A-Level Physics

Gravitational Fields

Mark Scheme

Time available: 77 minutes
Marks available: 61 marks

www.accesstuition.com

Mark schemes

1. (a) **G** has a greater mass than **H** with a reason ✓$_1$

because the null point is closer to **H** ✓$_2$

✓$_1$ The reason can be the second mark

OR

*Because the density of the field is greater around **G***

2

(b) The lines given tangential arrows that flow towards **G** and **H**. ✓

1

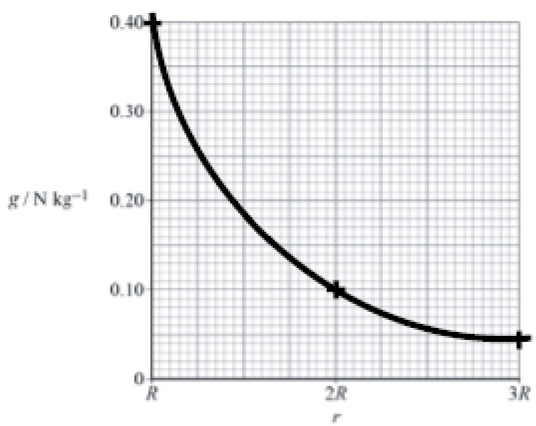
(c)

$$R = \left(\left\{\frac{GM}{g}\right\}^{1/2} = \left\{\frac{6.67\times10^{-11}\times2.0\times10^{20}}{0.40}\right\}^{1/2}\right) = 1.8\times10^{5}\text{ (m)} \checkmark$$

1

(d) Sketch must pass through coordinates (R, 0.40), ($2R$, 0.10) and ($3R$, 0.044) ✓

Must be within one small division of coordinates requested.



1

(e) The area underneath represents the energy/work needed (for an object) to move from R to $2R$ ✓

of 1 kg / unit mass ✓

If no mark is scored then award a single mark for saying:

Area represents the gravitational potential difference between R and $2R$

2

(f) Use of $F = \frac{GMm}{r^2}$ to find the force between **P** and **H** ✓$_1$

($F_{(PH)}$ = 1.8 × 10^{13} N)

(Calculation of the resultant force

$$F_{total} = \left(F_{(PH)}^2 + F_{(PG)}^2\right)^{1/2})$$

$$F_{total} = \left(\left\{1.8 \times 10^{13}\right\}^2 + \left\{6.4 \times 10^{12}\right\}^2\right)^{1/2} \checkmark_2$$

$$F_{total} = 1.9 \times 10^{13} \checkmark_3$$

Use of $a = \frac{F}{m} = \frac{1.9 \times 10^{13}}{2.0 \times 10^{20}} = 9.5 \times 10^{-8}$ (m s^{-2}) ✓$_4$

✓$_1$ $F_{(PH)} = \frac{6.67 \times 10^{-11} \times 3.0 \times 10^{25} \times 2.0 \times 10^{20}}{\left(1.5 \times 10^{11}\right)^2}$

✓$_2$ Mark is for the use of the equation allowing for ecf from candidate's force calculation.

✓$_3$ Correct answer only, no ecf

✓$_4$ Allow ecf from F_{total}

4

(g) The resultant force is not (centripetal and) directed towards the centre of **H**.
OR
A circular orbit does not follow a gravitational equipotential (owtte)
✓

The answer can focus on the conditions necessary for circular motion eg the need for a centripetal force.

Or

At different locations on a circular path the total gravitational potential energy is different which requires energy which is not provided.

1

[12]

2. (a) (centripetal) force = $m\, r\, (2\, \pi\, /\, T)^2$ Or m r $(\omega)^2$
(is given by the gravitational) force = $G\, m\, M\, /\, r^2$ ✓ (mark for both equations)
(equating both expressions and substituting for ω if required) T^2 = ($4\pi^2$ / GM) r^3 ✓ ($4\pi^2$ / GM is constant, the constants may be on either side of equation but T and r must be numerators)

First mark is for two equations (gravitational and centripetal)

The second mark is for combining.

2

(b) (use of $T^2 \propto r^3$ so $(T_P / T_E)^2 = (r_P / r_E)^3$)

$(T_P /1.00)^2 = (5.91 \times 10^9 /1.50 \times 10^8)^3$ ✓ (mark is for substitution of given data into any equation that corresponds to the proportional equation given above)

($T_P^2 = 61163$)

$T_P = 250$ (yr) ✓ (247 yr)

Answer only gains both marks

The calculation may be performed using data for the Sun in $T^2 = (4\pi^2 / GM)\, r^3$ easily spotted from $M_s = 1.99 \times 10^{30}$ kg giving a similar answer 247 – 252 yr.

2

(c) using $M (= g\, r^2 / G) = 0.617 \times (1.19 \times 10^6)^2 / 6.67 \times 10^{-11}$ ✓

$M = 1.31 \times 10^{22}$ kg ✓

answer to 3 sig fig ✓ (this mark stands alone)

The last mark may be given from an incorrect calculation but not lone wrong answer.

