PHYSICS

BOOKS - IE IRODOV PHYSICS (HINGLISH)

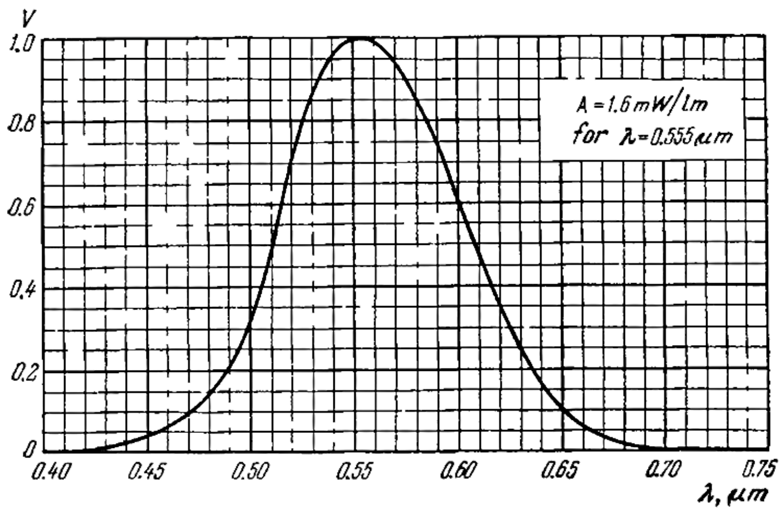
OPTICS

Photometry And Geometrical Optics

1. Making use of the spectral response curve for an eye (see Fig.), find :

(a) the energy flux corresponding to the luminous flux of $1.01m$ at the wavelength 0.51 and $0.64 \mu m$,

(b) the luminous flux corresponding to the wavelength interval from 0.58 to $0.63\mu m$ if the respective energy flux, equal to $\Phi = 4.5mW$, is unifromly distributed over all wavelengths of the interval. The function $V(\lambda)$ is assumed to be linear in the given spectral interval.



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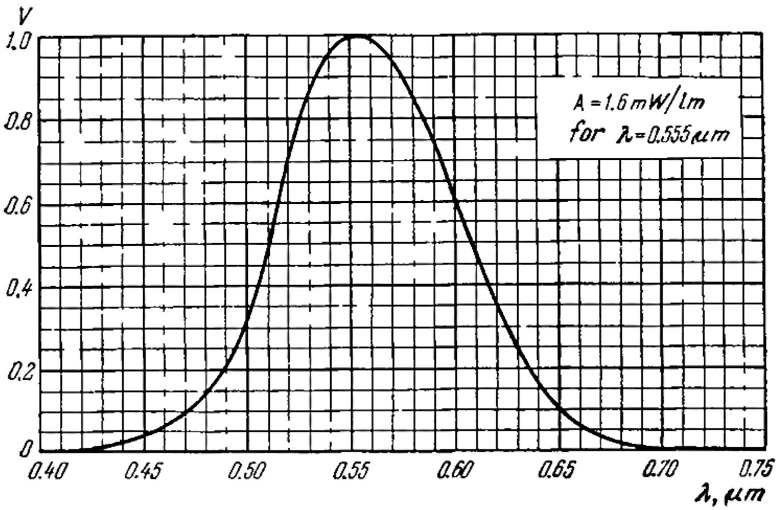
2. A point isotropic source emits a luminous flux $\Phi = 101m$ with wavelength $\lambda = 0.59\mu m$. Find the peak strength values of electric and magentic fields in the luminous flux at a distance $r = 1.0m$ from the osurce. Make use of the curve illustrated in Fig.



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3. Find the mean illuminance of the irradiated part of an opaque sphere receiving

(a) a parallel luminous flux resulting in illuminance E_0 at the point of normal incidence,

(b) light from a point isotropic source located at a distance $l = 100 cm$ from the cnetre of the sphere, the radius of the sphere is $R = 60 cm$ and the luminous intensity is $I = 36 cd$.

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4. Determine the luminosity of a surface whose luminance depends on direction as $L = L_0 \cos \theta$, where θ is the angle between the radiation direction and the normal to the surface.

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5. A certain luminous surface obeys Lambert's law. Its luminance is equal to L. Find:

(a) the luminous flux emitted by a element ΔS of this surface into a cone whose axis is normal to the given element and whose aperture angle is equal to θ,

(b) the luminosity of such a source.

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6. An illuminant shaped as a plane horizontal disc $S = 100cm^2$ in area is suspended over the centre of a round table of radius $R = 1.0m$. Its luminance does not depend on direction and is equal illuminant be suspended to provide maximum illuminance at the circumference of the table ? How great will that illuminance be? The liuminant is assumed to be a point source.

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7. A point source is suspended at a hight $h = 1.0m$ over the centre of a round table of radius $R = 1.0m$. The luminous intensity I of the source depends on direction so that illuminance at all points of the table is the same. Find the function $I(\theta)$, where θ is the angle between the radiation direction and the vertical, as well as the luminous flux reaching the table if $I(0) = I_0 = 100cd$.

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8. A vertical shaft of light from a projector forms a light spot $S = 100cm^2$ in area on the celling of a round room of radius $R = 2.0m$. The illuminance of the spot is equal to $E = 10001x$. The reflection coeffiecient of the celling is equal to $\rho = 0.80$. find the maximum illuminance of the well produced by the light reflected from the celling. the reflection is assumed to obey Lambert's law.

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9. A luminous done shaped as a hemisphere rests on a horizontal plane. Its luminosity is uniform. Determine the illuminance at the centre of that plane if its luminance equals L and is independent of direction.

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10. A Lambert source has the from of an infinite plane. Its luminance is equal to L. Find the illuminance of an area element oriented parallel to the given source.

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11. An illuminant shaped as a plane horizontal disc of raiud $R = 25cm$ is suspended over a table at a hight $h = 75cm$. The illuminance of the table below the cnetre of the illuminant is equal to $E_0 = 70Ix$. Assuming the source to obey Lambert's law, find its luminosity.

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12. A small lamp having the form of a unfromly luminous sphere of radius $R = \frac{6}{0}cm$ is suspended at a height $h = 3.0m$ above the floor. The luminance o fthe lamp is equal to

$L = 2.0. 10^4 cd/m^2$ and is independent of direction. Find the illuminance of the floor directly below the lamp.

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13. Write the law of reflection of a light beam from a mirror in vector from, using the directing unit vectors e and e' of the incident and reflected beams and the unit vector n of the outside normal to the mirror surrfcae.

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14. Demostrate that a light beam reflected from three mutually perpendicular plane mirrors in succession reverses its direction.

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15. At what value of the angle of incident θ_1 is a shaft of light reflected from the surface of water perpendicular to the refracted shaft?

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16. Two optical media have a plane boundary between them. Suppose θ_{1cr} is the critical angle of incidence of a beam and θ_1 is the angle of incidence at which the refracted beam is perpendicular to the reflected one (the beam is assumed to come from an optically denser medium). Find the relective index of these media if $\sin\theta_{1cr}/\sin\theta_1 = \eta = 1.28$.

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17. A light beam falls upon a plane-parallel glass plate $d = 6.0cm$ in thickness. The angle of incidence is $\theta = 60^\circ$. Find the value of deflection of the beam which passed through that plate.

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18. A man standing on the bottom. The depth o fthe swimming pool looks at a stone lying on the bootom. The depth of the swimming pool is equal to h. At what distance from the surafce of water is the image of the stone formed if the line of vision makes an angle $\theta$with the normal to the surface?

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19. Demonstrate that in a prism with small refracting angle θ the shaft of light deviates through the angle $\alpha \approx (n-1)\theta$ regard less of the angle of incidence, provided that the latter is also small.

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20. Demonstrate that in a prism with small refracting angle θ the shaft of light deviates through the angle $\alpha \approx (n-1)\theta$ regard less of the angle of incidence, provided that the latter is also small.

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21. The least deflection angle of a ceratin glass prism is equal to its refracting angle. Find the latter.

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22. Find the minimum and maximum deflectrion angls for a light ray passing through a glass prism with refracting angle $\theta = 60^\circ$.

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23. A trihedral prism with refracting angle 60° provides the least deflection angle 37° in air. Find the least deflection angle of that prism in water.

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24. A light ray composed of two monochromatic components passes through a trihedral prism with refracting angle $\theta = 60^\circ$. Find the angle $\Delta\alpha$ between the components of the ray after its passage through the prism if their respective indies of refraction are equal to 1.515 and 1.520.

the prism is oriented to provide the least deflection angle.

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25. Using Fermat's principle derive the laws of deflection and refraction of light on the plane interface between two media.

