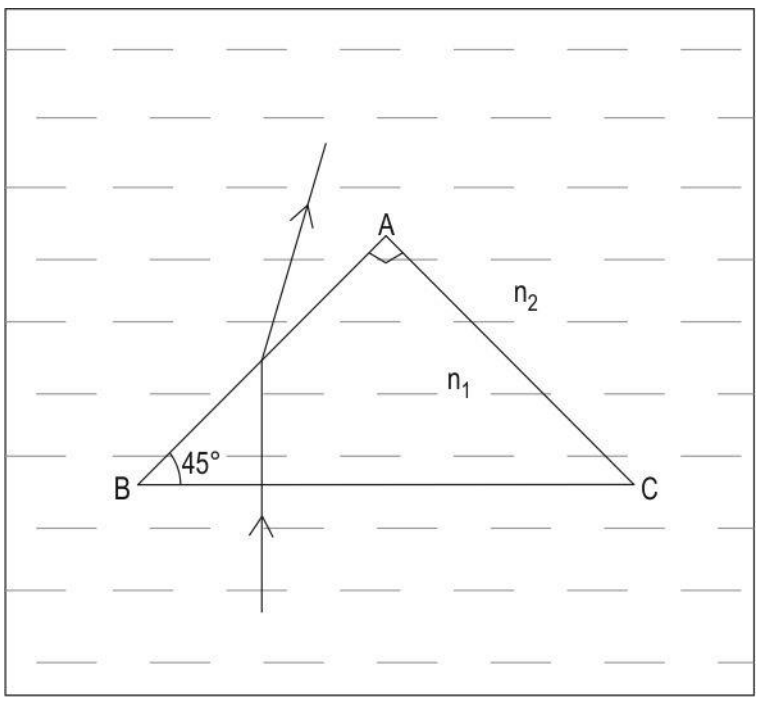
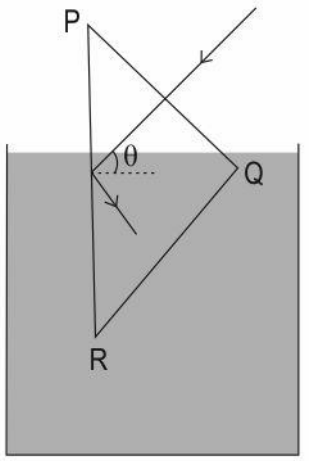
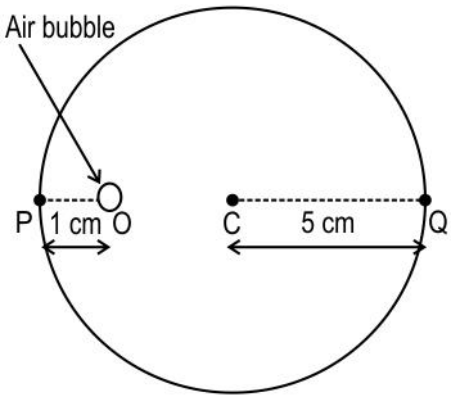
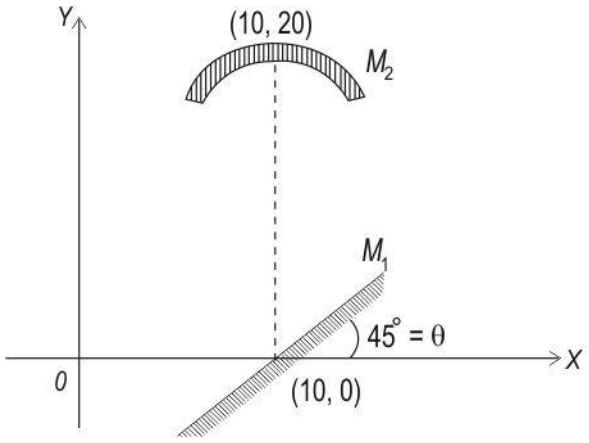
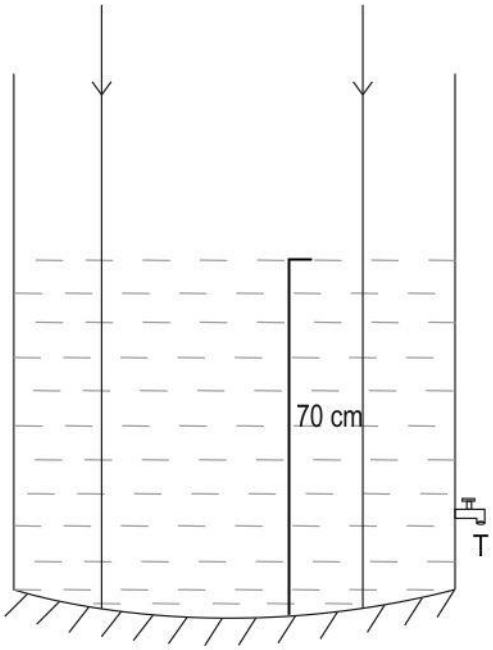
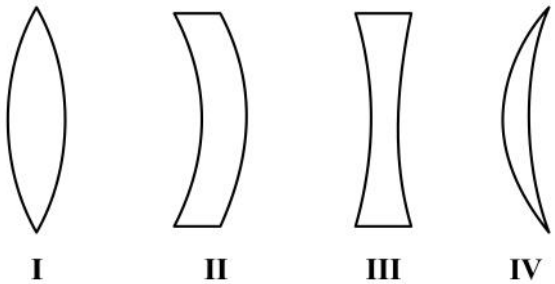
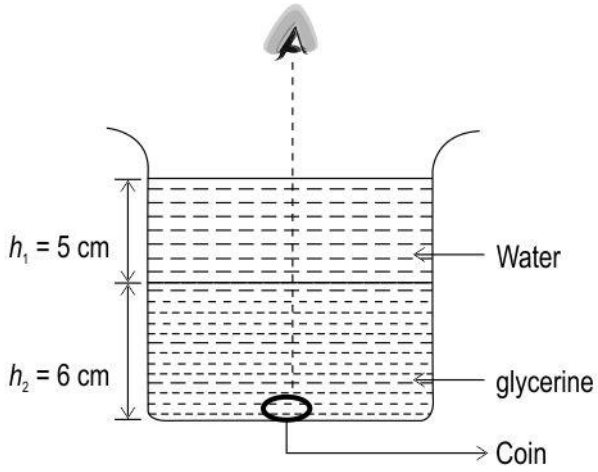
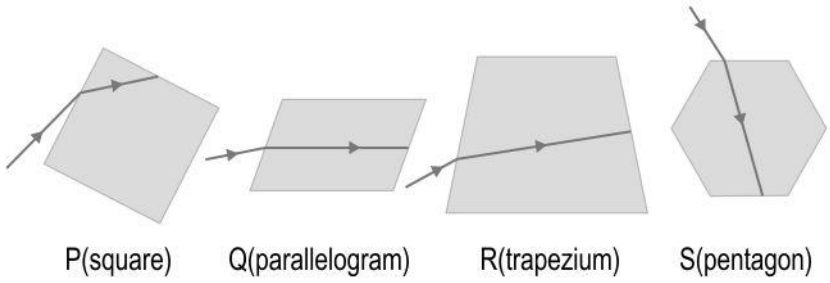
Ray Optics and Optical Instruments

