11th Physics-9 : Light 2016-17

A. The Property of Light

[Q1] What is light?

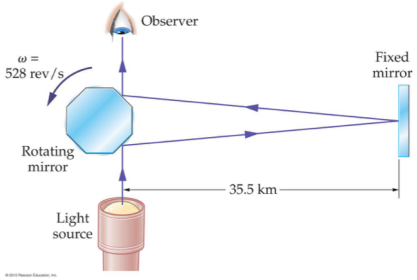
[Q2] By what factor does light travel with respect to sound in air?

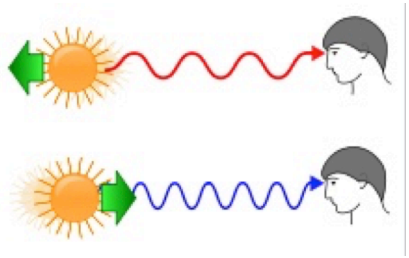
[Q3] What is the frequency of light whose wavelength is 5.0 x 10^{-7} m in vacuum?

[Q4] The distance from the Sun to Earth is 1.50 x 1011 m. How long does it take for light to cover this distance?

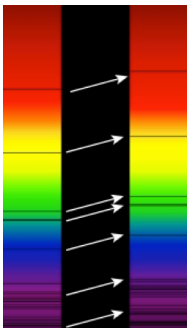
[Q5] In 1610, how did Romer determine the speed of light?

[Q6] In 1926, Albert Michelson measured the speed of light with the technique shown in Fig. 4, where he used an eight-sided mirror rotating 528 rev/s. The distance from the rotating mirror to a distant reflector was 35.5 km. If the light completed 71.1-km round trip in the time it took the mirror to complete one-eighth of a revolution, what is the speed of light?



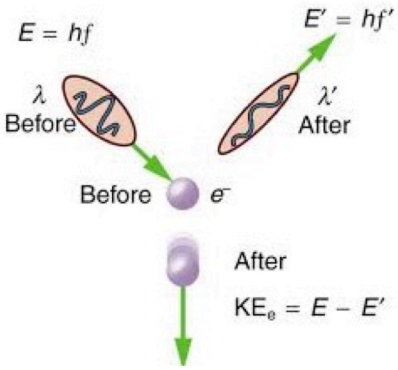


[Q7] A distant star is traveling directly away from Earth with a speed of 36,500 km/s. (a) When the wavelengths in this star's spectrum are measured on Earth, are they greater than less than, or the same as the wavelengths that would be observed if the star were at rest relative to Earth? Explain. (b) By what fraction are the frequencies in this star's spectrum shifted?

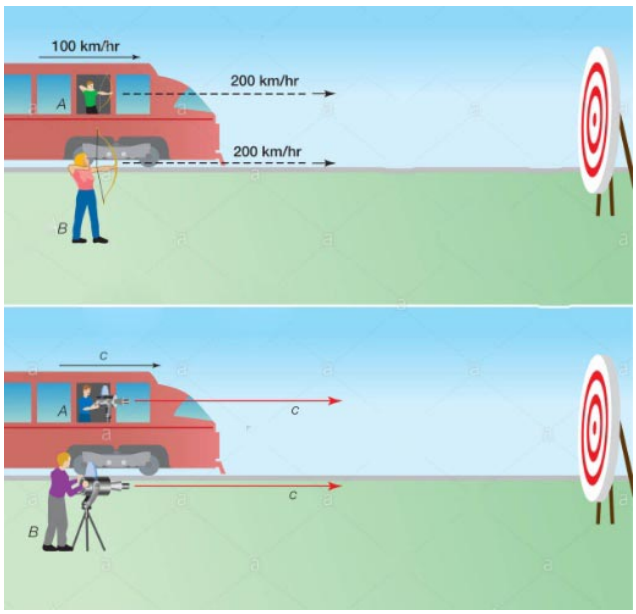


Spectrum

[Q8] Which of the following properties of a light wave is "bottled" in particle-like lumps: (A) wavelength, (b) frequency, (c) speed, or (d) energy?

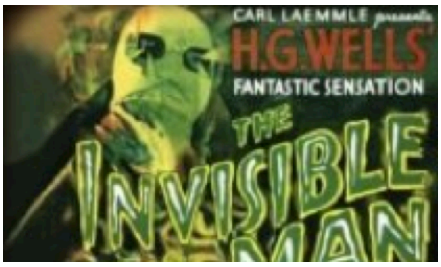


[Q9] Explain the two figures: shooting arrows and light.



