OFFICE OF THE DEPUTY VICE CHANCELLOR
ACADEMIC, RESEARCH AND STUDENT AFFAIRS

UNIVERSITY EXAMINATIONS

2023 /2024 ACADEMIC YEAR

FIRST YEAR SECOND SEMESTER REGULAR MAIN EXAMINATION

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: **PHY 121**

COURSE TITLE: **GEOMETRIC OPTICS**

DATE: 23RD, APRIL, 2024 **TIME: 2 PM – 5 PM**

INSTRUCTION TO CANDIDATES

- **SEE INSIDE**

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REGULAR – MAIN EXAM

PHY 121: GEOMETRIC OPTICS

STREAM: Bed Sc. **DURATION: 3 Hours**

INSTRUCTIONS TO CANDIDATES

i. *Answer Question **ONE** and **TWO** in **SECTION A** and any other **THREE** questions in **SECTION B**.*

ii. *Where necessary the following constants maybe used:*

Refractive index of air=1
Refractive index of water = 1.33
Refractive index of glass = 1.5
Velocity of light in vacuum/air $= 3 \times 10^8\, m/s$

SECTION A (24 MARKS)

Question One (12 Marks)

a)

(i) State the conditions that must be fulfilled in order for total internal reflection to occur. (2 Marks)

(ii) A glass optical fiber ($n = 1.50$) is submerged in water ($n = 133$). What is the critical angle for light to stay inside the fiber? (1 Mark)

b) A ray of light traveling in water is incident on an interface with a flat piece of glass. The wavelength of the light in the water is 726 nm and its wavelength in the glass is 544 nm. If the ray in water makes an angle of 42° with respect to the normal to the interface, what angle does the refracted ray in the glass make with respect to the normal? (2 Marks)

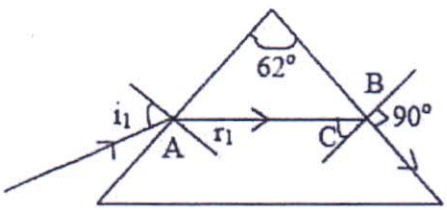
c) A concave spherical mirror has a radius of curvature of magnitude 24.0 cm.

(i) Determine the object position for which the resulting image is upright and larger than the object by a factor of 3.00. (2 Marks)

(ii) Draw a ray diagram to determine the position of the image and determine if the image real or virtual? (1 Mark)

d) An object of height 2.00 cm is placed 30.0 cm from a convex spherical mirror of focal length of magnitude 10.0 cm. (a) Find the position and height of the image. (2 Marks)

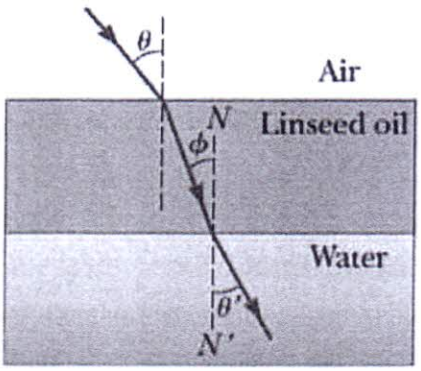
e) The refracting angle of a prism is 62° and the refractive index of the glass for yellow light is 1.65. What is the smallest possible angle of incidence of a ray of this yellow light which is transmitted without total reflection? (2 Marks)



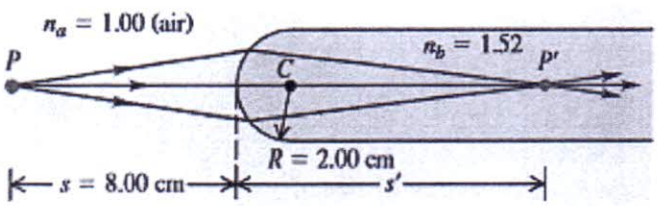
Question Two (12 Marks)

a) Two thin lenses of focal length +9.0cm and -6.0cm are placed in contact. Calculate focal length of the combination. (1 Mark)

b) The Figure below shows a refracted light beam in linseed oil making an angle of $\phi = 20°$ with the normal line NN'. The index of refraction of linseed oil is 1.48. Determine the angles (i) θ and (ii) θ'. (4 Marks)