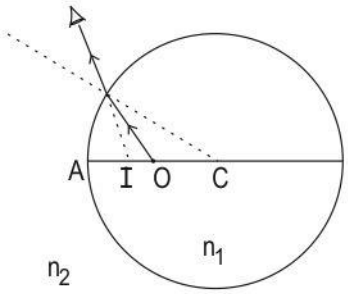
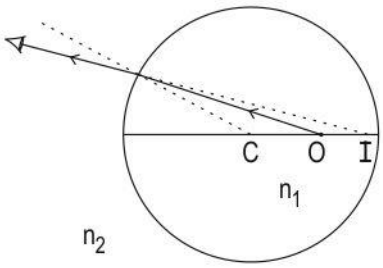
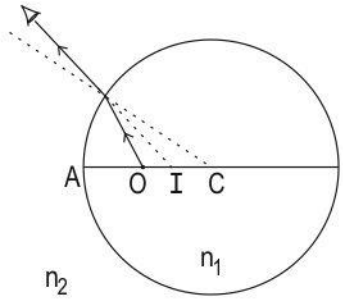
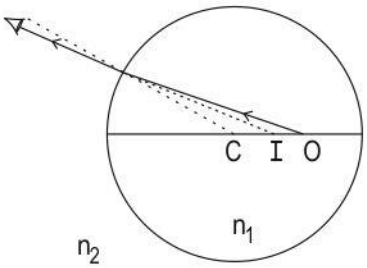
Q.No	Question	Marks
	Multiple Choice Question	
Q.111	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): A ray of light travelling from one media to another always changes its path. Reason(R): The speed of light changes when it travels from one medium to another. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation of assertion. C. Assertion is true but reason is false. D. Assertion is false but reason is true.	1
Q.112	A right-angled isosceles prism of refractive index n_1, is placed in a medium whose refractive index is n_2. The path of a ray of light that falls normally on side BC of the prism is shown in the image below.  	1

