Cambridge Assessment International Education

Interactive

Interactive Example Candidate Responses Paper 4 (May/June 2016), Question 1

Cambridge International AS & A Level Physics 9702

Version 1.0

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1 A binary star consists of two stars A and B that orbit one another, as illustrated in Fig. 1.1.

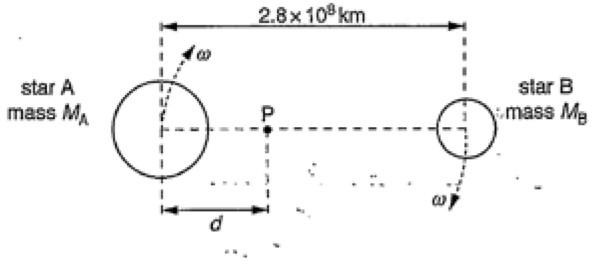

Fig. 1.1

The stars are in circular orbits with the centres of both orbits at point P, a distance *d* from the centre of star A.

(a) (i) Explain why the centripetal force acting on both stars has the same magnitude.

Because the centripetal force acting on both stars are provided by the gravitational force $F_G = \frac{G M_A M_B}{r^2} = m\omega^2 r = m\left(\frac{2\pi}{T}\right)^2 r$ The angular velocity ω and period T of both stars are the same. So the centripetal force (and gravitational forces) for both stars are the same. [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed ω of the stars.

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{4 \times 365 \times 24 \times 3600}$$

$$= 4.98 \times 10^{-8} \text{ rads}^{-1}$$

ω = 4.98×10^{-8} rads^{-1} [2]

Your Mark

1(a)(i)

1(a)(ii)

1(b)(i)

1(b)(ii)

Q1	Mark scheme		
(a)(i)	gravitational force provides/is the centripetal force	B1	
	same gravitational force (by Newton III)	B1	[2]
(a)(ii)	$\omega = 2\pi / T$		
	$= 2\pi / (4.0 \times 365 \times 24 \times 3600)$	C1	
	$= 5.0\ (4.98) \times 10^{-8}$ rad s^{-1}	A1	[2]
(b)(i)	(centripetal force =) $M_A d\omega^2 = M_B(2.8 \times 10^8 - d)\omega^2$ **or**		
	$M_A d_A = M_B dB$	C1	
	$M_A / M_B = 3.0 = (2.8 \times 10^8 - d) / d$	C1	
	$d = 7.0 \times 10^7$ km	A1	[3]
(b)(ii)	$GM_AM_B / (2.8 \times 10^{11})2 = M_A d\omega^2$	B1	
	$M_B = (2.8 \times 10^{11})^2 \times d\omega^2 / G$		
	$= (2.8 \times 10^{11})^2 \times (7.0 \times 10^{10}) \times (4.98 \times 10^{-8})^2 / (6.67 \times 10^{-11})$	C1	
	$= 2.0 \times 10^{29}$ kg	A1	[3]
			[Total: 10]

(b) The separation of the centres of the stars is 2.8 × 10⁸ km.
The mass of star A is M_A. The mass of star B is M_B.

The ratio $\frac{M_A}{M_B}$ is 3.0.

(i) Determine the distance *d*.

$\because \omega, T, F_c$ are the same for A and B

$\therefore M_A \cancel{\omega^2} d = M_B \cancel{\omega^2} (2.8 \times 10^8 - d)$

$\therefore \frac{M_A}{M_B} = \frac{2.8 \times 10^8 - d}{d} = 3$

$\therefore d = \cancel{7 \times 10}\ 7.0 \times 10^7$ km

d = ...7.0 × 10⁷.... km [3]

(ii) Use your answers in (a)(ii) and (b)(i) to determine the mass M_B of star B. Explain your working.

