre of) planet                                                                                         |
| 1(b)(ii) | (changes in) height (very) much smaller than radius                                                                |
|          | $(\text{radius} + \text{height})^2 \approx \text{radius}^2$<br><b>or</b><br>field lines are approximately parallel |
| 1(c)(i)  | $9.81 \times R^2 = 3.99 \times 10^{14}$                                                                            |
|          | $R = 6.38 \times 10^6 \text{ m}$                                                                                   |
| 1(c)(ii) | gravitational potential $= - (GM / R)$                                                                             |
|          | $= - (3.99 \times 10^{14}) / (6.38 \times 10^6)$                                                                   |
|          | $= - 6.25 \times 10^7 \text{ J kg}^{-1}$                                                                           |
| 1(d)     | potential (energy) zero at infinite separation                                                                     |
|          | (gravitational) force is attractive                                                                                |