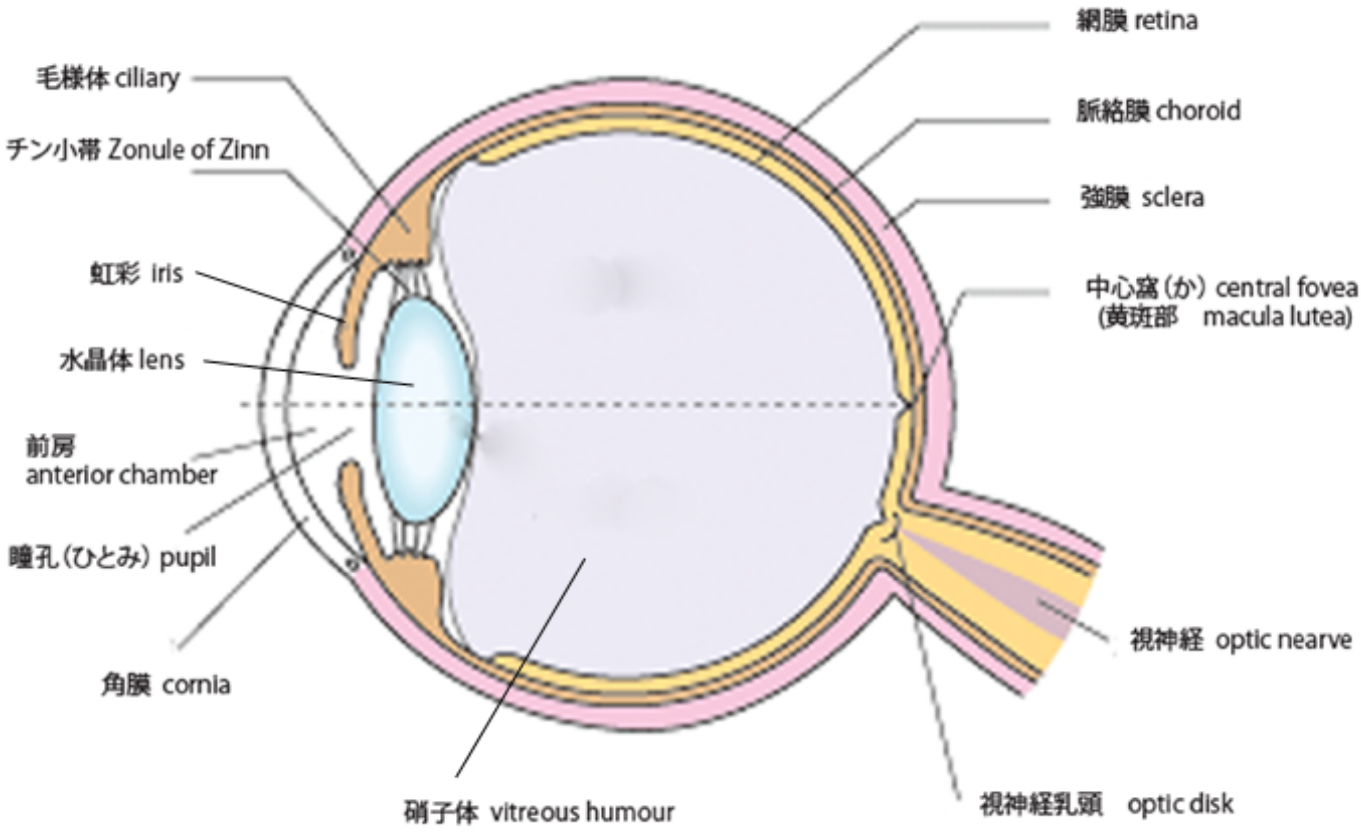
Images Formed by Light

[Q6-1] How we can see an object or what is the sense of sight?



[Q6-2] Why the "invisible man" would be unable to see.

[6-3] The Human Eye



Color

[Q11] What color do you see when red and blue light combine?

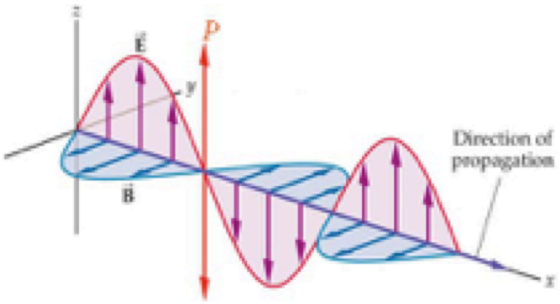
[Q12] Which subtractive primary color corresponds to the combination of green and blue additive primaries?

[Q13] A TV screen has 3,000,000 pixels. This means that it has 3,000,000 red color dots, 3,000,000 green color dots, and 3,000,000 blue color dots. When the screen shows the image in the figure at the right, (a) how many red color dots are lit? (b) How many green color dots are lit? (c) How many blue color dots are lit?

Polarization

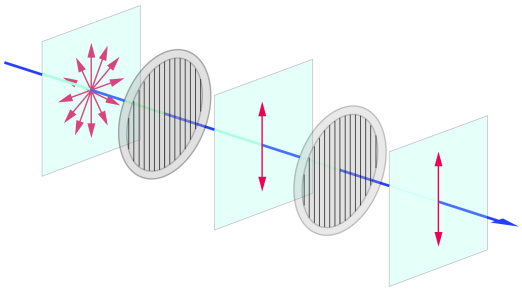
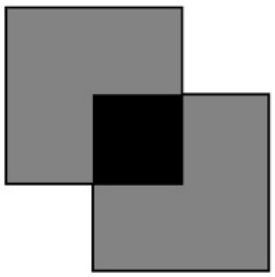
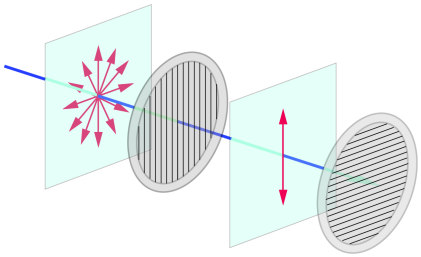
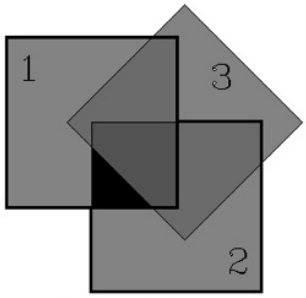
[Q14] Light is a wave. Is it transverse or longitudinal?