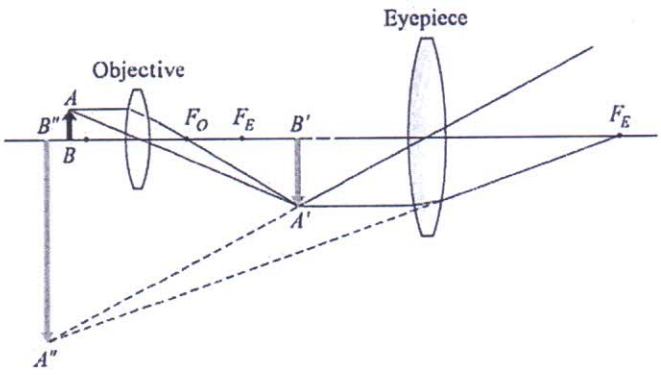
c) A cylindrical glass rod shown below has index of refraction 1.52. It is surrounded by air. One end is ground to a hemispherical surface with radius $R = 2.00\ cm$. A small object is placed on the axis of the rod, 8.00 cm to the left of the vertex.



i) Find the image distance and the lateral magnification. (2 Marks)

ii) If the glass rod is immersed in water, which has index of refraction, $n_{water} = 1.33$. The object distance is again 8.00 cm. Find the image distance and lateral magnification. (2 Mark)

d) In a compound microscope shown below the objective and eye piece have fixed focal lengths +0.80cm and +2.5cm respectively. The real image $A'B'$formed by the objective is 16cm from the objective.

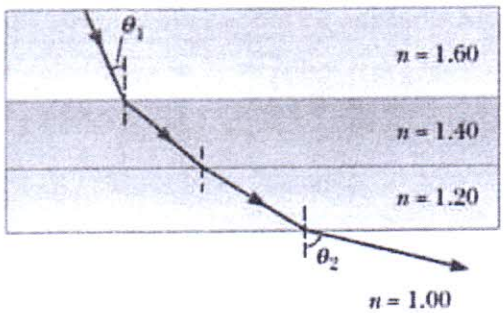


Determine total magnification, if the eye is held close to the eye piece and views virtual image AB at a distance of 25cm. (3 Marks)

SECTION B (36 MARKS)

Question Three (12 Marks)

a) The figure below shows the path of a light beam through several slabs with different indices of refraction.



i) If $\theta_1 = 30°$, what is the angle θ_2 of the emerging beam? (1 Mark)

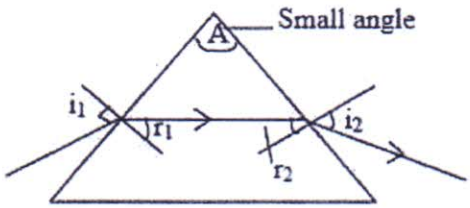
ii) What must the incident angle θ_1 be to have total internal reflection at the surface between the medium with $\eta = 1.20$ and the medium with $\eta = 1.00$? (2 Marks)

b) State three applications of optical fibres. (2 Marks)

c)

i) A certain prism is found to produce a deviation of 51°, while it produces a deviation of 62.8° for two values of the angle of incidence namely 40.1° and 82.7° respectively. Determine the refracting angle of the prism, the angle of incidence at minimum deviation and the refractive index of the material of the prism. (4 Marks)

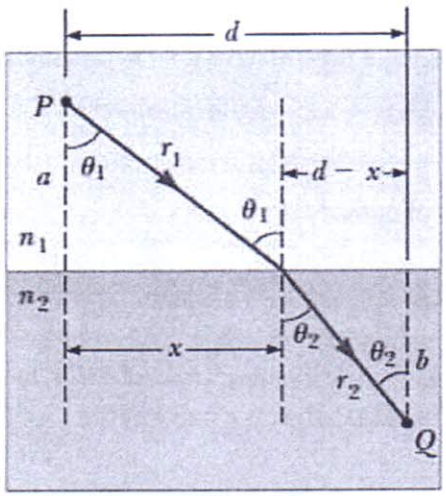
ii) Show that when a ray of light passes nearly normally through a prism of small angle A and refractive index μ, the deviation d is given by d=(μ-1) A. (3 Marks)