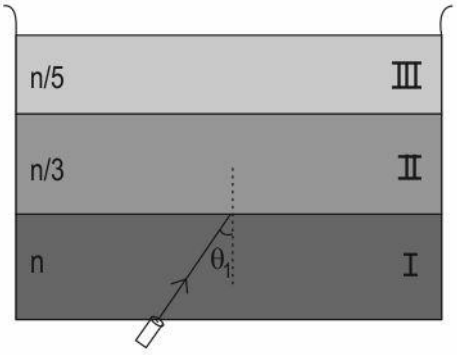
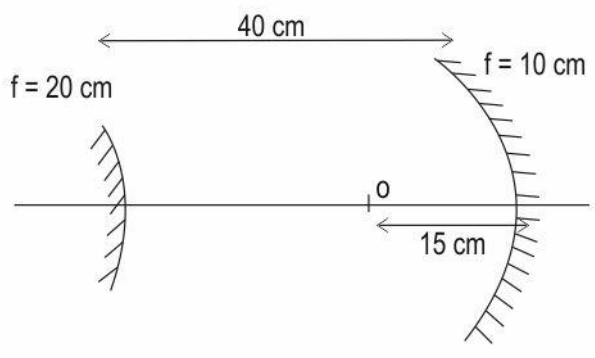
	If $n_2 = \sqrt{2}$, then what could be the possible value of n_1? (take $\sqrt{2}$ =1.414) A. 1.3 B. 1.6 C. 2 D. 2.5	
Q.113	A ray of light enters perpendicularly into the prism PQR that is partially immersed in the liquid. Given the refractive indices of prism and liquid as n_g = 3/2 and n_l = 5/4.  Which one of the following conditions ensures that the ray of light undergoes total internal reflection at the surface PR? A. sin θ = 1 B. sin θ ≥ 5/6 C. sin θ ≤ 8/15 D. 2/3 > sin θ > 4/5	1
Q.114	An air bubble is trapped at position O that is 1 cm inside the surface of glass sphere of radius 5 cm. C is the centre of the glass sphere. The air bubble is viewed from side P and then from side Q.  Which of the following statements is correct?	1

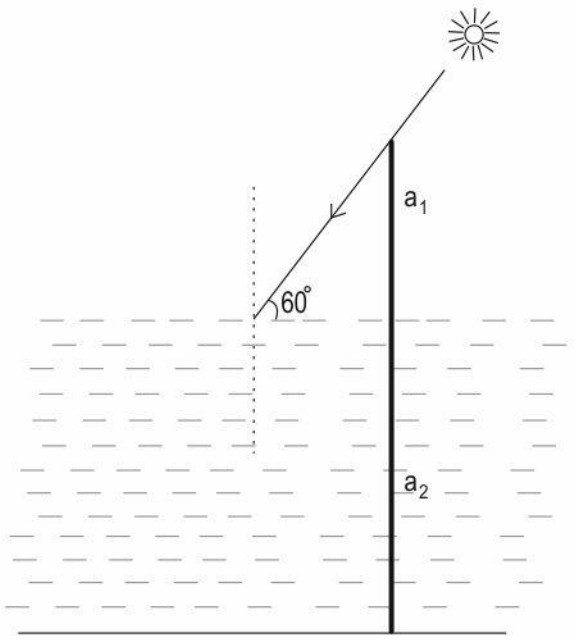
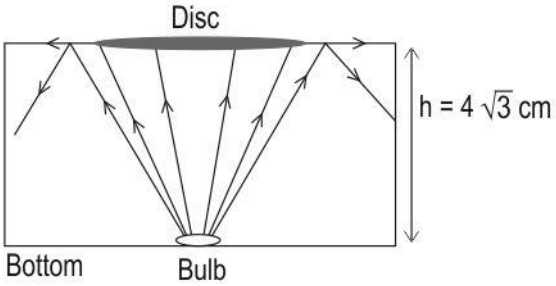
	A. The bubble appears to be on the surface of the sphere when seen from side P. B. The bubble appears to be at the center of the sphere when seen from side Q. C. The bubble appears at a position that is beyond 9 cm from the surface of the sphere when seen from side Q. D. The bubble appears at a position that is more than 1 cm from the surface of the sphere when seen from side P.	
Free Response Questions/Subjective Questions		
Q.115	M_1 is the plane mirror initially placed at angle $\theta = 45^o$ to the x-axis at (10,0) coordinates. M_2 is the concave mirror of focal length 10 cm with its center coinciding with coordinates (10, 20). Also, its principal axis coincides with the centre of the plane mirror as shown in the figure.  A beam of light parallel to x-axis is incident on the plane mirror. Determine the coordinates of the image formed by M_2 for the initial angle $\theta = 45^o$ of the plane mirror. Explain how you arrived at the answer.	2
Q.116	The base of a tank of water is a concave mirror of radius of curvature equal to 100 cm. The initial level of the water in the tank is 70 cm.	3

