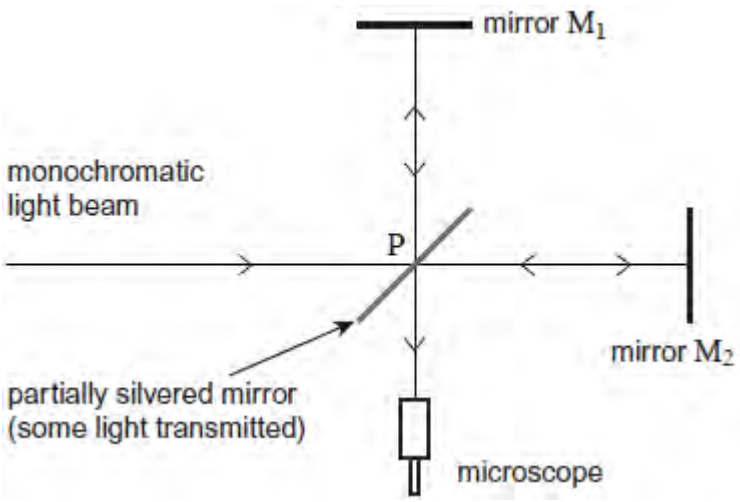
Q1. The diagram shows the paths of light rays through a simplified version of the apparatus used by Michelson and Morley.



In the apparatus, light waves reflected by the mirrors M_1 and M_2, meet at P so that they superpose and produce interference fringes. These are observed using the microscope.

Michelson and Morley predicted that the fringes would shift when the apparatus was rotated through 90°. They thought that this shift would enable them to measure the speed of the Earth through a substance, called the aether, that was thought to fill space.

(a) Explain why Michelson and Morley expected that the fringe positions would shift when the apparatus was rotated through 90°.

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(2)

(b) In their apparatus they made the distances PM_1 and PM_2 the same and equal to d. They used light of wavelength (λ) about 550 nm and knew that the speed of light c was 3.0×10^8 m s^{-1}. Using known astronomical data, they calculated the speed v at which they thought the Earth moved through the aether. They were then able to predict that when the apparatus was rotated through 90° the fringes should shift by a distance $0.4f$, where f was the fringe spacing.

(i) To determine v, Michelson and Morley assumed that the Sun was stationary

with respect to the aether as the Earth moved through it.
Suggest, using this assumption, how the speed v of the Earth through the aether could be determined. You do not need to do the calculation.

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(1)

(ii) Michelson and Morley calculated v to be 3.0×10^4 m s^{-1}.
They worked out Δf, the magnitude of the expected shift of the fringes, using the

formula $\Delta f = \frac{2v^2 d}{c^2 \lambda} f$.

Calculate the distance d they used in their experiment.

d = ... m

(1)

(c) Although a shift of 0.4 f was easily detectable, no shift was observed. Explain what this null result demonstrated and its significance for Einstein in his special theory of relativity.

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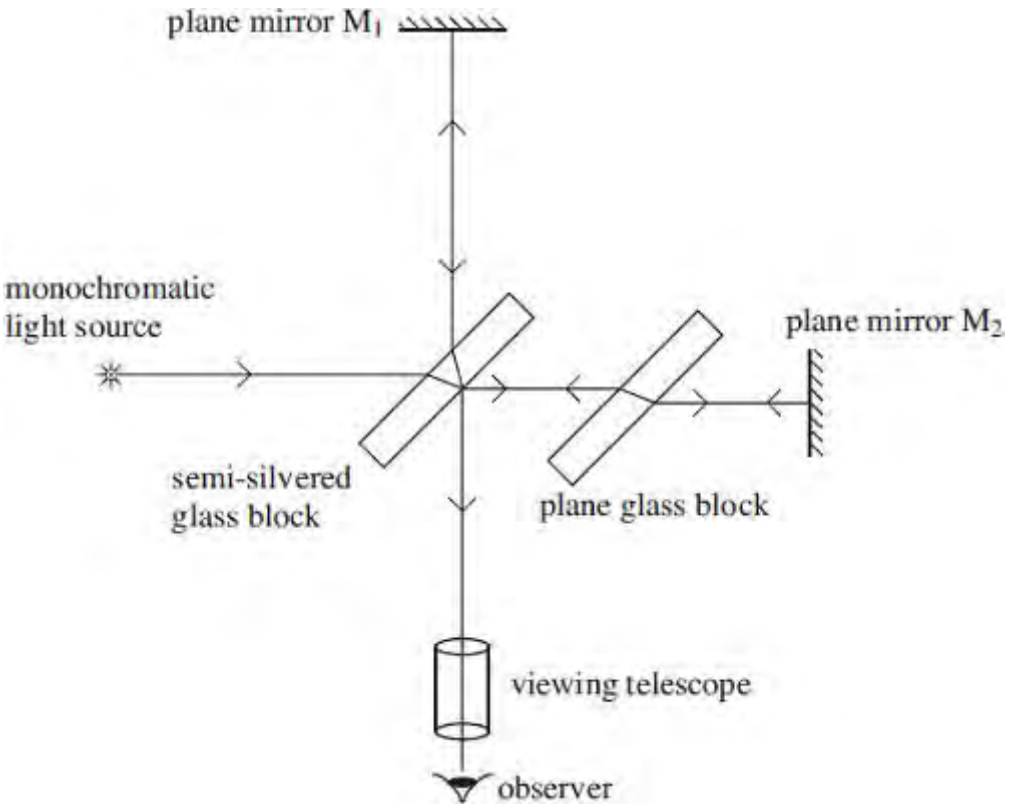
(2)
(Total 6 marks)