~~MA/MB = 3~~ ∴ ~~MB = MA/3~~ ~~MA = 3MB~~

~~(7×10⁷) MA~~ ~~3MB×(7×10⁷) = MB×(2.8×10⁸ − 7×10⁷)~~

~~ℓ = dA + dB~~ → ~~dB = ℓ − dA~~ dA = ℓ − dB

~~MA · dA = MB · dB~~

~~MA dA = M~~

~~MA (ℓ − dB) = MB · dB~~

~~MB = MA(ℓ − dB) / dB~~

$\because \frac{M_A}{M_B} = 3 \quad \therefore \cancel{M_B =}\ M_A = 3M_B$

$\therefore G \frac{3M_B \cdot \cancel{M_B}}{\ell^2} = \cancel{M_B}\ \omega^2 \ell$

$6.67 \times 10^{-11} \times \frac{3M_B}{(2.8 \times 10^8 \times 10^3)^2} = (4.98 \times 10^{-8})^2 \times (2.8 \times 10^8 \times 10^3 - 7 \times 10^7)$

$M_B = 2.72 \times 10^{29}$ kg

M_B = ...2.72 × 10²⁹.... kg [3]

[Total: 10]

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Your Mark

1(a)(i)

1(a)(ii)

1(b)(i)

1(b)(ii)

Q1	Mark scheme		
(a)(i)	gravitational force provides/is the centripetal force	B1	
	same gravitational force (by Newton III)	B1	**[2]**
(a)(ii)	$\omega = 2\pi / T$		
	$= 2\pi / (4.0 \times 365 \times 24 \times 3600)$	C1	
	$= 5.0\ (4.98) \times 10^{-8}$ rad s^{-1}	A1	**[2]**
(b)(i)	(centripetal force =) $M_A d\omega^2 = M_B(2.8 \times 10^8 - d)\omega^2$		
	or		
	$M_A d_A = M_B dB$	C1	
	$M_A / M_B = 3.0 = (2.8 \times 10^8 - d) / d$	C1	
	$d = 7.0 \times 10^7$ km	A1	**[3]**
(b)(ii)	$GM_A M_B / (2.8 \times 10^{11})2 = M_A d\omega^2$	B1	
	$M_B = (2.8 \times 10^{11})^2 \times d\omega^2 / G$		
	$= (2.8 \times 10^{11})^2 \times (7.0 \times 10^{10}) \times (4.98 \times 10^{-8})^2 / (6.67 \times 10^{-11})$	C1	
	$= 2.0 \times 10^{29}$ kg	A1	**[3]**
			[Total: 10]

EXAMINER COMMENTS

MARK SCHEME

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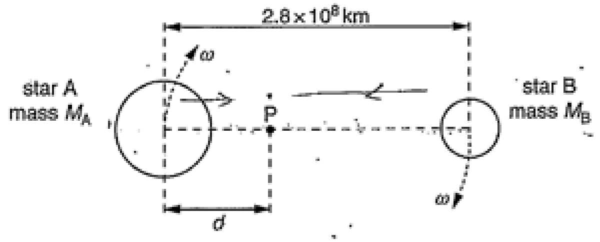

$m r \omega^2$

$\frac{mv^2}{r}$ $mv\omega$

$F_c = ma$

Fig. 1.1

The stars are in circular orbits with the centres of both orbits at point P, a distance d from the centre of star A.

(a) (i) Explain why the centripetal force acting on both stars has the same magnitude.

Both stars have same angular speed ~~and acceleration~~. They act as point masses so mass has negligible effect on force. [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed ω of the stars.

$$\omega = \theta/T = \frac{2\pi}{T} = \frac{2\pi}{T} = 2\pi f = \frac{2\pi}{4 \times 365 \times 24 \times 3600}$$

rad

$$= 4.98 \times 10^{-8}$$

ω = 4.98 × 10⁻⁸ rad s⁻¹ [2]

Your Mark

1(a)(i)

1(a)(ii)

1(b)(i)

1(b)(ii)

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EXAMINER COMMENTS

MARK SCHEME

(b) The separation of the centres of the stars is 2.8×10^8 km.
The mass of star A is M_A. The mass of star B is M_B.
The ratio $\frac{M_A}{M_B}$ is 3.0.