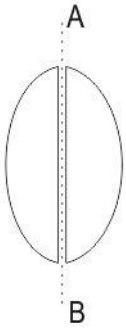
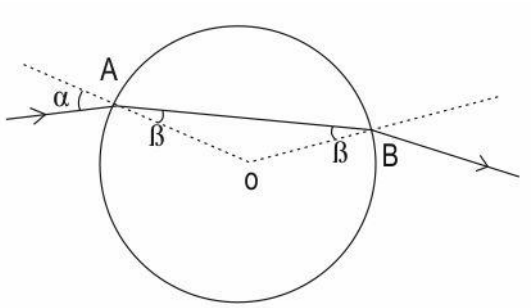
	 (a) Draw a ray diagram to show the image formation due to the incident parallel beam of sun's rays falling perpendicular to the water surface. (b) Determine the position of the image formed. (c) Tap T of the tank is opened and the water begins to drain out of the tank. How does the position of the image change as the water level in the tank drops from 70 cm to 40 cm?	
Q.117	A plano concave lens forms a virtual image at a distance of 5 cm in front of the lens of an object placed in front of it. The image formed is 1/2 times the size of the object. If the speed of light in the Plano concave lens is 2/3 times the speed of light in air, then find (a) the refractive index of the lens. (b) the radius of curvature of the curved surface of the lens.	4
Q.118	Each of the four lenses shown below is constructed by a material of refractive index n which is bounded by two curved surfaces of radii of curvatures R_1 and R_2 respectively. 	4

	For all four lenses identify if the two radii of curvature and the focal length are positive or negative when kept in air.	
Q.119	A coin is placed at the bottom of a beaker. The beaker is then filled with a layer of glycerine followed by a layer of water as shown below. When viewed normally by an observer in air, the coin appears to be at a depth of 7.9 cm.  (a) If the refractive index of water is 1.3, calculate the refractive index of the glycerine. (b) If the observer slowly moves the eye away from the normal, the object suddenly disappears at a certain position. Explain the observation.	3
Q.120	Shown below are the cross-sections of four transparent objects. The direction of the incident ray and the refracted ray are shown.  (a) In which of the case(s) will the emergent ray be parallel to the direction of the incident ray? Explain why. (b) In each of the four cases draw the direction of the emergent ray. (Note: TIR does not take place for the given angles of incidence on the second surface.)	3
Q.121	An air bubble is stuck inside a glass ball of refractive index n_1. The surrounding medium outside the glass ball is of refractive index n_2. Each of the ray diagrams given here depict the virtual position of bubble as seen from outside the glass ball.	4

	In Fig I and II the bubble is nearer to the viewing surface and in Fig III & IV, the bubble is away from the viewing surface.  Fig I  Fig III  Fig II  Fig IV a. Identify the correct ray diagrams depicting the virtual position of the air bubble as seen from outside the glass ball in each of the following cases. i. $n_1 > n_2$ ii. $n_1 < n_2$ b. State true or false: When viewed from outside: i. For $n_1 > n_2$ and the bubble to the left of C, the apparent position of the bubble is closer to viewing surface. ii. For $n_1 > n_2$ and the bubble is to right of C, the apparent position of the bubble is farther away from viewing surface. iii. For $n_1 < n_2$, and the bubble is to left of C, the apparent position of the bubble is closer to viewing surface. iv. For $n_1 < n_2$, and the bubble is to right of C, the apparent position of the bubble is farther away from viewing surface.	
Q.122	A transparent container contains layers of 3 immiscible transparent liquids of different refractive indices. A laser beam is pointed at the layer I as shown in the figure.	2

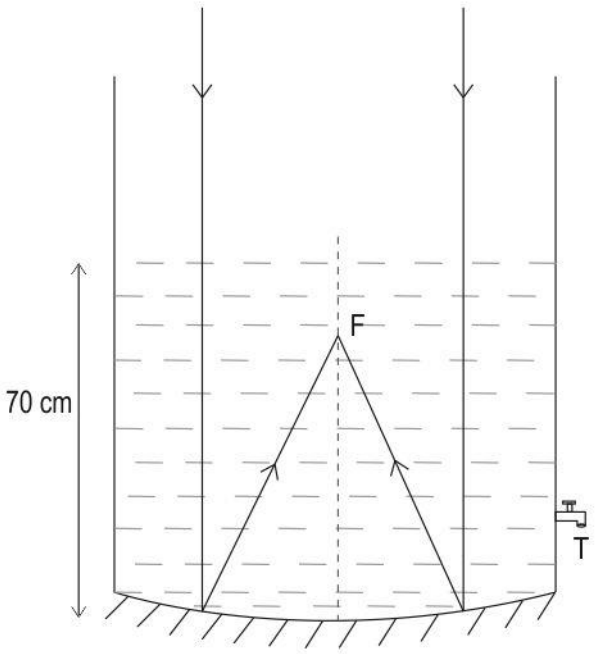
	 What minimum angle of θ_1 will ensure that laser beam does not enter region III at all?	
Q.123	A thin convex lens of focal length 10 cm and refractive index $n_1 = 1.5$ is immersed in a medium of refractive index n_2. In each of the following instances, determine whether the lens behaves as a converging lens, plane glass or a diverging lens. Also find the focal length of the lens in each case. (a) $n_2 = 1.2$ (b) $n_2 = 1.5$ (c) $n_2 = 2$	4
Q.124	A concave mirror and a convex mirror of focal lengths 10 cm and 20 cm respectively are placed coaxially as shown. The distance of separation between the two mirrors is 40 cm.  If an object O is placed in between them as shown, at a distance of 15 cm from the concave mirror, find the position of final image that is formed by two successive reflections, (a) first by concave mirror, and (b) then by convex mirror.	3
Q.125	A pole stands in a pool of water such that the sun shines at an angle as shown in the diagram. The ratio of the height of the pole above the water, a_1 to that inside the water, a_2 is √3/ √55.	3

