

## Mark schemes

1

- (a) bright (or dark) fringe is seen where the two beams are in phase  
(or out of phase by  $180^\circ$ ) ✓

changing the distance to either mirror changes the path (or phase) difference  
(between the two beams) so fringes shift ✓

2

- (b) (i) speed of light was thought to depend on the speed of the light source  
(or the speed of the observer) ✓ (or on the motion of the Earth  
(through the aether))

distance travelled by each beam unchanged (by rotation) ✓

time difference between the two beams would change on rotation ✓

phase difference would therefore change (so fringes would shift) ✓

3

- (ii) speed of light is independent of the speed (or motion) of the light source  
(or the observer) ✓

(or 'aether' hypothesis incorrect (owtte)) or absolute motion does not exist)

1

[6]

2

- (a) They expected the time taken for the light to travel in one direction to be different from the other ✓

or

Expected light to travel at different speeds in the two directions

*However expressed e.g. in terms of the different times taken  
parallel and at right angles to the Earth's motion (through the  
Aether)*

There would be a phase shift / change in the phase relationship

*Not*

*longer / different paths*

*or*

*path difference*

2

- (b) (i) Speed through aether

$$= \frac{\text{circumference of Earth orbit around the Sun}}{\text{time for one orbit (1 year)}}$$

*Need to be clear about the distance and time*

or  $v = (GM/r)^{1/2}$  with  $M$  and  $r$  defined

*Watch out for confusion between Earth's orbit around the Sun and Earth's rotation on its axis*

1

- (ii) 11 m

1

- (c) Experiment showed speed of light from moving object is same as that from stationary object or

Speed of light in direction of motion is same as in perpendicular direction or

Speed of light does not depend on speed of source or observer

Speed of light being invariant

or

Aether theory incorrect / no aether / no absolute motion

*Allow is always  $3 \times 10^8 \text{ m s}^{-1}$  in air or vacuum instead of invariant*

It was a postulate / assumption of the theory of special relativity

Or this supports the theory ✓

*Second mark is for explicitly linking the observation to Einstein's theory*

2

[6]

3

- (a) (i) two beams (or rays) reach the observer **(1)**  
interference takes place between the two beams **(1)**  
bright fringe formed if/where (optical) path difference =  
whole number of wavelengths  
(or two beams in phase)  
[or dark fringe formed if/where (optical) path difference =  
whole number + 0.5 wavelengths]  
(or two beams out of phase by  $180^\circ$  /  $\pi/2$  /  $1/2$  cycle) **(1)**

- (ii) rotation by  $90^\circ$  realigns beams relative to direction of Earth's motion **(1)**  
no shift means no change in optical path difference between the two beams **(1)**  
( $\therefore$ ) time taken by light to travel to each mirror unchanged by rotation **(1)**  
distance to mirrors is unchanged by rotation **(1)**  
( $\therefore$ ) no shift means that the speed of light is unaffected [or disproves other theory] **(1)**

max 5

- (b) the speed of light does not depend on the motion of the light source **(1)** or that of the observer **(1)**

2

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4

- (a) (i) beam splitter [or semi-silvered mirror] **(1)**  
 (ii) a compensator [or a glass block] **(1)**  
 allows for the thickness of the (semi-silvered) mirror to obtain equal optical path lengths in the two branches of the apparatus) **(1)**

3

- (b) (i) concentric rings **(1)**  
 an interference pattern **(1)**

[*alt.* whole view shows one shade **(1)** because there is a constant phase difference**(1)**]

- (ii) fringes [or rings] shift **(1)**  
 $0.5\lambda$  extra for  $l_1$  gives one complete fringe shift  
 [or fraction of wavelength extra causes noticeable fringe shift or noticeable change of intensity (if uniform)] **(1)**

4

- (c) (i) rotate apparatus through  $90^\circ$  **(1)**  
 observe the fringes at the same time **(1)**  
 observed fringes did not change [or shift] **(1)**  
 (ii) speed of light in free space is invariant  
 [or does not depend on motion of source or observer or no evidence for absolute motion] **(1)**

max 3

[10]

5

- (a) no change in the fringe pattern on rotation **(1)**  
 the speed of light is the same in the two directions **(1)**  
 the speed of light from a light source on Earth is  
 unaffected by the motion of the Earth **(1)**  
 [or the speed of light is invariant  
 or independent of the motion of the source or observer] **(1)**  
 the laws of dynamics cannot be applied to light **(1)**  
 no ether **(1)**

(max 3)

(b) (i)  $\text{time} \left( = \frac{\text{distance}}{\text{speed}} = \frac{16cT_{\text{one year}}}{0.8c} \right) = 20 \text{ yr (1)}$

(ii)  $L_0 = 16c$  [or 16 light years] (1)

$$L \left( = L_0 \left( 1 - \frac{v^2}{c^2} \right)^{\frac{1}{2}} \right) = 16(1 - 0.8^2)^{\frac{1}{2}} (= 0.6 \times 16c) = 9.6c \text{ (1)}$$

(iii)  $\Delta t = 20 \text{ years (1)}$

$$\Delta t_0 = \Delta t \left( 1 - \frac{v^2}{c^2} \right)^{\frac{1}{2}} = 20(1 - 0.8^2)^{\frac{1}{2}} \text{ (1)}$$

$$= 0.6 \times 20 = 12 \text{ yr} \therefore \text{age} = 21 + 12 = 33 \text{ yr (1)}$$

(6)

**[9]**