Fc force.

(i) Determine the distance *d*.

$M_A \times d \times \omega^2 = M_B \times (2.8 \times 10^8 - d)\ \omega^2$

$\frac{M_A}{M_B} \times d \times \cancel{\omega^2} = (2.8 \times 10^8 - d)\ \cancel{\omega^2}$

$3 \times d = 2.8 \times 10^8 - d$

$3d + d = 2.8 \times 10^8$

7.0×10^7 km

d = 7.0×10^7 km [3]

(ii) Use your answers in **(a)(ii)** and **(b)(i)** to determine the mass M_B of star B. Explain your working.

$F_c = mr\omega^2$. $r = 2.1 \times 10^8$ km.

$mr\omega^2 = \frac{GMA}{r^2}$

$(7.0 \times 10^7) \times (4.98 \times 10^{-8})^2 = \frac{(6.67 \times 10^{-11})(M_A)}{(7.0 \times 10^7)^2}$

2602.7
2600 2.6×10^3 kg.

$\frac{M_A}{M_B} = 3$

M_B = 8.7×10^2 kg [3]

$\frac{(2.6 \times 10^3)}{3} = M_B$. 870

[Total: 10]

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Your Mark

1(a)(i)

1(a)(ii)

1(b)(i)

1(b)(ii)

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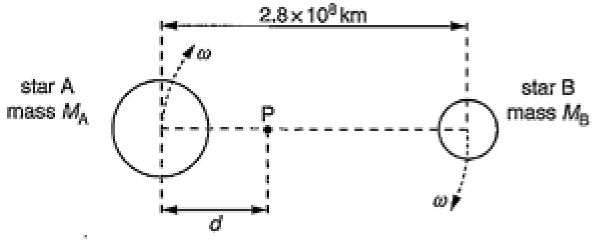

Fig. 1.1

The stars are in circular orbits with the centres of both orbits at point P, a distance *d* from the centre of star A.

(a) (i) Explain why the centripetal force acting on both stars has the same magnitude.

The ~~forces~~ Torque of on both stars are a couple. The ~~force~~ of torque is equal to the centripetal force ~~which~~ is. The torque forces = force on ~~each~~ one × the distance between them, which are same. [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed *ω* of the stars.

$\omega = \frac{2\pi}{T}$ $T = 4 \times 365 \times 24 \times 60 \times 60$

$= \frac{2\pi}{126144000}$ $= 126144000$ s

$= 4.98 \times 10^{-8}$

$= 6.0 \times 10^{-8}$

ω = ...5.0 × 10⁻⁸...... rad s⁻¹ [2]

Your Mark

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1(a)(ii)

1(b)(i)

1(b)(ii)

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EXAMINER COMMENTS

MARK SCHEME

(b) The separation of the centres of the stars is 2.8×10^{8} km.
The mass of star A is M_A. The mass of star B is M_B.

The ratio $\frac{M_A}{M_B}$ is 3.0.

(i) Determine the distance d.

$\frac{GMm}{r} = F \times d$

$\frac{M_A}{r^2} = \frac{M_B}{r^2}$

$3 = (2.8\times10^{8})^2$

$\frac{M_A}{M_B} = \frac{r^2}{r^2}$

d = ...1.6 × 10^8.... km [3]

(ii) Use your answers in (a)(ii) and (b)(i) to determine the mass M_B of star B.
Explain your working.

$F = m\omega^2 r$

$m = \frac{F}{\omega^2 r} = \frac{F}{(5.0\times10^{-8})^2 \times 1.6\times10^{8}}$

$= \frac{F}{4\times10^{-7}}$

$F = m\omega^2 r$

$m = \frac{F}{(5.0\times10^{-8})^2\times1.6\times10^{8}}$

M_B = ...$\frac{F}{4\times10^{-7}}$.... kg [3]

[Total: 10]

Select page

HIGH MIDDLE LOW

Your Mark

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EXAMINER COMMENTS

MARK SCHEME

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