	 *NOTE:Image not to scale.* (a) Complete the ray diagram to show the formation of the shadows of the pole on the water surface and at the bottom of the pool. (b) Show that the ratio of length of the shadow of the pole on the water surface to that at the bottom of the pool is 1/4. Take n for the pool water as 4/3.	
Q.126	Wide aromatic liquid containers with bulbs glowing at the bottom are used for decoration purposes in a garden. At night, instead of switching off the bulbs, the caretaker chooses to place a floating opaque disc at the center of each of the containers. In doing so, the bulbs become invisible from the surface!  Determine the minimum diameter of the circular opaque disc that the caretaker should place on surface of the liquid in each of the containers. The height of liquid in each container is 4√3 cm and the refractive index of the liquid is 2/√3.	2
Q.127	A small piece of paper is stuck on the surface of the glass sphere of radius 10 cm and refractive index 1.5. The paper is viewed from diametrically opposite side. a. Represent the image formation using a ray diagram. b. Determine the image position.	3

Q.128	A biconvex lens of glass (n=3/2) is shifted from air (n=1) to water (n = 4/3). Determine the factor by which the focal length of the lens changes.	2
Q.129	A thin equi-convex lens of focal length f is sliced into two equal parts by a vertical plane AB.  What is the focal length of each of the sliced part?	2
Q.130	Light falling on a glass sphere of refractive index n, at angle of incidence α refracts at angle of refraction β.  Refer to the given diagram above. a. Show that angle of emergence is equal to angle of incidence. b. Complete the given diagram to represent the deviation produced in the incident ray. c. Determine the angle of deviation produced in the incident light as it passes through the glass sphere in terms of α and β.	3
Q.131	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): The degree of convergence of a convex lens made of glass decreases when it is placed in water. Reason(R): The relative refractive index of the glass with respect to water is less than that of glass with air. A. Both assertion and reason are true and reason is the correct explanation for assertion.	1

	B. Both assertion and reason are true but reason is not the correct explanation of assertion. C. Assertion is true but reason is false. D. Both assertion and reason are false.	

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.111	D. Assertion is false but reason is true.	1
Q.112	B. 1.6	1
Q.113	B. $\sin\theta \geq 5/6$	1
Q.114	C. The bubble appears at a position that is beyond 9 cm from the surface of the sphere when seen from side Q.	1
Q.115	For angle $\theta = 45^{o}$ of the plane mirror, the reflected rays that fall on M_2 are all parallel to principal axis. So the reflected rays converge at the focus F of the M_2. (1 mark for the correct argument of image formation) The coordinates of the image formed by concave mirror : (10, 10) (1 mark for the correct value of coordinates)	2
Q.116	(a)  The image is formed at the position of the principal focus of the mirror inside the water. [1 mark for the correct representation of the diagram with clear indication of the location of the image formed]	3

	(b) Using mirror formula: As R = -100 cm, f = - 50 cm of the concave mirror. $1/v+1/(-\infty)=1/(-50)$ Calculating, v = -50 cm It's a real image of the sun. [1 mark for the correct determination of the actual position of the image] (c) For the water level in between 70 cm till 50 cm, the image continues to be fixed at the position of the principal focus of the mirror, that is, at a distance of 50 cm from the mirror. As the water level falls below, 50 cm, the rays begin to refract at water-air interface before meeting at the image point. Since the rays refract away from the normal, the image position will be below the earlier position of 50 cm (at F) mark. As the level drops further, the image position continues to shift downwards. [1 mark for the correct description of the change in position of the image due to falling level of the liquid and the corresponding explanation]	
Q.117	(a) Refractive index = c/v $n = c /(2/3c) =1.5$ (b) v = - 5.0 cm $m = v/u = h_i/h_o$ (0.5 marks) $-5/u = (1/2h_o)/h_o$ u = - 5 × 2 = -10 cm (0.5 marks) $1/f = 1/v - 1/u$ (0.5 marks) $1/f = -1/5 + 1/10 = -1/10$ f = - 10 cm (0.5 marks) By lens maker formula $1/f = (n - 1)(1/R_1 - 1/R_2)$ (0.5 marks) $-1/10 = (1.5 - 1)(1/R_1 - 1/-\infty)$	4