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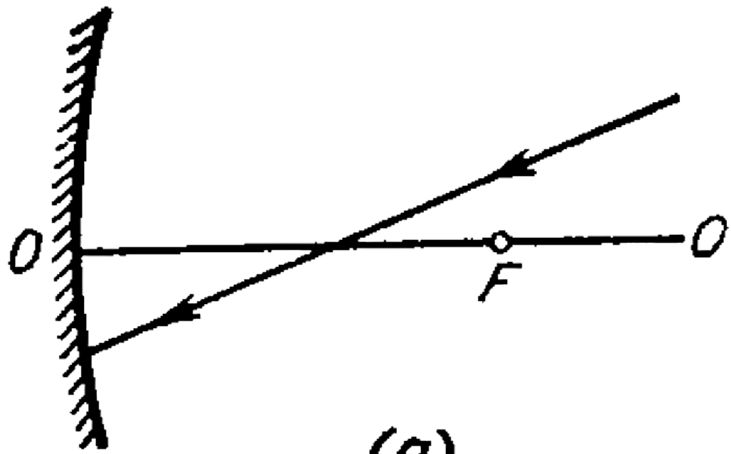
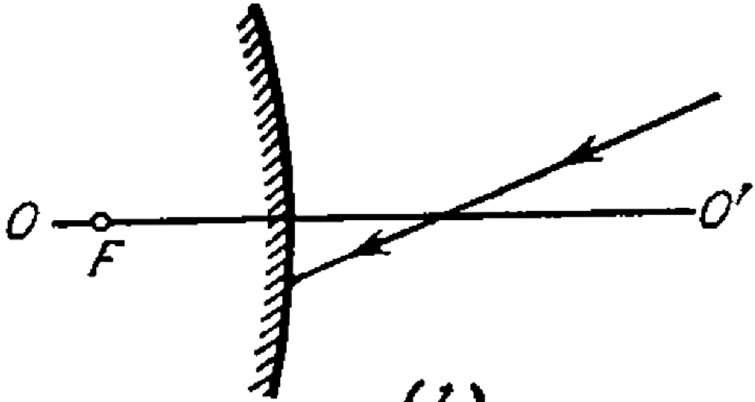
26. By means of plotting find :

(a) the path of a light ray after reflectin from a concave and convex spherical mirrors (see Fig. where F is the focal point, OO' is the optical axis) ,



(a)

(b) the positions of the mirror and its focal point in the cases illunstrated in Fig. where P and P' are the conjugate points.



(b)

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27. Determine the focal length of a concave mirror if:

(a) with the distance between an object and its image being equal to $l = 15cm$, the transverse magnification $\beta = 02.0$,

(b) in a certain position of the object the transverse magnification is $\beta_1 = -0.50$ and in another position displaced with respect to the former by a distance $l = 5.0cm$ the transverse magnification $\beta_2 = -0.25$.

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28. A point source with luminous intensity $I_0 = 100cd$ is positioned at a distance $s = 20.0cm$ from the crest of a concave mirror with focal length $f = 25.0cm$. Find the luminous intensity of the reflected ray if the reflection coefficient of the mirror is $\rho = 0.80$.

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29. Proceeding from Fermat'sprinciple derive the refraction formula for paraxial rays on a spherical boundary surface of radius R between media with refractive indices n and n'.

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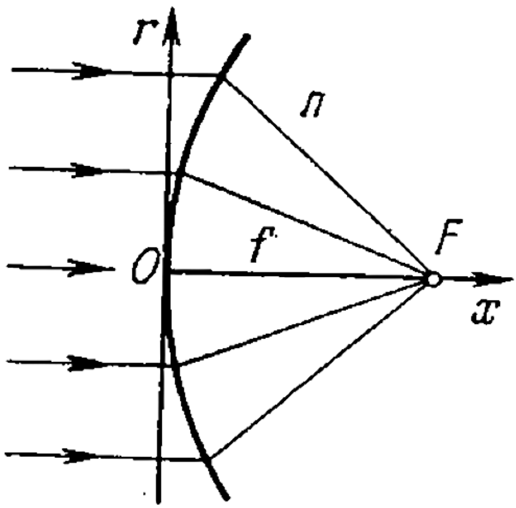
30. A parallel beam of light falls from vacuum on a surface enclosing a medium with refractive3 index n (Fig.) Find the shape of that surface, $x(r)$ if the beam is brought into focus at the point F at a distance f from the crest O. What is the maximum radius of a beam that can still be focussed ?



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31. A point source is located at a distance of $20cm$ from the front surface of a symmetrical glass biconvex lens. The lens is $5.0cm$ thick and the curvature radius of its surfaces is $5.0cm$. How far beyond the rear surface of this lens is the image of the source fromed ?

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32. An object is placed in front of convex surface of a glass plano-convex lens of thickness $d = 9.0cm$. The image of that object is formed on the plane surface of the lens serving as a screen. Find:

(a) the transverse magnification if the curvature radius of the lens's convex surface is $R = 2.5cm$,

(b) the image illuminance if the luminance of the object i s$L = 7700cd/m^2$ and the entrance apertune diameter of the lens is $D = 5.0mm$, losses of light are negligible.

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33. Find the optical power and the focal lengths

(a) of a thin glass lens in liquid with refractive index $n_0 = 1.7$ if its optical power in air is $\Phi_0 = 5.0D$,

(b) of a thin symmetrical biconvex glass lens, with air on one side and water on the other side, if the optical power of that lens in air is $\Phi_0 = +10D$.

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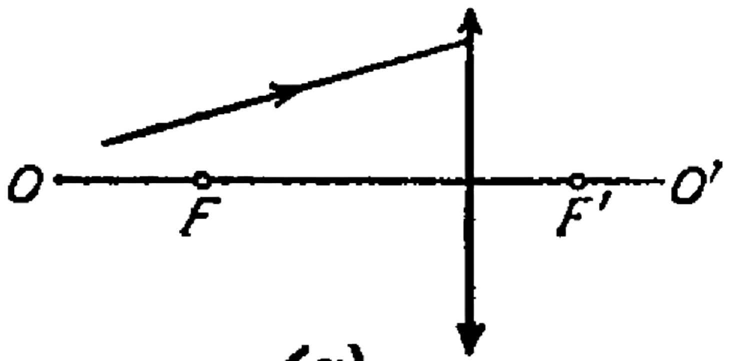
34. By means of plotting find :

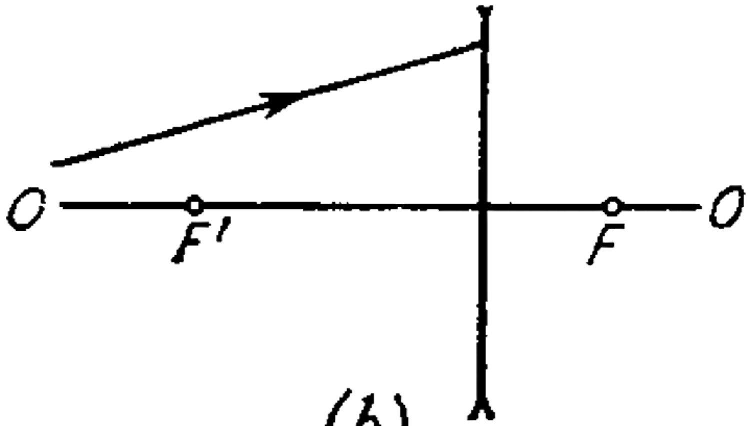
(a) the path of a ray of light beyound thin converging and diverging lenses (Fig. where OO' is the optical axis, F and F' are the front and rear focal points),



(a)

(b) the position of a thin lens and its focal points if the position of the optical axis OO' and the positions of the cojugate3 points P, P (see Fig.) are knows , the media on both sides of the lenses are identical,

(c) the path of ray 2 beyond the converging and diverging lenses (Fig.) if the path of ray 1 and the positions of the lens and of its



(b)

optical axis OO' are all known, the media on both sides of the lenses are identical.

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35. A thin converging lens with focal length $f = 25cm$ projects the image of an object on a screen removed from the lens by a distance

$l = \quad = 5.0m$. Then the screen was draws closer to the lens by a distance $\Delta l = 18cm$. By what distance should the object be shifted for its image to become sharp again ?

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36. A source of light is located at a disatnce $l = 90cm$ from a screen. A thin converging lens provides the sharp image of the source when placed between the source of light and the screen at two positions. Determine the focal length o fthe lens if

(a) the distance between the two positions of the lens is $\Delta l = 30cm$,

(b) the transverse diamensions of the image at one position o fthe lens are $\eta = 4.0$ greater than those at the pther position.