Q2. The figure below represents the Michelson-Morley interferometer. Interference fringes are seen by an observer looking through the viewing telescope.



(a) Explain why the interference fringes shift their position if the distance from either of the two mirrors to the semi-silvered block is changed.

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(2)

(b) Michelson and Morley predicted that the interference fringes would shift when the apparatus was rotated through 90°. When they tested their prediction, no such fringe

shift was observed.

(i) Why was it predicted that a shift of the fringes would be observed?

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(ii) What conclusion was drawn from the observation that the fringes did not shift?

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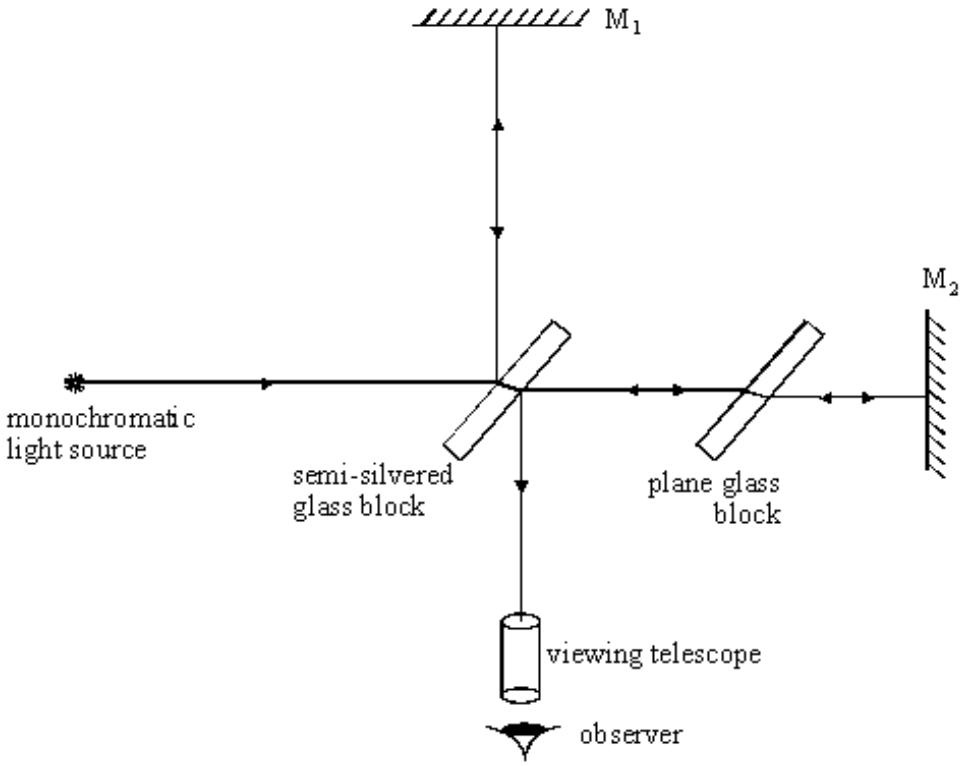
(1)
(Total 6 marks)

Q3. The Michelson-Morley experiment represented in the diagram was designed to find out if the speed of light depended on its direction relative to the Earth's motion through space. Interference fringes were seen by the observer.