<table>
<tr><td></td><td>R_1 = - 10 × 0.5 cm = - 5 cm (0.5 marks)</td><td></td></tr>
<tr><td>Q.118</td><td>
<table>
<tr><th></th><th>R_1</th><th>R_2</th><th>f</th></tr>
<tr><td>lens 1</td><td>positive</td><td>negative</td><td>positive</td></tr>
<tr><td>lens 2</td><td>negative</td><td>negative</td><td>converging if $|R_1| > |R_2|$
diverging if $|R_1| < |R_2|$</td></tr>
<tr><td>lens 3</td><td>negative</td><td>positive</td><td>negative</td></tr>
<tr><td>lens 4</td><td>positive</td><td>positive</td><td>diverging if $|R_1| > |R_2|$
converging if $|R_1| < |R_2|$</td></tr>
</table>
(1 mark for each lens)
</td><td>4</td></tr>
<tr><td>Q.119</td><td>(a) The height by which the coin appears to be displaced when viewed normally = 11 - 7.9 = 3.1 cm

The displacement due to water

$d_w = h_1 (1 - 1/n_w)$

$d_w = 5 (1 -1/1.3)$

On solving

d_w = 1.15 cm (1 mark)

The displacement due to glycerine

$d_g = h_2 (1 - 1/n_g)$

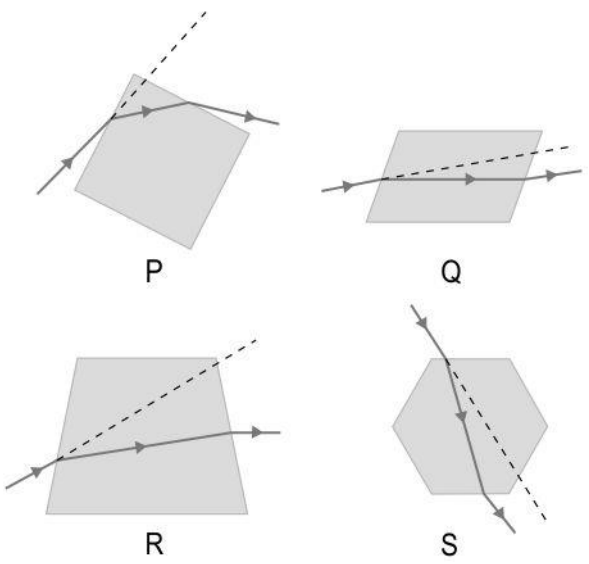
d_g = 3.1 - 1.15 = 1.95 cm

$1.95 = 6 (1-1/n_g)$

On solving

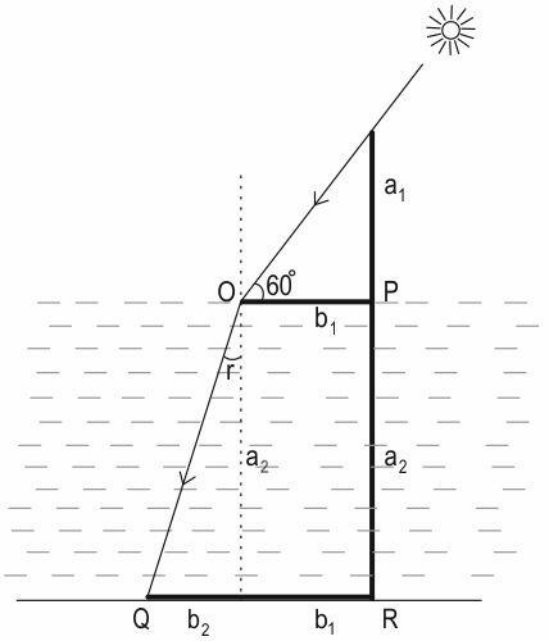
n_g = 1.48 (1 mark)

(b) As the ray travels from glycerine to air, it refracts at two surfaces, glycerine-water, and water-air. Since, at both surfaces the ray of light travels from denser media to rarer, for a particular angle of incidence the ray of light will undergo total internal reflection at either of the interfaces, and hence the coin becomes invisible.</td><td>3</td></tr>
<tr><td>Q.120</td><td>(a) In Q and S, the emergent ray will be parallel to the incident ray because the two refracting surfaces are parallel.</td><td>3</td></tr>
</table>