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37. A thin converging lens is placed between an object and a screen whose the sharp image of the object is formed on the screen. Find the transverse diamension of the object if at one position of the lens the image diamension equals $h' = 2.0mm$ and at the other, $h'' = 4.5mm$.

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38. A thin converging lens with aperture ratio $D:f = 1:35$(D is the lens diameter, f is its focal length) provided the image of a sufficiently distance object on a photographic plate. The object luminance is $L = 260cd/m^2$. The losses of light in the lens amount to $\alpha = 0.10$. Find the illuminance of the image.

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39. How does the illuminance of a real image depend on diameter D of a thin converging lens if that image is observed

(a) directly,

(b) on a white screen backscatting according to Lamber's law ?

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40. There are two thin symmetrical lenses : one is converging , with refractive index $n_1 = 1.70$, and the other is diverging with refractive index

$n_2 = 1.51$. Both lenses have the same curavature close together and submerged into whater. What is the focal length of this system in water ?

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41. Determine the focal length of a concave spherical mirror which is manufactured in the form of a thin symmetric biconvex glass lens one of whose surfaces is silvered. The curvature radius of the lens surface is $R = 40cm$.

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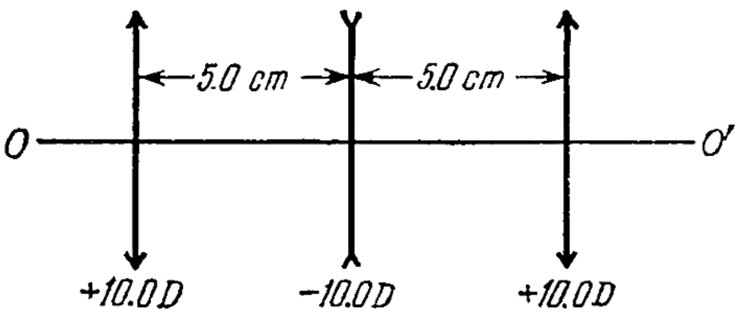
42. Figure illustrates an aligned system consisting of three thin lenses. The system is located in air. Determine:



(a) the position of the point of convergence of a parallel incoming from the left after passing through the system,

(b) the distance between teh first lens and a point lying on the axis to the left of the system, at which that point and its image are located symmetrically with respect to the lens system.

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43. A Galilean telescope of 10-fold magnification has the length of $45cm$ when adjusted to infinity. Determine :

(a) the focal lengths of the telescope's objective and ocular,

(b) by what distance the ocualr should be displaced to adjust the telescope to the distance of $50m$.

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44. Find the magnification of a Keplerian telescope adjusted to infinity if the mounting of the objective has s diamter D and the image of that mounting formed by the telescope's ocular has a diameter d.

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45. On passing thorugh a telescope a flux of light increases its intensity $\eta = 4.0.10^4$ times. Find the angular dimension of a distance object if its image formed by that telescope has an angualr dimension $\Psi = 2.0^\circ$.

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46. A Keplerian telescope with magnification $T = 15$ was submerged into water which filled up the inside of the telescope. To make the system work as a telescope again within the former dimensions, the objective was replaced. What has the magnification of the telescope become equal to ? the refractive index of the glass of which the ocular is made is equal to $n = 1.50$.

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47. At what magnification T of a telescope with a diameter of the objective $D = 6.0cm$ is the illuminance of the image of an object on the retina not less than without the telescope ? The pupil diameter is assumed do be equal to $d_0 = 3.0mm$. The losses of light in the telescope are negligible.

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48. The optical powers of the objective and the ocular of a microscope are equal to 100 and $20D$ respectively. The microscope magnification is equal to $50.$ What will the magnification o fthe microscope be when the distance between the objected and the ocaular is increased by $2.0cm$?

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49. A microscope has numberical apertune $\sin\alpha = 0.12$, where α is the aperture angle subtended by the entrance pupil of the microscope. Assuming the diameter of an eye's pupil to be equal to $d_0 = 4.0mm$ determine the microscope magnification at which

(a) the diameter of the beam of light coming from the microscope is equal to the diameter of the eye's pupil,

(b) the illuminance of the image on the retina is independent of magnification (consider the case when the beam of light passing through teh sysytem "microscope-eye" is bounded by the mounting of the objective).

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50. Find the positions of the perinciple planes, the focal and model points of a thin biconvex symmetric glass lens with curvature radius of its surfaces equal to $R = 7.50cm$. There is air on one side of the lens and water on the other.

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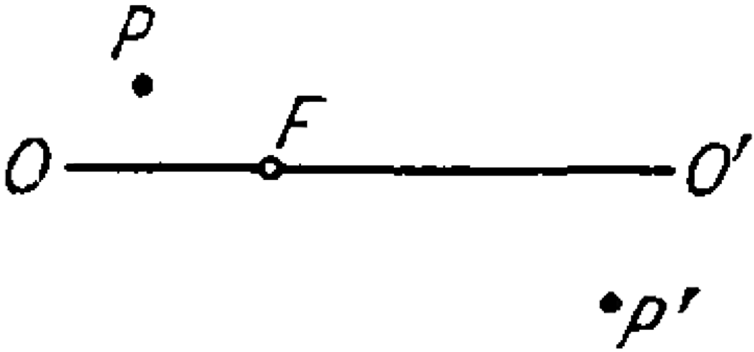
51. An optical system is located in air. Let OO' be its optical axis, F' and F' are the front and rear focal points, H and H' are the front and rear principle planes, P and P' are the conjugate points. By means of plotting find:

(a) the position F' and H' (Fig.),

(b) the position of the point S' conjugate to the point S (Fig.),



(c) the positions F, F', and H' (Fig. where the path of the ray of light is shown before and after pasing through the system).

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52. Suppose F' and F' are the front and rear focqal points of an optical system, and H' and H' are its front and rear principle points. By means of plotting relative positions of the points $S, F, F', H,$ and H':

(a) $FSHH'F'$, (b) $HSF'FH'$, (c) $H'S'FH$, (d) $F'H'SHF$.

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53. A telephoton lens consists of two lenses, the front converging lens and the rear diverging lens with optical power $\Phi_1 = +10D$ and $\Phi_2 = -10D$. Find:

(a) the focal length and the positions of principle axes of that system if the lenses are seperated by a distance $d = 4.0cm$, (b) the distance d between the lenses at which the ratio of a focal length f of the system to a distance l between the converging lens and the rear principle focal points is the highest. what is this ratio equal to ?

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54. Calculate the positions of the principle planes and focal points of a thick convex-concave glass lens if the curvature radius of the convex surface is equal to $R_1 = 10.0cm$ and of the concave surface to $R_2 = 5.0cm$ and the lens thickness is $d = 3.0cm.$

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55. An aligned optical system consists of two thin lenses with focal lengths f_1 and f_2, the distance between the lenses being equal to d. The given system has to be replaced by one thin lens which, at any position of an object, would provide the same transverse magnification as the system. what must the focal length of this lens be equal to and in what position must it be placed with respect to the two-lens system?

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56. A system consists of a thin symmetrical converging glass lens with the curvature radius of its surfcaes $R = 38cm$ and a plane mirror oriented at right angles to the optical axis of the lens. What is the optical power of this system when the space between the lens and the mirror is filed up with water ?

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57. At what thickness will a thick convex-cancave glass lens in air

(a) serve as a telescope provided the curvature radius of its convex surface is $\Delta R = 1.5cm$ greater than that of its concave surface?

(b) have the optical equal to $-1.0D$ if the curvature radii of its convex and concave surfaces are equal to 10.0 and $7.5cm$ respectively ?

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58. Find the poistions of the principle planes, the focal length and the sign of the optical power of a thick convex-concave glass lens

(a) whose thickness is equal to d and curvature radii of the surfaces are the same and equal to R,

(b) whose refractive surfaces are concentric and have the curvarure radii R_1 and $R_2 (R_2 > R_1)$.

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59. A telephoton system consists of two glass balls with radii $R_1 = 5.0 cm$ and $R_2 = 1.0 cm$. What are the distance between the centres of the balls and the magnification of the system if the bigger ball serves as no objective ?

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60. Two identical thick symmetrical biconvex lenses are put close together. The thickness of each equals the curvature radius of its surfaces, i.e $d = R = 3.0cm$. Find the optical power of this system in air.

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61. A ray of light propagating in an isotropic medium with refractive index n varying gradually from point to points has a curvature radius ρ determined by the formula

$$\frac{1}{\rho} = \frac{\partial}{\partial N}(Inn),$$

where the derivative is taken with respect to the principle normal to the ray. Derivethis formula, assuming that is such a medium the law of refraction $n \sin \theta =$ const holds. Here θ is the angle between the ray and the direction of the vector Δn at a given point.