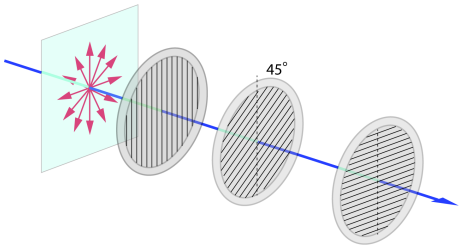
[Q15] The electric field in a given electromagnetic wave is vertical and the magnetic field is horizontal. What is the direction of polarization of this wave?



[Q16] Vertically polarized light passes through a polarizer whose transmission axis is 30° from the vertical. What is the polarization direction of light that passes through this filter?

[Q45] A polarizer preferentially transmits light that vibrates along a specific direction. Compare the following figures, a, b and c and explain what happens.

<table>
<tr>
<td> 
a</td>
<td> 
a. Parallel</td>
</tr>
<tr>
<td> 
b</td>
<td> 
b. Crossed</td>
</tr>
<tr>
<td> 

c</td>
<td> 

c.
Three Polarizers</td>
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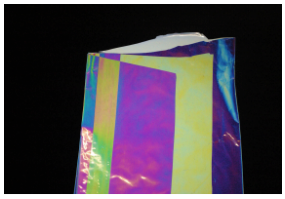
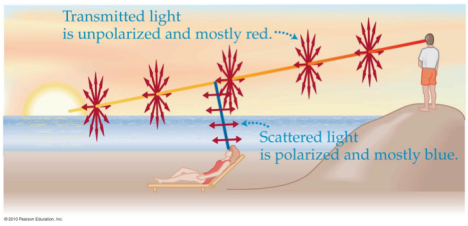
[

Q47] Plastics between crossed polarizers.



[Q46] Explain why the LCD is polarized?

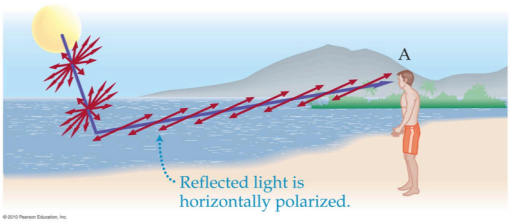
[Q47] Explain why the sky is blue.



[Q48] Explain why sunsets are red.

[Q49] Explain why the sea is blue.

[Q50] Explain why a reflected light from the surface of water, glass, plastic etc. is polarized?



