BINDURA UNIVERSITY OF SCIENCE EDUCATION

Faculty of Science Education

Department of Mathematics and Science Education

Diploma in Science Education (Physics)

NOV 2024

DP004

Optics and Waves Motion

Duration: Three (3) Hours

100 MARKS

INTSRUCTIONS

- *Answer ALL questions in Section A and any THREE questions from Section B. Section A carries 40 marks and each question of Section B carries 20 marks.*
- *Show formulae and substitutions in ALL calculations.*

You may not start to read the questions printed on the subsequent pages until instructed to do so by the Invigilator.

SECTION A (40 Marks)

QUESTION 1 [40 MARKS]

a) Derive the relation between the velocity of a wave, its wavelength and frequency. Hence use it to calculate the wavelength of light traveling through water at $2.25 \times 10^8 ms^{-1}$ and whose frequency is $4.0 \times 10^{14} Hz$. (7)

b) Find the wavelength (in nanometers) of a photon with energy $2.88 \times 10^{-19} J$. (5)

c) An ambulance is moving towards a stationary listener at a constant speed of 30 $m \cdot s^{-1}$. The siren of the ambulance emits sound waves having a wavelength of 0,28 m. Take the speed of sound in air as 340 $m \cdot s^{-1}$.

i) State the Doppler effect as applied to sound. (2)

ii) Calculate the frequency of the sound waves emitted by the siren as heard by the ambulance driver. (3)

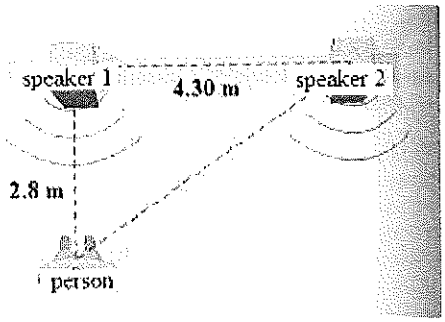
iii) Calculate the frequency of the sound waves emitted by the siren as heard by the listener. (5)

iv) How would the frequency change if the speed of the ambulance were LESS THAN 30 $m \cdot s^{-1}$? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

v) An observation of the spectrum of a distant star shows that it is moving away from the Earth. Explain, in terms of the frequencies of the spectral lines, how it is possible to conclude that the star is moving away from the Earth. (2)

d) Briefly explain how a telephone conversation can be transmitted using optical fibres and state the main advantages of this system over the conventional copper cables. Use a well labelled diagram of an optical fibre to support your answer (5)

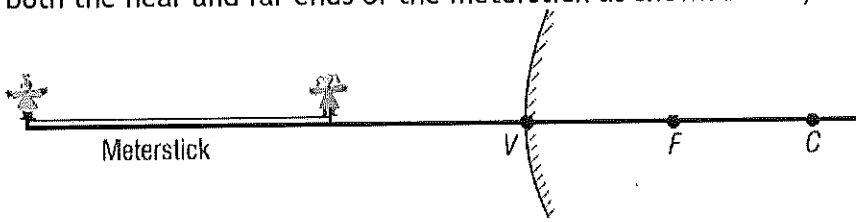
e) An interesting case on applying path difference to determine whether the type of interference is: Two speakers separated by a distance of $4.30m$ (Refer to the diagram below) emit sound of frequency $221Hz$. The speakers are in phase with one another. A person listens from a location $2.8m$ directly in front of one of the speakers. Does the person hear constructive or destructive interference? Justify your answer. (10)



SECTION B (60 Marks)

QUESTION 2 [20 MARKS]

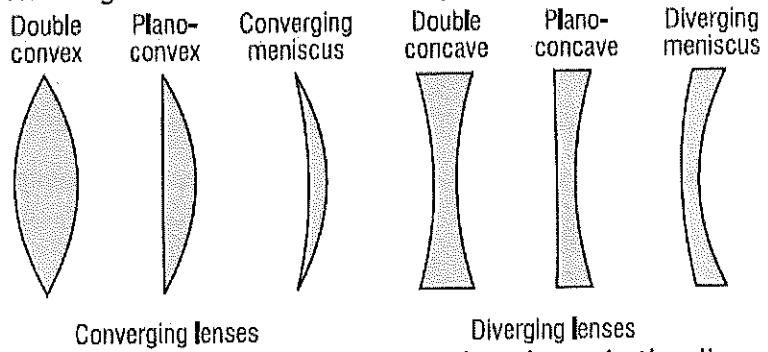
A meter stick lies along the optical axis of a convex mirror of focal length 40 cm, with its near end 60cm from the mirror surface. Five-centimeter toy figures stand erect on both the near and far ends of the meterstick as shown below;



i) How long is the virtual image of the meterstick? (10)
ii) How tall are the toy figures in the image, and are they erect or inverted? (10)

QUESTION 3 [20 MARKS]