Question Four (12 Marks)

a) State Fermat's principle. (1 Mark)

i) Derive Snell's law of refraction from Fermat's principle.
Proceed as follows. In the figure shown below a light ray travels from point P in medium 1 to point Q in medium 2. The two points are, respectively, at perpendicular distances a and b from the interface. The displacement from P to Q has the component d parallel to the interface, and we let x represent the coordinate of the point where the ray enters the second medium. Let $t = 0$ be the instant the light starts from P.



i) Show that the time at which the light arrives at Q is (2 Marks)

$$t = \frac{r_1}{v_1} + \frac{r_2}{v_2} = \frac{\sqrt{a^2 + x^2}}{c/n_1} + \frac{\sqrt{b^2 + (d-x)^2}}{c/n_2}$$

ii) To obtain the value of x for which t has its minimum value, differentiate t with respect to x and set the derivative equal to zero. Show that the result implies (2 Marks)

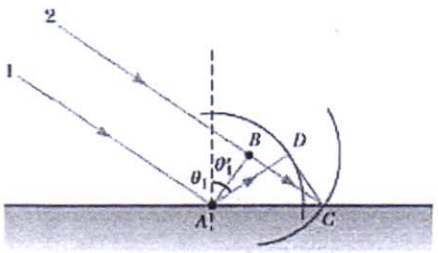
$$\frac{n_1 x}{(a^2 + x^2)^{1/2}} = \frac{n_2(d-x)}{[b^2 + (d-x)^2]^{1/2}}$$

iii) Show that this expression in turn gives Snell's law, (2 Marks)

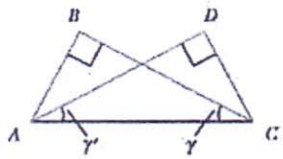
$$n_1 sin\theta_1 = n_2 sin\theta_2$$

b) i) State Huygen's principle (1 Mark)

ii) In the figure shown below, the wave at A sends out a Huygens wavelet toward D. At the same time, the wave at B emits a Huygens wavelet toward C. Both rays 1 and 2 move with the same speed.



(a)



(b)

Use Huygen's principle illustrated in the figure to prove the law of reflection, $\theta_1 = \theta_1'$

(4 Marks)

Question Five (12 Marks)

a) Derive an expression of the focal length of the lens in terms of radii of curvature of its faces and its refractive index: (6 Marks)

$$\frac{1}{f} = (\eta - 1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

b) A double convex lens has radii of 18cm and 20cm. When an object is 24cm from the lens, a real image is formed 32cm from the lens. Determine

i) The focal length of the lens (2 Marks)

ii) Refractive index of the lens material (2 Marks)

c) i) A certain lens has focal length 79.0 cm in air and index of refraction 1.55. Find its focal length in water. (2 Marks)

Question Six (12 Marks)

a) A telephoto lens consists of a converging lens of focal length 6.0 cm placed 4.0 cm in front of a diverging lens of focal length 2.5 cm. Determine

(i) The Location of the image of a very distant object. (5 Marks)

(ii) What is the nature of image formed by this combination (1 Mark)

b) State the demerits of erecting lens situated between the objective and eye lens in a terrestrial telescope. (2 Marks)

c) Determine the resolving power of a telescope, if the objective of a telescope has a diameter of 300mm. The mean wavelength of the light from stars is$6 \times 10^{-7} m$.
(2 Marks)

d) A lens that has a focal length of 5.00 cm is used as a magnifying glass. (a) To obtain maximum magnification and an image that can be seen clearly by a normal eye, where should the object be placed? (b) What is the magnification? (2 Marks)

Question Seven (12 Marks)

a) Sketch well labelled ray diagrams to explain what is meant by short sightedness (myopia) and how this eye defect can be corrected. (4 Marks)

b) A near sighted person cannot see objects clearly that are beyond 50cm from his eye. Determine the focal length and power of the glasses that will enable him see distant objects clearly. (2 Marks)

c) Differentiate between chromatic and spherical aberration (4 Marks)

d) Explain why a mirror cannot give rise to chromatic aberration. (2 Marks)

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