3 D-Movie and Circular Polarization

Fig. 51

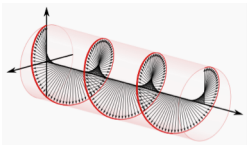


Fig. 54 Clockwise circularly polarized ight

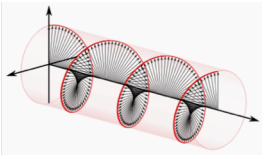
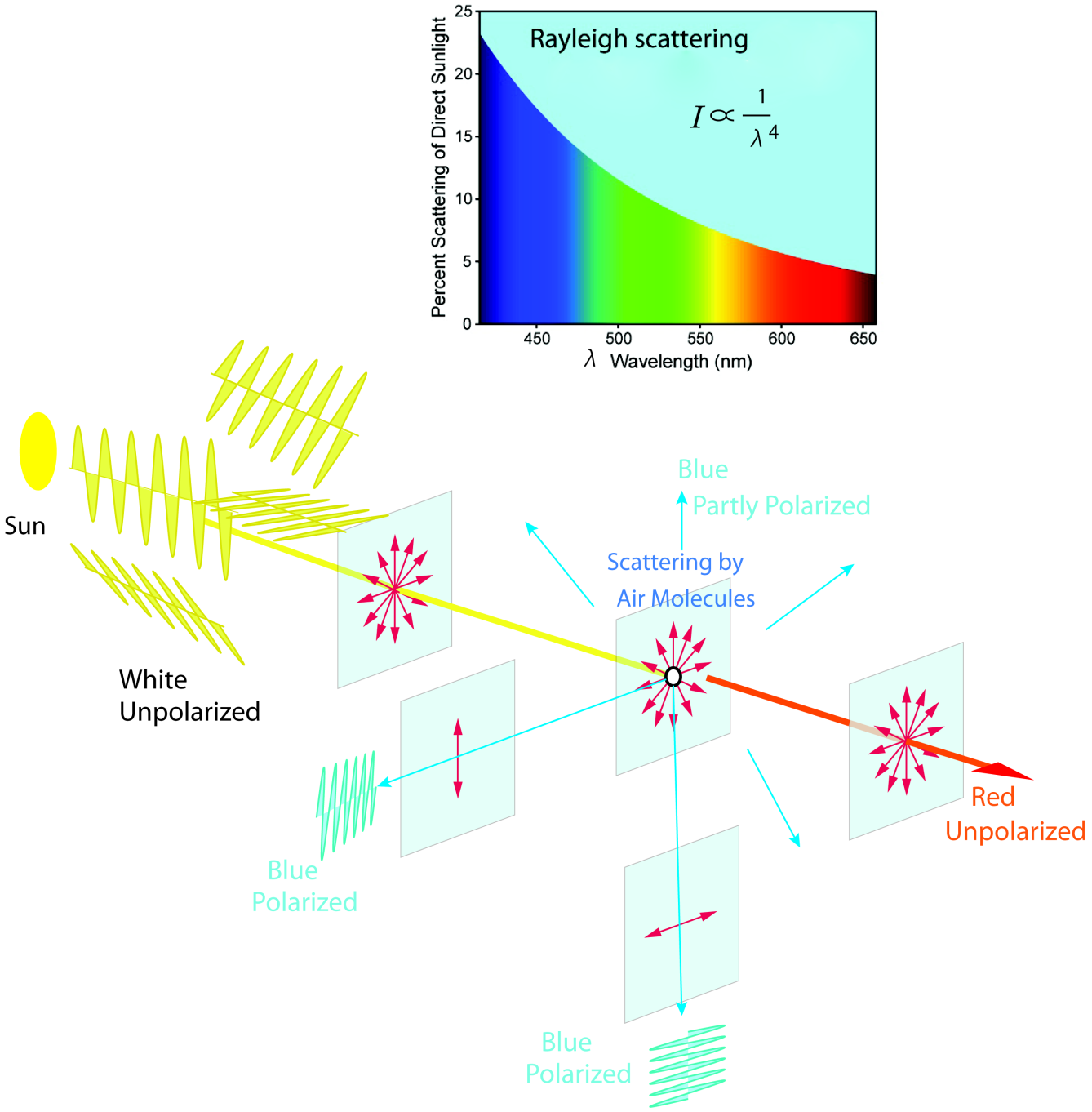
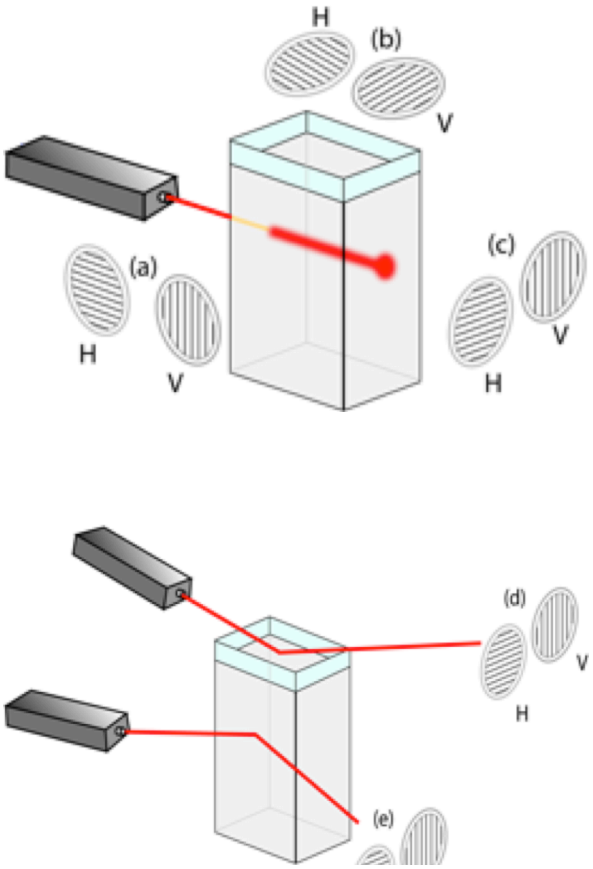


Fig. 55 Counter-clockwise circularly polarized ight


Rayleigh scattering
$I \propto \frac{1}{\lambda^4}$
Percent Scattering of Direct Sunlight
25
20
15
10
5
0
450
500
550
600
650
λ Wavelength (nm)
Sun
White
Unpolarized
Blue
Partly Polarized
Scattering by
Air Molecules
Red
Unpolarized
Blue
Polarized
Blue
Polarized

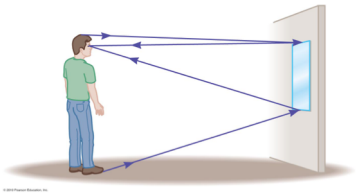
(Q51) A ray of He-Neon laser light passes through an aqueous suspension including a small amount of milk. You are observing the polarization of light from the three different sides, (a) to (c), of the water tank. You also observed two reflected light, at the surface of the suspension (d) and at the surface of the side glass of the tank (e).

Find which polarization angle, horizontal (H) or Vertical (V), gives weaker brightness. If no difference is expected, answer N.

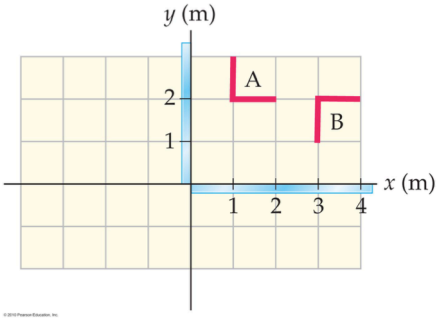


C. Reflection and Refraction

[Q1] To save expenses, you would like to buy the shortest mirror that will allow you to see your entire body. Should the mirror be (a) half your height, (b) two-third your height, or (c) equal to your height?