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62. Find the curvature radius of a ray of light propagating in a horizontal direction close to the Earth's surface where the gradient of the refractive index in air is equal to approximately $3.10^{-8}m^{-1}$. At what value of that gradient would the ray of light propagate all the way round the Earth?

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Interference Of Light

1. Demonstrate that when two harmonic oscillations are added, the time-averged energy of the resultant oscillation is equal to the sun of the energies of the consituent osciallations, if both of them

(a) have the same direction and are incoherent, and all the values of the phase difference between the oscillations are equal probable,

(b) are mutually perpendicular, ahve teh same frequency and an arbitary phase difference.

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2. By means of plotting find the amplitude of the oscillation resulting from the addition of the following three oscillations of the same direction:

$\xi_1 = a\cos\omega t, \xi_2 = 2a\sin\omega t, \xi_3 = 1.5a\cos(\omega t + \pi/3)$

.

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3. A certain oscillation results from the addition of coherent oscillations of the same direction results from the addition of coherent where k is the number of the oscillation $(k = 1, 2, \ldots\ldots\ldots, N)$, φ is the phase difference between the kth and ~$(k-1)th$ oscillations. Find the amplitude of the resultant oscillation.

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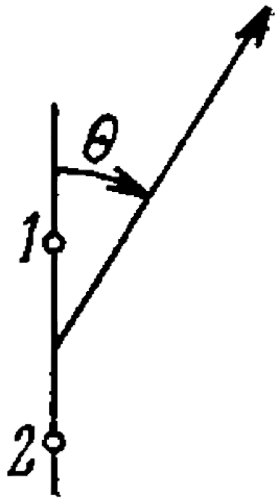
4. A system illustrated in Fig. consists of two coherent point sources 1 and 2 located in a certain plane so that their dipole moments are oriented at right angles to that plane. The sources are separated by a disatnce d, the radiation wavelength is equal to λ. Taking into account that the oscillations of source I by $\varphi(\varphi < \pi)$, find:

(a) the angles θ at which the radiation intensity is maximum,

(b) the conditions under which the radiation intensity in the direction $\theta = \pi$ is maximum and in the opposite direction, minimum.



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5. A stationary radiating system consists of a linear chain of parallel oscillators separated by a distance d, with the oscillation phase varting linearly along the chain. Find the time oscillators at which the principle radiation maximum of the system will be "scanning" the surroundings with the constant angular velocity ω.

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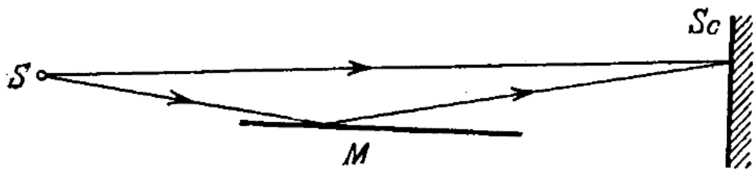
6. In Lloyd's mirror experiment (Fig.) a light wave emitted directly be the source S (narrow slit) interferes with the wave reflected form a mirror M.

As s result, an interference fringe pattern is



formed on the screen Sc. the source and the mirror are separated by a distance $l = 100cm$.At a certain position of the source the fringe width on the screen was equal to $\Delta x = 0.25mm$, and after source was moved away from the mirror plane by $\Delta h = 0.60mm$, the fringe width decreased $\eta = 1.5$ times. Find the wavelength of light.

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7. Two coherent plane light waves propagating with a divergence angle $\psi < \; < 1$ fall almost normally on a screen. The amplitudes neighbouring maxima on the screen is equal to $\Delta x = \lambda / \psi$, where λ is the wavelength.

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8. Figure. Illustrates the interference axperiment with Fresnel mirrors. The angle between the mirrors is $\alpha = 12'$ the distance from the mirrors intersection line to the narrow slit S and the screen Sc are equal to $r = 10.0cm$ and $b = 130cm$ resoectively. the wavelength of light is $\lambda = 0.55\mu m$

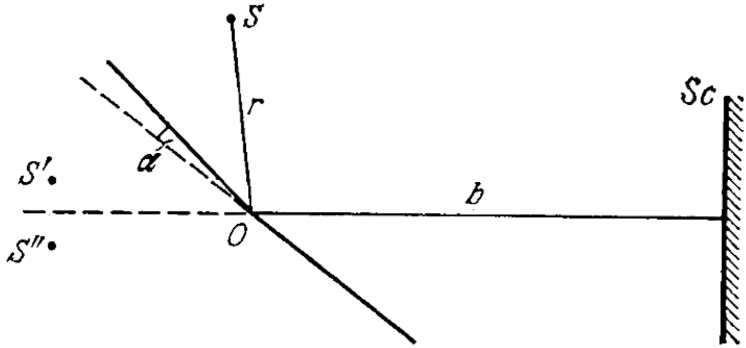
. Find:

(a) the width of a fringe on the screen and the number of possible maxima,

(b) the shift of the interference pattern on the screen when the slit is displaced by $\partial l = 1.0mm$ along the are of radius r with centre at the point O

,

(c) at what maximum width $\partial_{\max}$ of the slit the interference fringes on the screen are still observed sufficiently sharp.



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9. A plane light wave falls on Fresnel mirrors with an angle $\alpha = 2.0$ between them. Determine the wavelength of light if the width of the fringe on the screen $\Delta x = 0.55mm.$

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10. A lens of diameter $5.0cm$ and focal length $f = 25.0cm$ was cut along the diameter into two identical halves. In the process, the layer of the lens $\alpha = 1.00mm$ in thieckness was lost. Then the halves were put together to form a composite lens. In this focal plane a narrow slit was placed, emitting monochromatic light with wavelength $\lambda = 0.60\mu m$. Behind the lens a screen was located at a distance $b = 50cm$ from it. Find:

(a) the which of a fringe on the screen and the number of possible maxima,

(b) the maximum width of the slit $\partial_{\max}$ at which the fringes on the screen will be still observed sufficiently sharp.

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11. The distances from a Fresnel prisum to a narrow slit and a screen are equal to $a = 25cm$ and $b = 100cm$ respectively. The refracting angles of the glass biprism is equal to $\theta = 20$. Find the wavelength of light if the width of the fringe on the screen is $\Delta x = 0.55mm$.

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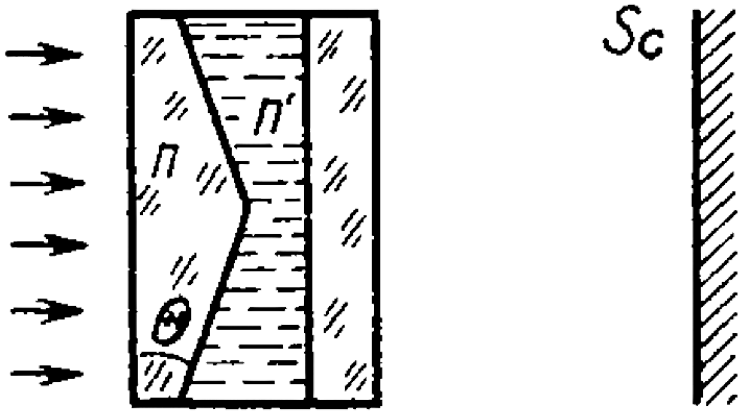
12. A palne light wave with wavelength $\lambda = 0.70\mu m$ falls normally on the base of a biprism made of glass $(n = 1.520)$ with refracting angle $\theta 5.0^{\circ}$. Behind the biprism (Fig.) there is a plane-parallel plate, with the space between them filled up with benzence $(n' = 1.500)$. Find the width of a fringe on the screen Sc placed behind this system.



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13. A plane monochromartic light wave falls normally on a diaphragm with two narrow slist separated bya distance $d = 2.5mm$. A fringe pattern is formed on a screen placed at a distance

$l = 100cm$ behind the diaphragm. By what distance and in which direction will these fringes be dispalced when one of the slits is covered by a glass plate of thickness $h = 10\mu m$?

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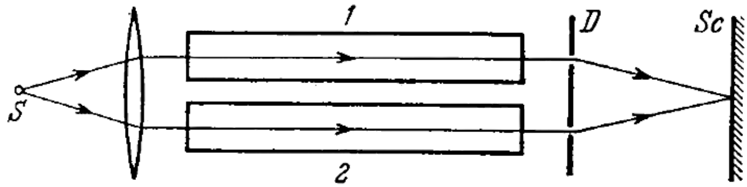
14. Figure illumstrates an interferometer used in measurements of refreactive indices of transparent substances. Here S is



a narrow slit illuminated by monochromatic light with wavelength $\lambda = 589nm$, 1 and 2 are identical tubes with air of length $l = 10.0cm$ each, D is a diaphragm with two slits. After the air in tube I was replaced with ammonia gas, the interference pattern on the screen Sc was displaced upwards by $N = 17$ fringes. The refreactive indec of air is equal to $n = 1.000277$. Determine the refractive index of ammonia gas.