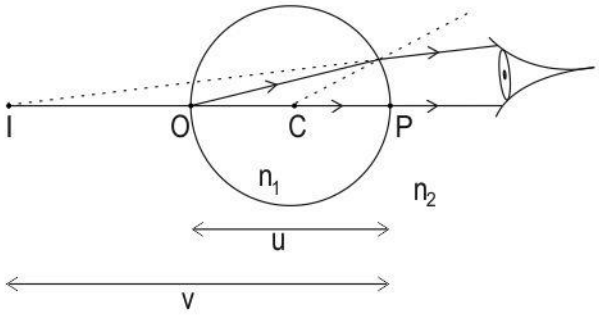
	In P and R, the refracting surfaces are not parallel.(1 mark) (b)  (0.5 marks for each correct diagram)	
Q.121	a. i. $n_1 > n_2$: Fig I & Fig III ii. $n_1 < n_2$: Fig II & Fig IV [0.5 mark each for the correct identification of the diagrams] b. State true or false: i. For $n_1 > n_2$, the apparent position of the bubble is closer to viewing surface in case the bubble is to left of C. TRUE ii. For $n_1 < n_2$, the apparent position of the bubble is closer to viewing surface in case the bubble is to right of C. TRUE iii. For $n_1 > n_2$, the apparent position of the bubble is closer to viewing surface in case the bubble is to right of C. FALSE iv. For $n_1 < n_2$, the apparent position of the bubble is farther to viewing surface in case the bubble is to left of C. FALSE [0.5 mark for each correct answer]	4
Q.122	Snell's law for each of the interfaces: $n \sin\theta_1 = n/3 \,.\, \sin\theta_2 = n/5.\, \sin(90)$	2

	[1 mark for the correct representation of Snells law at each of the interfaces] $n \sin\theta_1 = n/5. \sin(90) = n/5 \times 1$ $\sin\theta_1 = 1/5$ $\theta_1 = \sin^{-1}(1/5)$ [1 mark for the correct final result]	
Q.123	(a) $\frac{n_2}{f_1} = (n_1 - n_2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ for lens of refractive index n_1 & focal length f_1 surrounded by medium of refractive index n_2 $\frac{1}{f_1} = (1.5 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \ldots(1)$ Here $n_1 = 1.5$, $f_1 = 10$ cm, $n_2 = 1$ (air) [1 mark for correct formula and substitution] $\frac{1.2}{f_2} = (1.5 - 1.2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \ldots(2)$ Here $n_1 = 1.5$, $f_1 = 10$ cm, $n_2 = 1.2$ Ratio of equations (1) and (2) $\frac{f_2}{1.2 \times f_1} = \frac{(1.5 - 1)}{(1.5 - 1.2)} = \frac{0.5}{0.3}$ Solving for f_2, $f_2 = +20$ cm. The lens behaves as converging. [1 mark for each correct result and calculation] (b) $\frac{n_2}{f_2} = (n_1 - n_2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$	4

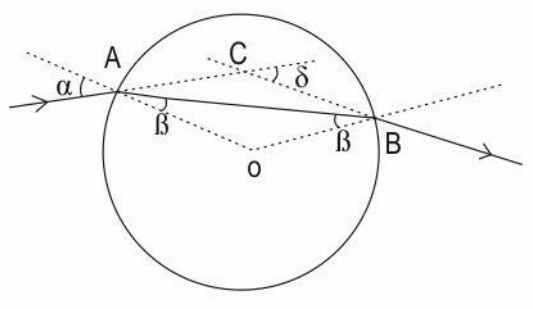
	Here $n_1 = 1.5$, $f_1 = 10$ cm, $n_2 = 1.5$ $n_2/f_2 = 0$ f_2 = infinite. The lens behaves as a plane glass. [1 mark for each correct result and calculation] (c) $\frac{2}{f_2} = (1.5 - 2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ ...(4) Here $n_1 = 1.5$, $f_1 = 10$ cm, $n_2 = 2$ Solving (1) and (4) $f_2 = -2\ f_1 = -2 \times 10 = -20$ cm The lens behaves as a diverging lens. [1 mark for each correct result and calculation]	
Q.124	(a) First by concave mirror: u = -15 cm f = -10 cm Using lens formula, 1/f = 1/v + 1/u Substituting and calculating v = -30 cm. [1 mark for correct calculation of image distance of I_1] Image is real. This image I_1 formed by concave mirror acts as an object. [0.5 mark for identifying that image I_1 behaves as an object for convex mirror] (b) And then by convex mirror, u = +10 cm	3

	f = - 20 cm Using lens formula, and substituting, v = -20/3 cm [1 mark for correct calculation of image distance of I_2] Final image I_2 is formed behind the convex mirror at a distance of 20/3 = 6.66 cm. [0.5 mark for stating the correct position of the image by the convex mirror]	
Q.125	(a)  *NOTE:Image not to scale.* OP is shadow on water surface. QR is the shadow at the bottom of the pool. [1 mark for the correct representation of the two shadows] (b) Given $a_1/a_2 = \sqrt{3}/\sqrt{55}$ To find: $b_1/(b_1 + b_2)$ From the figure, $\tan 60 = a_1/b_1$	3