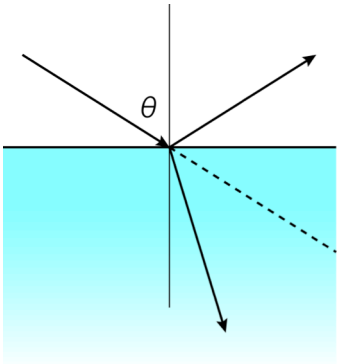
[Q2] Two plane mirrors meet at right angles at the origin, as indicated in Fig. 17. Suppose two L-shaped objects have the positions and orientations labeled A and B. Draw the location and orientation of *all* their images formed by the two mirrors.



[Q5] The refraction index of water is 1.33. Find the speed of light in water.

[Q6] How long does it take for light to travel 2.5 m in water?

[Q7] A beam of light in air enters (a) water (n = 1.33) or (b) diamond (n = 2.42) at an angle of $\theta = 60.0^\circ$ relative to the normal. Find the angle of refraction for each case.



[Q8] Fig. 8-a shows that a beam of light enters from Medium 1 ($n = n_1$) to Medium 2 ($n = n_2$) where the incident angle is θ_1 and the refracted angle θ_2. As shown in fig. 8-b, another medium, Medium 3 ($n = n_3$) is inserted between Medium 1 and Medium 2. Find the refracted angle θ'_2.

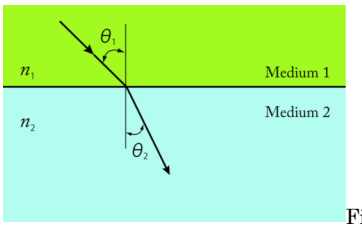


Fig.8-a

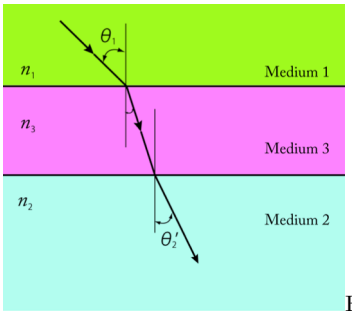
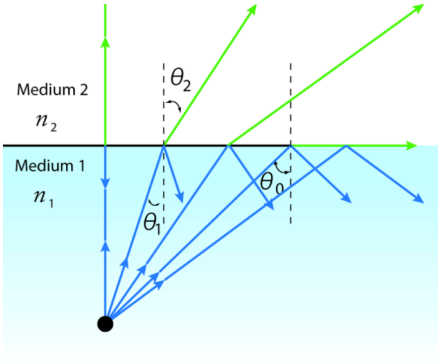


Fig.8-b

[Q9] A beam of light passing through a slab of glass with parallel surfaces travels to the same direction when leaving the glass as when entering to the glass. Verify this statement.

4. Total Reflection 全反射

[Q11] Find the critical angle when a light travels from water with a refractive index 1.33 to air.



[Q12] Optical fiber.

[Q13] Fig. 13 is a prism with a refractive index of $\sqrt{3}$. A beam of light enterns at P with an incident angle 60° . Draw the pathes of th light after the incidence although you do not have to draw the pathes of reflection if they are not total reflection.

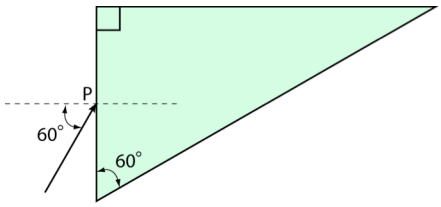


Fig. 13

[Q14] You discovered gold on the bottom of a pond 3.4 m deep. (17-a) Viewed from directly above the gold, how far below the surface of the water does the gold appear to be? (17-b) You want to place a circular board on the water surface to hide the gold completely from anywhere in the air. Find the smallest radius of the board assuming the refractive index of water as 1.33.

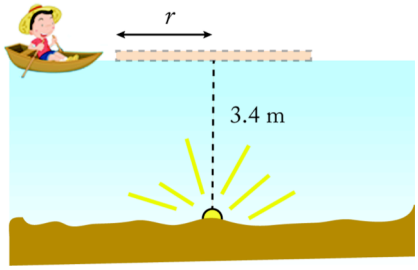
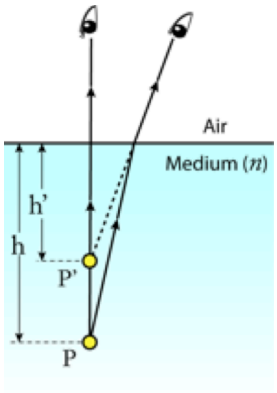


Fig. 14

5. "Bent Pencil" Effect or Apparent Depth

[Q18] A coin is lying at the bottom of a pool of water (refractive index n) that is h [m] deep. Viewed from directly above the coin, how far below the surface of the water does the coin appear to be? (We can use the small-angle approximations $\sin\theta \cong \tan\theta \cong \theta$)



[Q19] You place a sheet of glass on the textbook. The glass 4.2 cm thick has the refractive index of 1.5. How far do the letters appear to be closer than they really are?