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15. An electromagentic wave falls normally on the boundary between two isotropic dielectrics with refractive indies n_1 and n_2. Making use of the continuity condition for the tangential components, E and H across the boundary, demonstrate that at the interface teh electric field vector E

(a) of the transmitted wave experienced no Phase jump,

(b) of the reflected wave is subjected to the phase jump equal to π refractive from a medium of higher optical density.

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16. A parallel beam of white light falls on a thin film whose refractive index is equal to $n = 1.33$. The angle of indices is $\theta_1 = 52^\circ$. What must be the film thickness be equal to for the reflected light to be coloured yellow $(\lambda = 0.60 \mu m)$ most intensity ?

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17. Find the minimum thickness of a film with refractive index 1.33 at which light with wavelength $0.64 \mu m$ experiences maximum reflection while light with wavelength $0.40 \mu m$ is not reflected at all. The incidence angle of light is equal to 30°.

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18. To decrease light losses due to reflection from the glass surface the latter is coated with a thin layer of substance whose refractive index $n' = \sqrt{n}$, where n is the refractive index of the glass. In this case the amplitudes of electromagnetic oscillations that coating is the glass reflectivity in the direction of the normal equal to zero for light with wavelength λ?

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19. Diffused monochromatic light with wavelength $\lambda = 0.60 \mu m$ falls on a thin film with refractive index $n = .5$. Determine the film thickness if the angular separation of neighbouring maxima observed in reflected light at the amgles close to $\theta = 45^\circ$ to the normal is equal to $\partial\theta = 3.0^\circ$.

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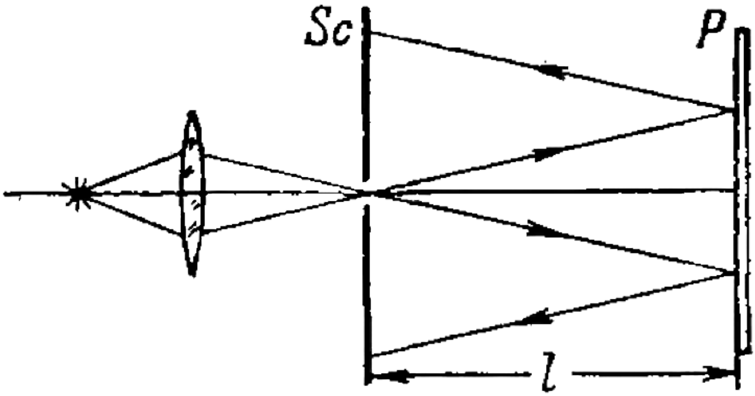
20. Monochromatic light passes through an orifice in a scrren Sc (Fig.) and being reflected from a thin transparent plate P produces fringes of equal inclinaiton on the screen. The thickness of the plate is equal to d, the distance between the plate and the screen is l, the radii of the ith and kthdark rings are r_i and r_k. find the wavalength of light taking into account that $r_{i,k} < < l$.



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21. A plane monochromatic light wave with wavelength λ falls on the surface of a glass wedge whose faces from an angle $\alpha < < 1$. The plane of incidence is perpendicualr to the edge, the angle of incidence is θ_1. Find the distance between the neighbouring fringe maxima on the screen placed at right angles to reflected light.

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22. Light with wavelength $\lambda = 0.55 \mu m$ from a distant point source falls normally on the surface of a glass wedge. A fringe pattern whose neighbouring maxima on the surface of the wedge are separated by a distance $\Delta x = 0.21 mm$ is observed in reflected light. Find:

(a) the angle between the wedge faces,

(b) the degree of light monochromatism $(\Delta\lambda / \lambda)$ if the fringes disappear at a distance $l \approx 1.5cm$ from the wedge's edge.

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23. The convex surface of a plano-convex glass lens comes into contact with a glass plate. The curvature radius of the lens's convex surface is R, the wavelength o flight is equal to λ. Find the width Δr of a Newton ring as a function of its radius r in the region where $\Delta r < \; < r$.

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24. The convex surface of a plano-convex glass lens with curvature radius $R = 40cm$ comes into contact with a glass plate. A certain ring observed in reflected light has a radius $r = 2.5mm$. Watching the given ring, the lens was gradually removed from the plate by a distance $\Delta h = 5.0\mu m$. What has the radius of that ring become equal to?

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25. At the crest of a spherical surface of a plano-convex lens there is a ground-off plane spot of radius $r_0 = 3.0mm$ through which the lens comes into contact with a glass plate. The curvature radius of the sixth bright ring when observed in reflected light with wavelength $\lambda = 655nm$.

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26. A plano-convex glass lens with curvqature radius of spherical surface $R = 12.5cm$ is pressed against a glass plate. The diameters of the tenth and fifteenth dark Newton's rings in reflected light are equal to $d_1 = 1.00mm$ and $d_2 = 1.50mm$.

Find the wavelength of light.

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27. Two plano-convex thin glass lenses are brought into contact with their spherical surfaces. Find the optical power of such a system if in reflected light with wavelength $\lambda = 0.60\mu m$ the diameter of the fifth bringht ring is $d = 1.50mm$.

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28. Two thin symmetric glass lenses, one biconvex and the other biconcave, are brought into contact to make a system with optical power $\Phi = 0.50D$. Newton's rings are observed in reflected light with wavelength $\lambda = 0.61\mu m$. Determine:

(a) the radius of the tenth dark ring,

(b) how the radius of that ring will change when the space between the lenses is filled up with water.

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29. The spherical surface of a plano-convex lens comes into contact with a glass plate. The space between the lens and the plate is filled up with carbon dioxide. The refractive indies of the lens, carbon dioxide, and the plate are equal to $n_1 = 1.50, n_2 = 1.63,$ and $n_3 = 1.70$ respectively. the curvature radius of the spherical surface of the lens is equal to $R = 100cm$. Determine the radius of the fifth dark Newton's ring in reflected light with wavelength $\lambda = 0.50\mu m$.

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30. In a two-beam interferometer the orange mercury line composed of two wavelengths $\lambda_1 = 576.97nm$ and $\lambda_2 = 579.03nm$ is employed. What is the least order of interference at which the sharpness of the fringe pattern is the worst ?

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31. In Michelson's interferometer the yellow sodium line composed of two wavelengths $\lambda_1 = 589.0nm$ and $\lambda_2 = 589.6nm$ was used. In the process of translational displacemnet of one of the mirrors the interference pattern vanished periodically (why?). Find the displacement of the mirror between two successive appearances of the sharpest pattern.

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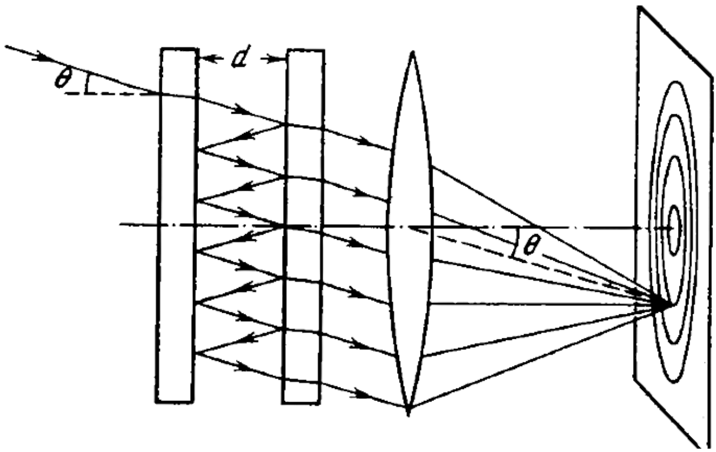
32. When a Fabry-Perot etalon is illuminated by monochrmatic light with wavelength λ an interference pattern, the system of concentric rings, appears in the focal plane of a lens (Fig.) The thickness of the etalom is equal to d. Determine how



(a) the position of rings,

(b) the angular width of fringes depends on the order of interference.

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33. For the Fabry-Perot etalon of thickness $d = 2.5 cm$ find:

(a) the highest order of interference of light with wavelength $\lambda = 0.50 \mu m$,

(b) the dispersion region $\Delta \lambda$, i.e the spectral interval of wavelengths, within which there is still no overlap with orders of interference if the observation is carried out appoximately at wavelength $\lambda = 0.50 \mu m$.