The diagram below shows the shapes of common thin lenses

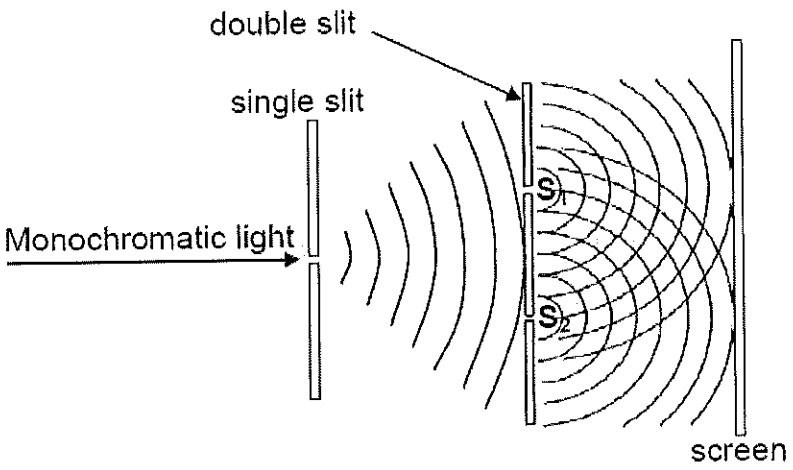


A double-convex thin lens such as that shown in the diagram above can be used as a simple "magnifier." It has a front surface with a radius of curvature of 20 cm and a rear surface with a radius of curvature of 15 cm. The lens material has a refractive index of 1.52. Answer the following questions to learn more about this simple magnifying lens.

a) What is its focal length in air? (7)
b) What is its focal length in water (n = 1.33)? (4)
c) Does it matter which lens face is turned toward the light? (3)
d) How far would you hold an index card from this lens to form a sharp image of the sun on the card? (2)
e) Draw a ray diagram for the double-convex lens (4)

QUESTION 4 [20 MARKS]

The diagram below shows monochromatic light that first passes through a single slit and then through a double slit. An interference pattern is observed on the screen.



a) Briefly explain why a double slit is used instead of two separate light sources in the above arrangement? (2)

b) The width of the two slits S1 and S2 and the distance between the slits are kept constant. How will the width of the bands in the interference pattern change if: (Write down only INCREASES, DECREASES or REMAINS THE SAME.). Give a reason for each of your answers

i) Light of longer wavelength is used (3)

ii) Light of higher frequency is used (3)

iii) The distance between the slits and screen is increased for a given frequency of light (3)

The double slit is now removed and the light passes through the single slit only.

c) Describe the pattern that will be observed on the screen when the light passes through the single slit. (2)

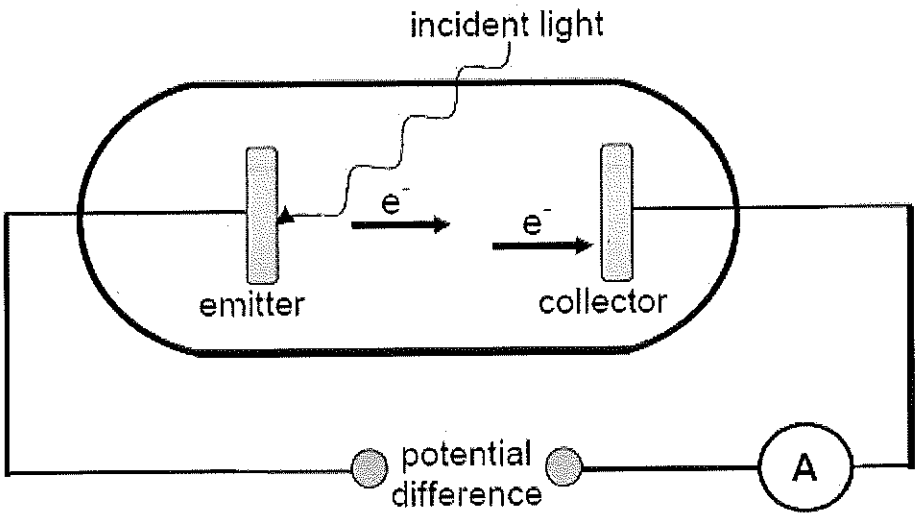
d) When light of wavelength 450 nm passes through the single slit, the FOURTH minimum occurs at an angle of 25°. Calculate the width of the single slit. (5)

One can hear sounds around the corners of a doorway, but cannot see around the corners.

e) Use your knowledge of diffraction to explain this observation. (2)

QUESTION 5 [20 MARKS]

The apparatus below is used to demonstrate the photoelectric effect.



a) Define the term 'photoelectric effect'. Give an example of its practical application and briefly describe how it works. (5)

b) The incident monochromatic light transfers 1,8 x 10-9 J of energy in one second to a certain area of the emitter. The wavelength of a photon in the incident light is 260 nm. If one photon releases one electron, calculate the:

i) Number of electrons released from the surface of that area of the emitter in one second (5)

ii) Current produced, in amperes (4)

c) The sketch below shows an example of a line emission spectrum.

i) Briefly explain how this type of spectrum is formed by referring to electron transitions in atoms. (2)

ii) One interesting application of the emission spectra is to measure stellar temperatures. Briefly discuss how this is done (4)

THE END

Some useful constants and formulae

Planck's constant,	$h = 6.63 \times 10^{-34} Js$
Speed of light,	$c = 3 \times 10^{8} 8\, ms^{-1}$
Speed of sound in air	$v = 3 \times 10^{8} 8\, ms^{-1}$
Charge of an electron	$e = -1.6 \times 10^{-19} C$

$v = f\lambda$ $\quad f_o = \frac{v \pm v_o}{v \pm v_s} f_s$ $\quad E = hf$ $\quad E = W_o + E_{k(\max)}$