7. Light Dispersion

[Q38] Explain how a rainbow is created: 1) the role of droplets of rain, 2) normal or "primary" rainbow and "secondary" rainbow, and 3) the order of colors.

8. Lenses

[Q8-1] A lens produced a real image that is twice as large as the object and is located 15 cm from the lens. Find (a) the object distance and (b) the focal length of the lens.

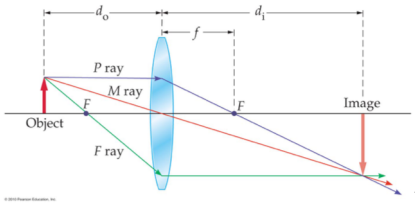


Fig.31

[Q8-2] A concave lens has a focal length of -32 cm. Find the image distance and magnification that result when an object is placed 29 cm in front of the lens.

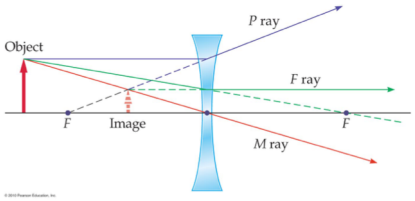
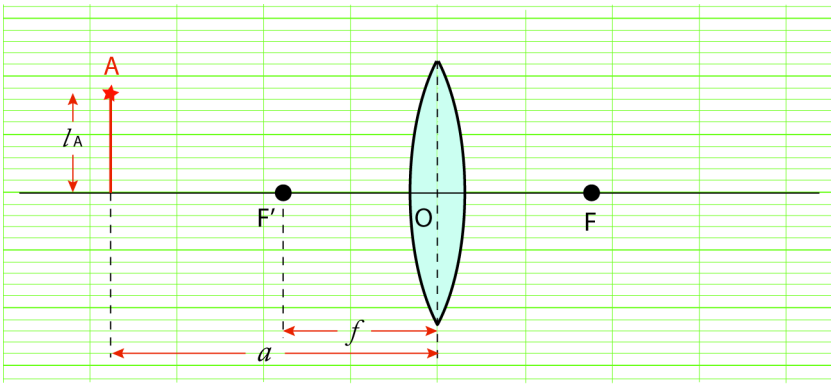


Fig. 32

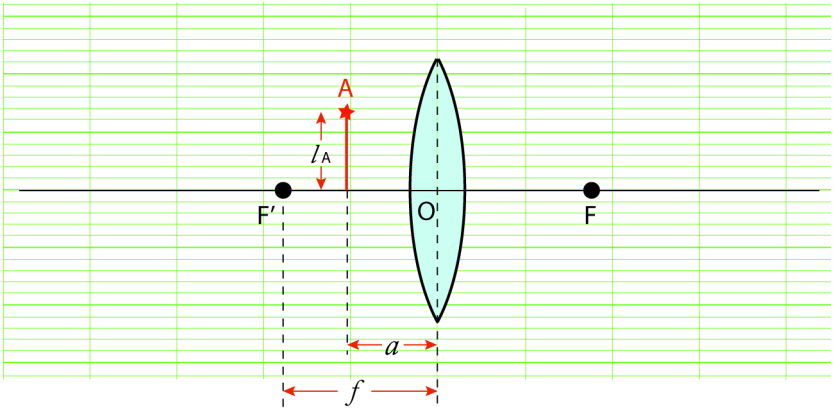
[Q8-3] Find the location and magnification of the image formed by the lens by ray tracing method. Also calculate them using the lens equations and compare with the results by the ray tracing method.

(a) Convex lens -1



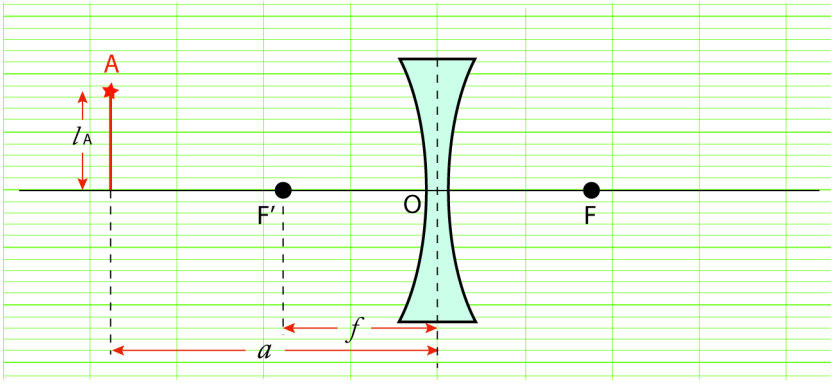
Observed	From the ray tracing method	From the lens equation
f mm	b mm	b mm
a mm	l_B mm	$m=\frac{b}{a}$
l_A mm	$m=\frac{l_B}{l_A}$	$l_B=m\cdot l_A$ mm

(b) Convex lens -2



Observed	From the ray tracing method	From the lens equation (b<0)
f mm	b mm	b mm
a mm	l_B mm	$m=\frac{b}{a}$
l_A mm	$m=\frac{l_B}{l_A}$	$l_B=m\cdot l_A$ mm