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Diffraction Of Light

1. A plane light wave falls normally on a diaphragm with round aperature opening the first N Fresnel zones for a point P on a screen located at a distance b form the diaphragm. The wavelength of light is equal to λ. Find the intensity of light I_0 in front of the diaphragm if the distribution of intensity of light $I(r)$ on the screen is knows. Here r is the distance from the point P.

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2. A point source of light with wavelength $\lambda = 0.50 \mu m$ is located at a disatnce $a = 100 cm$ in front of a diaphragm with round aperture of radius $r = 1.0mm$. Find the distance b between the diaphragm and the observation point for which the number of Fresnel zones in the aperture equals $k = 3$.

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3. A diaphram with round aperture, whose radius r can be varited during the experiment, is placed between a point source of light and a screen. The distance from the diaphram to the source and the screen are equal to $a = 100cm$ and $b = 125cm$.

determie the wavelength of light if the intensity maximum at the centre of the differaction pattern of the screen is observed at $r_1 = 1.00mm$ and the next maximum at $r_2 = 1.29mm$.

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4. A plane monochromatic light wave with intensity I_0 falls normally on an opaque screen with a round aperture. What is the intensity of light I behind the screen at the point for which the aperture

(a) is equal to the first Fresnel zone, to the internal half of the first zone,

(b) was made equal to the first Fresnel zone and then half of it was closed (along the diameter) ?

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5. A plane monochromatic light wave with intensity I_0 falls normally on an opaque disc closing the first Fresnel zone for the observation point P. What did the intensity of light I at the point P become equal to after

(a) half of the disc (along the diameter) was removed,

(b) half of the external half of the first Fresnal zone removed (along the diameter)?

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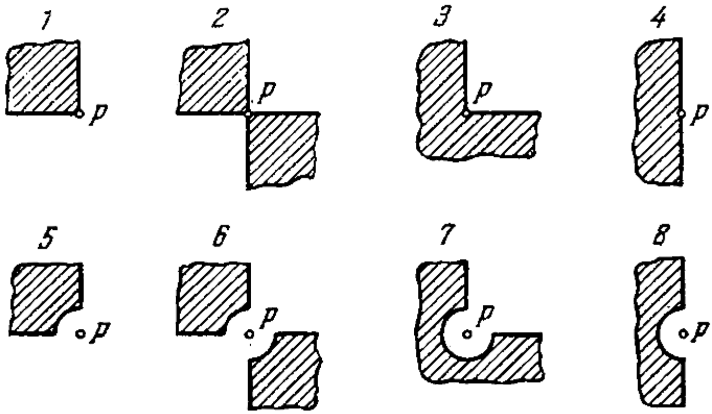
6. A plane monochromatic light wave with intensity I_0 falls normally on the surfaces of the opaque screens shown in Fig. Find the intensity of light I at a point P



(a) located behind the corner ponts of screens $1-3$ and behind the edge of half-plane 4,

(b) for which the rounded-off edge of screens $5-8$ coincides with the boundary of the first formula describing the result obtained for screens $1-4$, the same, for screens $5-8$.

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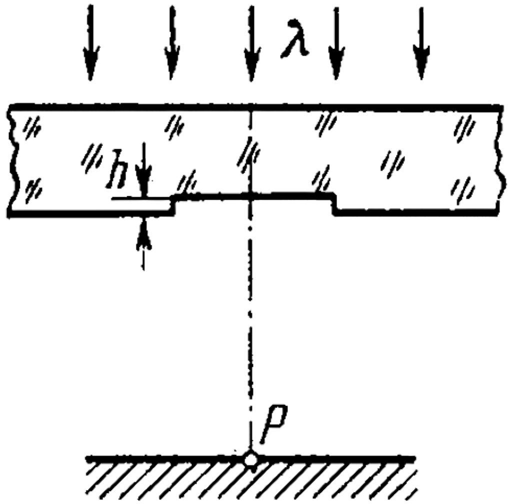
7. A plane light wave with wavelength $\lambda = 0.60\mu m$ falls normally on a sufficiently large glass plate having a round recess on the oppiste side (Fig.) For the observation point P that recess correcponds to the first one and and a half Fresnel zones. Find the depth h of the recess at which the intensity of light at the point P is

(a) maximum,

(b) minimum,

(c) equal to the intensity of incident light.



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8. A plane light wave with wavelength λ and intensity I_0 falls normally on a large glass plate whose opposite side serves as an opaque screen with a round aperture equal to the first Fresnel zone for the observation point P. In the middle of the aperture there is a round recess equal to half the Fresnel zone. What must the depth h of that recess be for the intensity of light at the point P to be the highest? What is this intensity equal to?

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9. A plane light wave with wavelength $\lambda = 0.57 \mu m$ falls normally on a suface on a surface of a glass $(n = 1.60)$ disc which shuts one and a half Fresnel zones for the observation point P. What must the minimum thickness of that disc be for the intensity of light at the point P to be the highest ? Take into account the interference of light on its passing through the disc.

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10. A plane light wave with wavelength $\lambda = 0.54 \mu m$ goes through a thin converging lens with focal length $f = 50 cm$ and an aperture stop fixed immediately after lens, and reaches a screen placed at a distance $b = 75 cm$ from the aperture stop. At what aperture radii has the centre of the differaction pattern on the screen the maximum illuminance ?

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11. A plane monochromatic light wave falls normally on a round aperture. At a distance $b = 9.0m$ from it there is a screen showing a certain diffraction pattern. The aperture diameter was decreased $\eta = 3.0$ times. Find the new distance b' at which the screen should be positioned to obtain the diffraction pattern simialer to the previous one but diminished η times.

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12. An opaque ball of diameter $D = 40mm$ is placed between a source of light with wavelength $\lambda = 0.55\mu m$ and a photographic plate. The distance between the source and the ball is equal to $a = 12m$ and that between the ball and the photographic plate is equal to $b = 18m$. find:

(a) the image dimension y' on the plate if the transverse dimension of the source is $y = 6.0mm$,

(b) the minimum height of irregularities, covering the surface of the ball at random, at which the ball obstructs light.

Note: As calculations and experience shown, that happens when the height of irregularities is comparable with the width of the Fresnel zone along which the edge of an opaque screen passes.

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13. A point source of monochromatic light is positioned in front of a zone plate at a distance $a = 1.5m$ from it. The image of the source is formed at a distance $b = 1.0m$ from the plate. Find the focal length of the zone plate.

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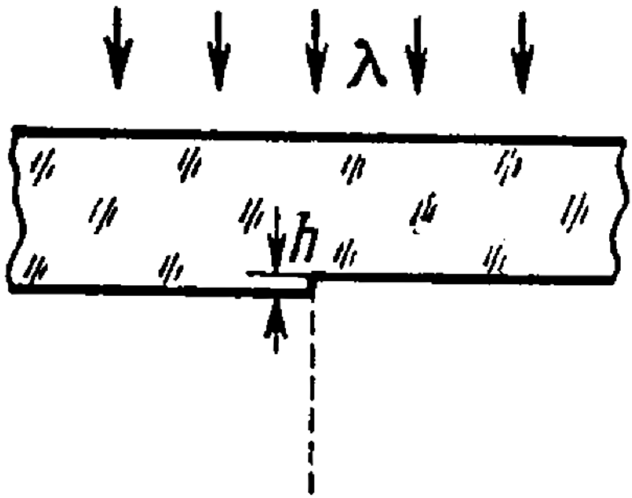
14. A plane light wave with wavelength $\lambda = 0.60 \mu m$ and intensity I_0 falls normally on a large glass plate whose side view is shown in Fig. At what height h of the ledge will be intensity of light at points located directly below be

(a) minimum,

(b) twice as low as I_0 (the losses due to reflection are to be neglected).



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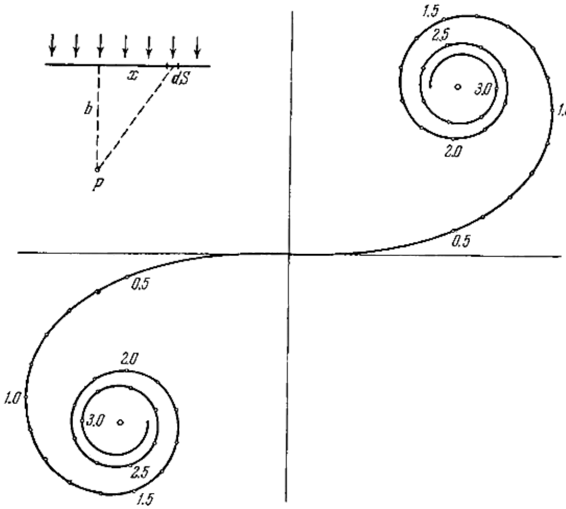
15. A plane monochromatic light wave falls normally on an opaque half-plane. A screen is located at a distance $b = 100 cm$ behind the half-plane. Making use of the cornu spiral (Fig.) find :

(a) the ratio of intensities of the first maximum and the neighbouring minimum,

(b) the wavelength of light if the first two maxima are separated by a distance $\Delta x = 0.63 mm$.