(a) (i) Explain why interference fringes were seen.

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(ii) The interference fringe pattern did not shift when the apparatus was rotated by 90°. Explain the significance of this null observation.

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(5)

(b) Einstein postulated that the speed of light in free space is invariant. Explain what is meant by this postulate.

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(2)
(Total 7 marks)

Q4.(a) Michelson and Morley attempted to detect absolute motion by investigating whether or not the speed of light in a direction parallel to the Earth's motion differs from the speed of light perpendicular to the Earth's motion.

Discuss what resulted from this experiment and what was concluded.

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(3)

(b) In a science fiction story, a space rocket left the Earth in 2066 and travelled out of the Solar System at a speed of $0.80c$, where c is the speed of light in vacuo, to a star 16 light years from the Earth.

(i) How many years, in the frame of reference of the Earth, did the spacecraft take to reach the star?

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(ii) What was the distance, in the frame of reference of the spacecraft, between the Earth and the star?

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(iii) A member of the crew was 21 years old on leaving the Earth. How old was this person on arrival at the star?

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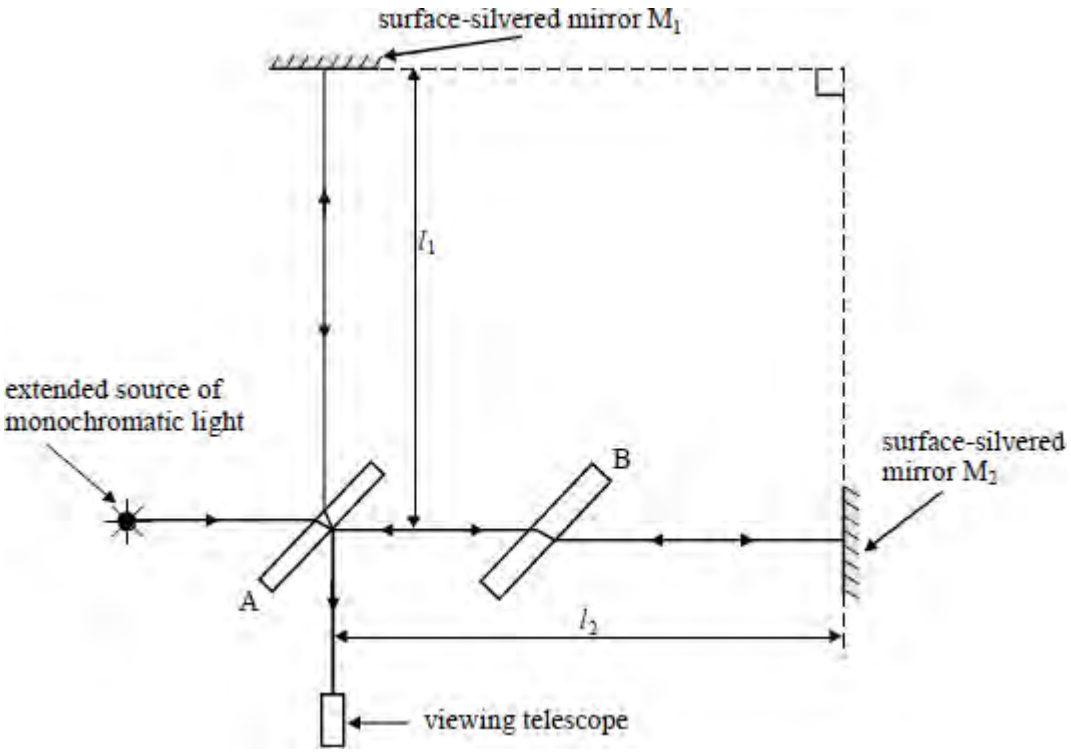
(6)
(Total 9 marks)

Q5. The diagram represents the Michelson-Morley interferometer.



(a) (i) Name the object labelled A.

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(ii) Name the object labelled B and explain its purpose.

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(3)

(b) Describe and explain what is observed through the viewing telescope

(i) when distances l_1 and l_2 are equal.

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(ii) as distance l_1 is made slightly longer than distance l_2.

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(4)

(c) Michelson and Morley used the interferometer to try to detect the motion of the Earth through the hypothetical ether.

(i) Outline how the apparatus was used and state what the result was.

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(ii) Explain the significance of the result.

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(3)
(Total 10 marks)