3

(d) Initial KE = ½ (m) $1400^2 = 9.8 \times 10^5$ (m) J✓

Energy needed to escape = 7.4×10^5 (m) J ✓

So sufficient energy to escape. ✓

OR For object on surface escape speed given by $7.4 \times 10^5 = \frac{1}{2} v^2$ ✓

escape speed = 1200 m s^{-1} ✓ (if correct equation is shown the previous mark is awarded without substitution)

So sufficient (initial) speed to escape. ✓

OR escape velocity = $\sqrt{\frac{2GM}{R}}$ substituting M from part (c) ✓

escape speed = 1200 m s^{-1} ✓ (1210 m s^{-1})

So sufficient (initial) speed to escape. ✓

OR escape velocity = $\sqrt{2Rg}$ substituting from data in (c) ✓

Third alternative may come from a CE from (c)

(1.06×10^{-8} × $(1.06 \times 10^{-8} \times \sqrt{\text{answer(c)}})$)

Conclusion must be explicit for third mark and cannot be awarded from a CE

3

[10]

3. (a) the work done per unit mass ✓

in moving from infinity to the point ✓

2

(b) Gravitational potential is defined as zero at ∞ ✓

(Forces attractive) so work must be done (on a mass) to reach ∞ (hence negative) ✓

2

(c) $V = -GM/r = 6.67 \times 10^{-11} \times 5.97\ 10^{24} / 6.37 \times 10^{6}$ ✓

$= -6.25 \times 10^{7}$ J kg^{-1} ✓

2

(d) in the plane of the equator

always above the same location on the earth

having the same period as the earth / 24 hours

✓✓any two lines

2

(e) $V = -GM/r = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / 4.23 \times 10^{7} = -9.41 \times 10^{6}$ J kg^{-1} ✓

$E_p = \Delta V \times m = = (6.26 - 0.94) \times 10^{7} \times 1200$ ✓

$= 6.38 \times 10^{10}$ J ✓

3

(f) radius must increase ✓

velocity gets smaller ✓

reference to R^3 is proportional to T^2 ✓

reference (from circular motion) v^2 is proportional to $1/r$ ✓

4

[15]

4. (a) Idea that both astronaut and vehicle are travelling at same (orbital) speed or have the same (centripetal) acceleration / are in freefall

Not falling at the same speed

B1

No (normal) reaction (between astronaut and vehicle)

B1

2

(b) (i) Equates centripetal force with gravitational force using appropriate formulae

E.g. $\frac{GMm}{r^2} = \frac{mv^2}{r}$ or $mr\omega^2$

B1

Correct substitution seen e.g. $v^2 = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{\text{any value of radius}}$

B1

(Radius of) 7.28×10^6 seen or $6.38 \times 10^6 + 0.9 \times 10^6$

B1

7396 (m s^{-1}) to at least 4 sf
Or $v^2 = 5.47 \times 10^7$ seen

B1

4

(ii) $\Delta PE = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 1.68 \times 10^{4} (1 / (7.28 \times 10^{6}) - 1 / (6.78 \times 10^{6}))$

C1

-6.8×10^{10} J

C1

$\Delta KE = 0.5 \times 1.68 \times 10^{4} \times (7700^2 - 7400^2) = 3.81 \times 10^{10}$ J

C1

$\Delta KE - \Delta PE = (-)\ 2.99 \times 10^{10}$ (J)

A1

OR

Total energy in original orbit shown to be $(-)GMm / 2r$
or $mv^2 / 2 - GMm / r$

C1

Initial energy
$= -6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 1.68 \times 10^{4} / (2 \times 7.28 \times 10^{6})$
$= 4.59 \times 10^{11}$

C1

Final energy
$= -6.67 \times 10^{-11} \times 5.97 \times 10^{24} \times 1.68 \times 10^{4} / (2 \times 6.78 \times 10^{6})$
$= 4.93 \times 10^{11}$

3.4×10^{10}(J)

Condone power of 10 error for C marks

A1

4

[10]

5. (a) (i) Use of $F - GMm/r^2$

C1

Allow 1 for
-correct formula quoted but forgetting square in substitution

Correct substitution of data

M1

-missing m in substitution

491 (490)N

A1

-substutution with incorrect powers of 10

Condone 492 N,

(ii) Up and down vectors shown (arrows at end) with labels

B1

allow W, mg (not gravity); R
allow if slightly out of line / two vectors shown at feet

up and down arrows of equal lengths

B1

condone if colinear but not shown acting on body

In relation to surface W ≤ R (by eye) to allow for weight vector starting in middle of the body

Must be colinear unless two arrows shown in which case R vectors ½ W vector(by eye)

(b) (i) Speed = $2\pi r / T$

B1

Max 2 if not easy to follow

$2\pi 6370000 / (24 \times 60 \times 60)$

B1

463 m s^{-1}

B1

Must be 3sf or more

(ii) Use of $F = mv^2/r$

C1

Allow 1 for use of $F = mr\omega^2$ with ω= 460

1.7 (1.66 – 1.68) N

A1

(iii) Correct direction shown
(Perpendicular to and toward the axis of rotation)
NB – not towards the centre of the earth

B1

(c) Force on scales decreases / apparent weight decreases
Appreciates scale reading = reaction force

C1

The reading would become 489 (489.3)N or reduced by 1.7 N)

A1

Some of the gravitational force provides the necessary centripetal force

B1

or $R = mg – mv^2/r$

[14]