(c) Concave lens

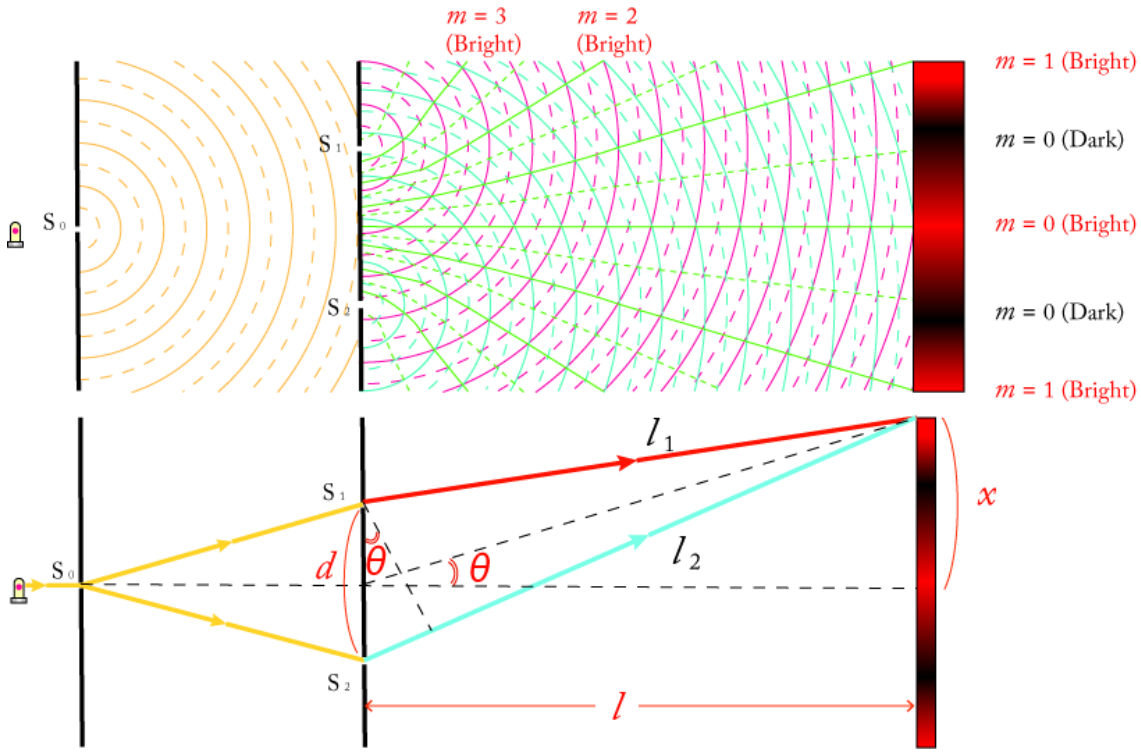


Observed	From the ray tracing method	From the lens equation (f<0, b<0)
f mm	b mm	b mm
a mm	l_B mm	$m=\frac{b}{a}$
l_A mm	$m=\frac{l_B}{l_A}$	$l_B=m\cdot l_A$ mm

D. Diffraction and Interference

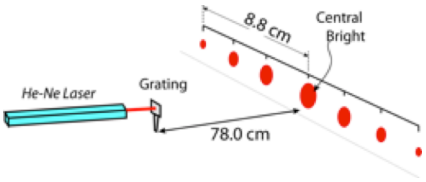
[Q34] In the Young's two-slit experiment shown below, find the distance, x, of the first bright fringe from the central bright fringe as the function of the wavelength, λ, of the source monochromatic light, slit clearance, d, and path length l.

[Q34] How does x change when blue light is used instead of red light as a source?



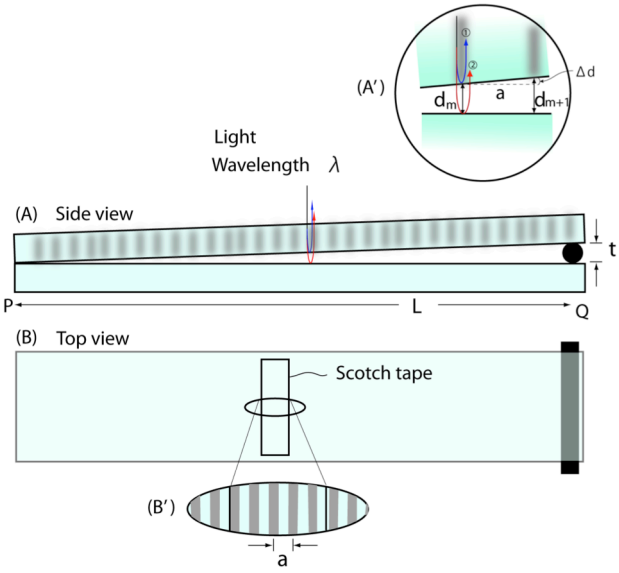
[Q35] A diffraction grating has 2000 ridges per 1 cm. What is the lattice constant? When a monochromatic light is directed at right angle onto the grating, the angle corresponding to the first bright fringe above the central bright fringe is 6.9° . Find the wavelength of the light.