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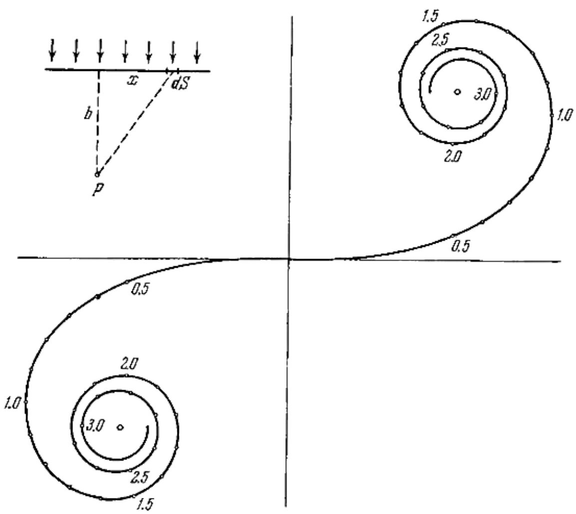
16. A plane light wave wityh wavelength $0.60\mu m$ falls normally on a long opaque strip $0.70mm$ wide. Behind it a screen is placed at a distance $100cm$. Using Fig. find the ratio of intensities of light in the middle of the diffraction pattern and at the edge of the geometrical shadow.



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17. A palne monochromatic ligth wave falls normally on a long rectangular slit behind which a screen is positioned at a distance $b = 60cm$. First the width of the slit has adjucted so that in the middle of the diffraction pattern the lowest minimum was observed. After widening the slit by $\Delta h 0.70mm$, the next minimum was obtained in the centre of the pattern. Find the wavelength of light.

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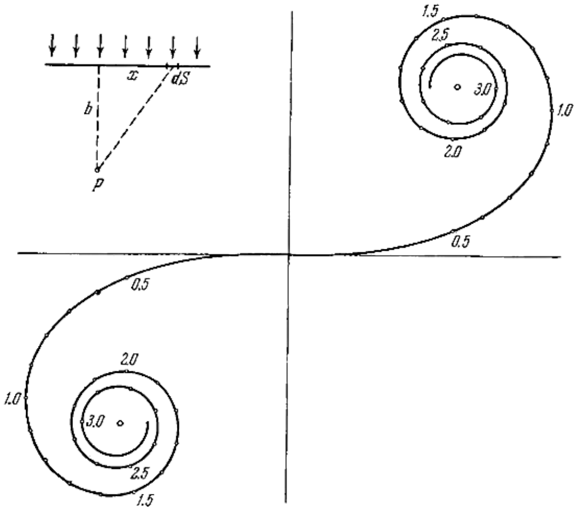
18. A plane light wave with wavelength $\lambda = 0.65\mu m$ falls normally on a large glass plate whose opposite side has a longrectangular recess $0.60mm$ wide. Using Fig. find the depth H of the recess at which the diffraction pattern on the screen $77cm$ away from the plate has the maximum illuminance at its centre.



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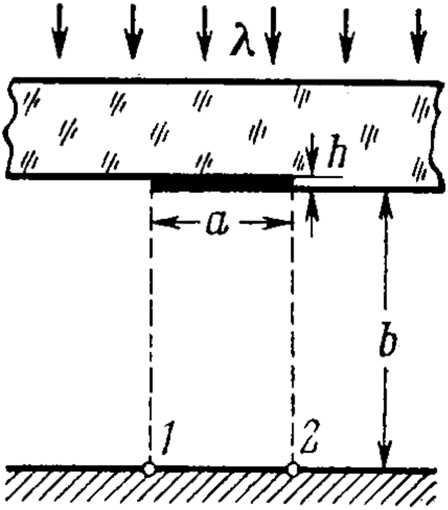
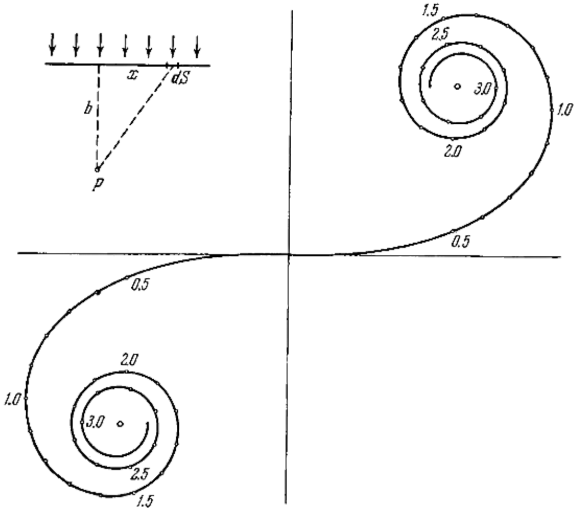
19. A plane light wave with wavelength $\lambda = 0.65\mu m$ falls normally on a large glass plate whose opposite side has a large and an opaque strip of width $a = 0.30mm$ (Fig.) A screen is placed at a distance $b = 110cm$ from the plate. The height h of the ledge is such that the intensity of light at point 2 of the screen is the heighest possible. making use of Fig. find the ratio of intensities at point 1 and 2.





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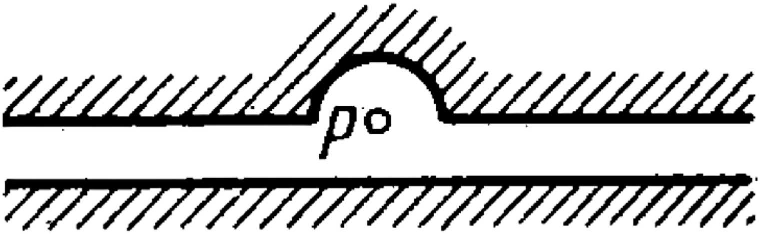
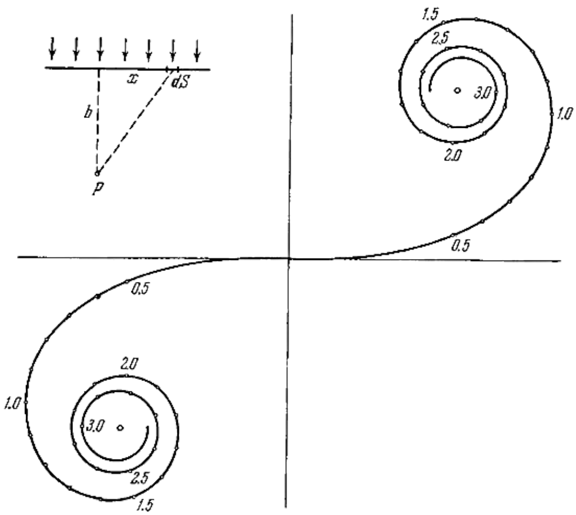
20. A plane monochromatic light wave of intensity I_0 falls normally on an opaque screen with a long slit having a semicircular cut on one side (Fig.) The edge of the cut coincides with the boundary line of the first Fresnel zone for the observation point P. Thw width of the slit measure 0.90 of the radius of the cut. using Fig. find the intensity of light at the point P.





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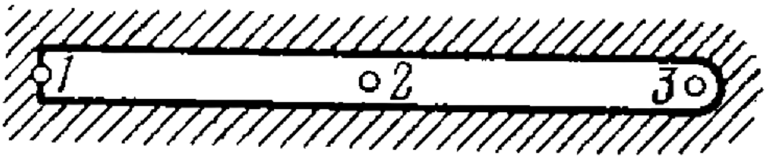
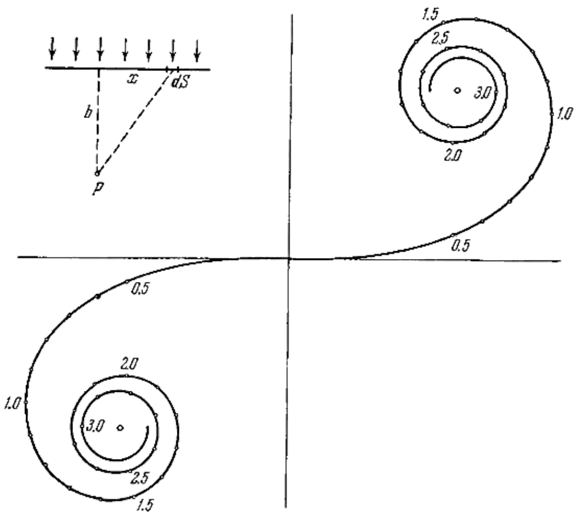
21. A plane monochromatic light wave falls normally on an opaque screen with a long slit whose shape is shown in Fig. Making use of Fig. find the ratio of intensities of light at points $1, 2$ and 3 located behind the screen at equal distances from it. For point 3 the rounded-off edge of the slit coincides with the boundary line of the first Fresnel zone.