	So $b_1 = a_1/\sqrt{3}$ Also, $n_1 \sin 30 = n_2 \sin r$ $\sin r = \sin 30/n = (3/4) \times (1/2) = 3/8$ $\cos r = \sqrt{(1 - \sin^2 r)} = \sqrt{(1 - 9/64)} = \sqrt{55}/8$ $\tan r = b_2/a_2$ $b_2 = a_2 \tan r = a_2 \sin r/\cos r$ $= 3 a_2/\sqrt{55}$ [1 mark for the correct calculation of values for b_1 and b_2] Ratio, $\frac{b_1}{b_1+b_2} = \frac{a_1/\sqrt{3}}{\left(\frac{a_1}{\sqrt{3}} + \frac{3a_2}{\sqrt{55}}\right)}$ Resolving and substituting for $a_2/a_1 = \sqrt{55}/\sqrt{3}$ Ratio, $\frac{b_1}{b_1+b_2} = ¼$ [1 mark for the correct final proof]	
Q.126	Light will not emerge from the liquid if at the edge of the disc, $i > \theta_c$ $\sin i > \sin\theta_c$ [0.5 mark for the correct condition of TIR] If R is the radius of the opaque disc and h is the depth of the bulb, $\sin i = R/\sqrt{(R^2+h^2)}$ and $\sin\theta_c = 1/n$ $R/\sqrt{(R^2+h^2)} > 1/n$ [0.5 mark for the correct equation using the ray diagram of the ray undergoing TIR]	2

	Transposing and solving, $R > h/\sqrt{(n^2-1)}$ $R_{min} = h/\sqrt{(n^2-1)}$ $R_{min} = \frac{h}{\sqrt{n^2-1}} = \frac{4\sqrt{3}}{\sqrt{(2/\sqrt{3})^2-1}} = 12\ cm$ Diameter of the required opaque disc = 24 cm [1 mark for the correct calculation and final result]	
Q.127	a.  [1 mark for the correct ray diagram depicting the location of the image] b. Using, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2-n_1}{R}$ Here, u = -20 cm, R = -10 cm, n_1 = 1.5, n_2 = 1 [1 mark for correct formula and identify correct values with signs] Upon substituting and calculating 1/v = -1/40 v = -40 cm Image is formed 20 cm behind the glass ball. [1 mark for the correct final value]	3

Q.128	As, $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} + \frac{1}{R_2}\right] = \left(\frac{n_2}{n_1} - 1\right)K$ $\frac{1}{f_A} = \left(\frac{3/2}{1} - 1\right)K = \frac{1}{2}K$ $\frac{1}{f_W} = \left(\frac{3/2}{4/3} - 1\right)K = \left(\frac{1}{8}\right)K$ $\frac{1/f_A}{1/f_W} = \frac{1/2}{1/8}$ [1 mark for the correct formulae] $f_W/f_A = 4$ Focal length of the lens increases by a factor of 4 as it is shifted from air into water. [1 mark for the correct result]	2
Q.129	For biconvex lens, $\frac{1}{f} = (n-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right] = (n-1)\left[\frac{1}{R} - \frac{1}{-R}\right] = \frac{2(n-1)}{R}$ For sliced lens, $\frac{1}{f'} = (n-1)\left[\frac{1}{R} - \frac{1}{\infty}\right] = \frac{n-1}{R} = \frac{1}{2f}$ f' = 2f The focal length of each sliced part is double the focal length of the undivided biconvex lens. [1 mark for the correct relations for biconvex lens and sliced plano convex lens] [1 mark for the correct calculations and final result]	2
Q.130	a. For refraction at A, 1 sin α = n sin β …(1) For refraction at B, n sinβ = 1 sin γ ….(2), here γ is the angle of emergence at interface B Comparing equations (1) and (2), γ = α	3

	[1 mark for the correct proof] b. Completed ray diagram representing angle of deviation.  [1 mark for the correct representation of angle of deviation} c. Angle of deviation, $\delta = (\alpha - \beta) + (\alpha - \beta) = 2(\alpha - \beta)$ (As Exterior angle of a triangle = sum of opposite interior angles) [1 mark for the correct final result of angle of deviation]	
Q.131	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1