InkPhysics

QUESTION WORKBOOK

The Michelson-Morley experiment

Turning points · Year 13

AQA 3.12.3.1, 3.12.3.2

17 questions · 49 marks

NAVY SCREEN EDITION

SECTION A · Warm-up

A1 Describe the principle of the Michelson interferometer. [2]

A2 State the two postulates of Einstein's theory of special relativity. [2]

A3 State what is meant by an inertial frame of reference. [2]

A4 Explain why nineteenth-century physicists expected light to require a medium, the ether. [2]

A5 State what the Michelson-Morley experiment was designed to detect. [1]

SECTION B · Standard

B1 A boat travels at 4.0 m s^{-1} in still water on a river flowing at 2.4 m s^{-1}. Calculate the round-trip times for 48 m straight across and back, and 48 m downstream and back, and state the relevance to the Michelson-Morley experiment. [4]

B2 For an effective arm length of 11 m and an ether wind equal to the Earth's orbital speed of 3.0×10^4 m s^{-1}, the expected time difference is roughly $\Delta t \approx (L/c)(v^2/c^2)$. Evaluate Δt and the corresponding path difference. [3]

B3 Explain why the apparatus was rotated through 90° during the experiment. [3]

B4 The experiment was repeated at different times of year. Explain why this mattered. [3]

B5 The interferometer was mounted on a massive stone block floated on liquid mercury. Suggest why. [2]

B6 State and explain whether each of the following is an inertial frame of reference: (a) a train travelling at a steady 55 m s^{-1} on a straight track; (b) a car rounding a bend at constant speed; (c) a rocket accelerating uniformly upwards. [3]

SECTION C · Stretch

C1 State and explain the two conclusions drawn from the failure of the Michelson-Morley experiment to detect any fringe shift. [4]

C2 A spacecraft approaching Earth at 0.40c switches on a landing light. Using the second postulate, state the speed at which the light arrives at Earth, and explain why the everyday rule for adding velocities fails here. [3]

C3 Explain why the Michelson-Morley result, though "null", is counted among the most important measurements in physics. [2]

C4 Michelson's first interferometer of 1881 had an effective arm length of only 1.2 m and could just detect a path-difference change of 0.05 wavelengths of the light used ($\lambda = 5.5 \times 10^{-7}$ m). The expected time difference from an ether wind of $v = 3.0 \times 10^{4}$ m s^{-1} is $\Delta t \approx (L/c)(v^2/c^2)$, with $c = 3.0 \times 10^{8}$ m s^{-1}. Deduce whether this first instrument could have detected the ether wind, and hence suggest why the 1887 apparatus used repeated reflections to give an 11 m effective arm. [5]

C5 Every other wave known in 1887 travelled through a material medium. Explain how an electromagnetic wave is able to travel through empty space. [2]

C6 Describe the Michelson-Morley experiment and explain the significance of its result. Your answer should include the principle of the interferometer, the reason the apparatus was rotated, and the conclusions drawn. [6]