[Q36]When 632.8 nm ($n = 10^{-9}$) laser light passes through a particular diffraction grating, the distance between the central bright and a third order light spot is observed as 8.8 cm. The distance between the grating and the screen is 78.0 cm. How many lines per millimeter does this grating have?



Air Wedge

[Q36] As shown in the Figure A, an air wedge is formed by placing a thin material between two glass plates on one end Q, and allowing them to touch on the other end P. When this wedge is illuminated with light (wavelength: λ), stripes are observed on the glass. They are created by the interference of the two rays, as shown in Figure A'. One ray reflects at the glass-to-air surface to experiences no phase change whereas the other reflects at the air-to-glass surface to experience a phase change and travels the distance 2d, where d is the thickness of the air layer.



(1) Find the condition where the two rays are destructive to create a dark line and express as a relation between λ, d_m and m, where m is 0 or an integer, and d_m is the air thickness at the m-th dark line.

(2) Which line should be located on the end side, P, bright line or dark line?

(3) Using the equation obtained in (1), find a relation between $d_{m+1} - d_m$ and λ.

(4) When the distance between neighboring two dark lines is "a", as shown in the figure (B'), the following relation can be assumed: $(d_{m+1} - d_m)/a = t/L$, where L represents the distance between P and Q while t the thickness of the material. Find the relation among t, L, a and λ.

(5) In the actual experiment, the thickness of the material, t, is known as 25.0 μm, the distance between P and Q is 19.2 cm. Five dark lines are observed in the Scotch tape (12 mm wide) put on the glass, as shown in Figure B'. Find the wavelength of the light from the above relations and values.

(6) If the material sandwiched at the Q side is replaced with a thicker one, does the distance between neighboring stripes increase or decrease?

1. Light 光
   Vision 視覚
   Visible Light 可視光
   Illuminated 照らされた
   White Light 白色光
   Monochromatic Light 単色光
   Laser レーザー
   Spectrum スペクトル
   Transmission 伝達
   Absorption 吸収
   Reflection 反射
   Transparent 透明な
   Translucent 半透明な
   Opaque 不透明な
2. Speed of Light 光速
   Fizeau フィゾー
   Foucault フーコー
3. Incident Light 入射光
   Reflected Light 反射光
   Refracted Light 屈折光
   Straightness 直進性
   Ray 光線
   Boundary 境界面
   Normal 法線
   Incidence Angle 入射角
   Reflected Angle 反射角
   Refracted Angle 屈折角
   Law of Refraction 屈折の法則
   Relative Refractive Index 相対屈折率
   Absolute Refractive Index 絶対屈折率
4. Total Refraction 全反射
   Critical Angle 臨界角
   Optical Fiber 光ファイバー
5. Apparent Depth 浮き上がり効果
6. Image 像
7. Plane Mirror 平面鏡
   Virtual Image 虚像
   Real Image 実像
   Apparent Depth 見かけの深さ
   Mirage 蜃気楼（しんきろう）
8. Lens レンズ
   Convex Lens 凸レンズ
   Concave Lens 凹レンズ
   Optical Axis 光軸
   Focus 焦点
   Focal Distance 焦点距離
   Lens-Equation レンズの式
   Magnification 倍率
   Distance of Distinct Vision 明視の距離
   Magnifying Glass 虫眼鏡

Speed of Light	$c = 2.99792458 \times 10^8$ m/s $\fallingdotseq 3.0 \times 10^8$ m/s
Law of Reflection	$\theta = \theta'$
Law of Refraction	$n_{1\to2} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$
Absolute Refractive Index	$n_1 = n_{Vac\to1} = \frac{c}{v_1}$ $n_{1\to2} = \frac{n_2}{n_1}$
Snell's Law	$n_1 sin\theta_1 = n_2 sin\theta_2$
Total Refraction	$\sin\theta_0 = \frac{n_2}{n_1}$ $\sin\theta_0 = \frac{1}{n_1}$
Apparent Depth	$h' = \frac{h}{n}$
Lens-Equation	$\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$
Magnifying Glass	$m = \left\|\frac{b}{a}\right\| = \left\|\frac{b}{f} - 1\right\| = 1 + \frac{D}{f}$
Young's Interference	$d\sin\theta \fallingdotseq \frac{dx}{l} = m\lambda = 2m \times \frac{\lambda}{2}$ Light Lines $= (2m+1) \times \frac{\lambda}{2}$ Dark Lines $(m = 0, 1, 2, \cdots\cdots)$
Diffraction Grating	$d\sin\theta = m\lambda$ $(m = 0, \pm1, \pm2, \cdots\cdots)$

9. Diffraction 回折
   Young ヤング
   Interference 干渉
   Path Difference 経路差
   Striped Pattern 縞模様
   Light Line 明線
   Dark Line 暗線
   (Diffraction) Grating 回折格子
   Grating Constant 格子定数
   Air Wedge くさび形空気層
   Thin Film 薄膜
   Newton's Ring ニュートンリング
10. Dispersion 分散
    Rainbow 虹
    Prism プリズム
11. Continuous Spectrum 連続スペクトル
    Line Spectrum 線スペクトル
12. Polarization 偏光
    Circular Polarization 円偏光
    Natural Light 自然光