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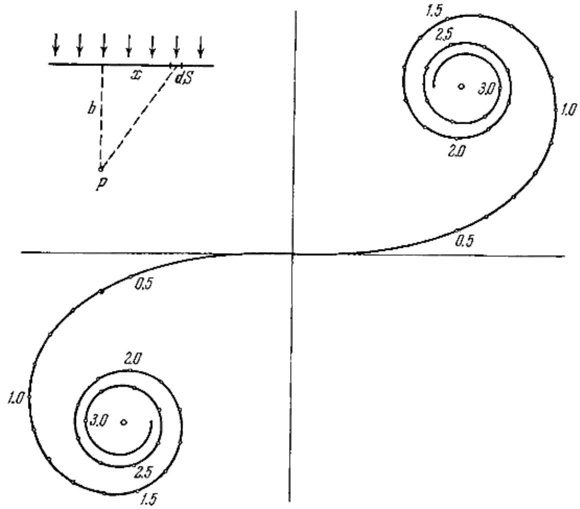
22. A plane monochromatic light wave falls normally on an opaque screen shaped as a long strip with a round hole in the middle. For the observation point P the hole corresponds to half the Fresnel zone, with the hole diameter being $\eta = 1.07$ times less then the width of the strip. Using Fig. find the intensity of light at the point P provided that the intensity of the incident light is equal to I_0.



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23. Light with wavelength λ falls normally on a long rectangular slit of width b. Find the angular distribution of the intensity of light in the case of

Fraunhofer diffraction, as well as the angular position of minima.

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24. Making use of the result obtained in the foregoing problem, find the conditions defining the angular position of maxima of the first, the second, and the third order.

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25. Light with wavelength $\lambda = 0.50 \mu m$ falls on a slit of width $b = 10 \mu m$ at an angle $\theta_0 = 30^\circ$ to its normal. Find the angular position of the first minima located on both sides of the central Fraunhofer maximum.

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26. A plane light wave with wavelength $\lambda = 0.60 \mu m$ falls normally on the face of a glass wedge with refracting angle $\Theta = 15^\circ$. The opposite face of the wedge is opaque and has a slit of width $b = 10 \mu m$ parallel to the edge. Final:

(a) the angle $\Delta\theta$between the direction to the Fqaunhofer maximum of zeroth order and that of incident light,

(b) the angular width of the frqunhofer maximum of the zeroth order.

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27. A monochromatic beam falls on a reflection grating with period $d = 1.0mm$ at a glancing angle $\alpha_0 = 1.0^\circ$. When it is diffracted at a glancing angle $\alpha = 3.0^\circ$ a Fraunhofer maximum of second order occurs. Find the wavelength of light.

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28. Draw the approximate diffraction pattern oringinating in the case of the fraunhofer diffraction from a greating consisting of three identical slits if the ratio of the grating period to the slit width is equal to

(a) two,

(b) three.

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29. With light falling normally on a diffraction grating, the angle of diffraction of second order is equal to 45° for a wavelength $\lambda_1 = 0.65\mu m$. Find the angle of diffraction of third order for a wave length $\lambda_2 = 0.50\mu m$.

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30. Light with wavelength $535nm$ falls normally on a diffraction grating. Find its period if the diffraction angle 35° corresponds to one of the Fraunhofer maxima and the highest order of spectrum is equal to five.

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31. Find the wavelength of monochromatic light falling normally on a diffraction grating with period $d = 2.2\mu m$ if the angle between the directions to the Fraunhofer maxima of the first and the second order is equal to $\Delta\theta = 15^{\circ}$.

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32. Light with wavelength $530nm$ falls on a transparent diffraction grating with period $1.50\mu m$

. Find the angle, relative to the grating normal. At which the Fraunhofer maximum of highest order is observed provided the light falls on the grating

(a) at right angles,

(b) at the angle 60° to the normal.

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33. Light with wavelength $\lambda = 0.60 \mu m$ falls normally on a diffraction grating inscribed on a plane surfcae of a plano-curvex cylinderical glass lens with curvature radius $R = 20 cm$. The period of the grating is equal to $d = 6.0 \mu m$. Find the distance between the principle maxima of first order located symmetrically in the focal plane of that lens.

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34. A plane light wave with wavelength $\lambda = 0.50 \mu m$ falls normally on the face of a glass wedge with an angle $\Theta = 30^\circ$. On the opposite face of the wedge a transparent diffraction grating with period, $d = 2.00 \mu m$ is inscibed, whose lines are parallel to the wedge's edge. Find the angles that the direction of incident light froms with the directions to the principle Fraunhofer maxima of the zero and the first order. waht is the highest order of the spectrum? At what angle to the direction of incident light of the observed?

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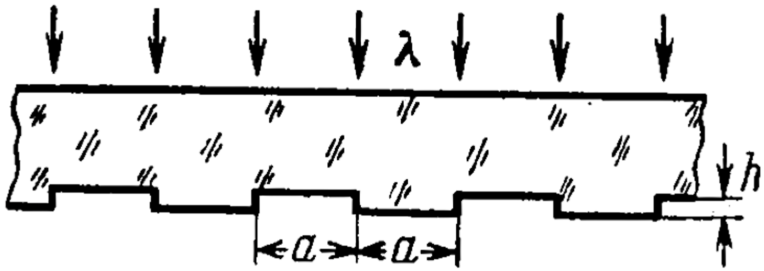
35. A plane light wave with wavelength λ falls normally on a phase diffraction grating whose side view is shown in Fig. The grating is cut on a glass plate with refractive index n. Find the depth h of the lines at which the intensity of the central Fraunhofer maximum is equal to zero. what is in this case the diffraction angle corresponding to the first maximum?



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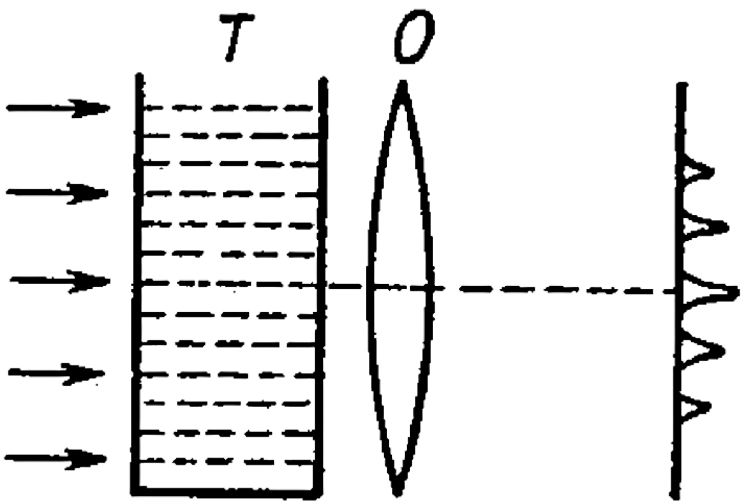
36. Figure illustrates an arrangement employed in observations of diffraction of light by ultrasound. A plate light wave with wavelength $\lambda = 0.55 \mu m$

passes through the water-filled tank T in which a standing ultrasonic wave is sustained at a frequency $v = 4.7MHz$. As a result of diffraction of light by the optically inhomogemeous periodic structure a diffraction spectrum can be observed in the foacl plane of the objective O with focal length $f = 35cm$. The separation between neighbouring maxima is $\Delta x = 0.60mm$. Find the propegation velocity of ultrasonic oscillations in water.



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37. To measure the angular diostance ψ between the components of a double star by Michelson's method, in front of a telescope's lens a diaphram was placeed, which has two narrow parallel slits separated by an adjustable disatnce d. While diminishing d, the first smearing of the pattern was observed in the focal plane of the objective at $d = 95cm$. Find ψ, assuming the wavelength of light to be equal to $\lambda = 0.55\mu m$.

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38. A transparent diffraction grating has a period $d = 1.50 \mu m$. Find the angular disperison D (in angular minutes per nanometers) corresponding to the maximum of highest order for a spectral line of wavelength $\lambda = 530 mm$ of light falling on the grating

(a) at right angles,

(b) at the angle $\theta_0 = 45^\circ$ to the normal.

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39. Light with wavelength λ falls on a diffracting grating at right angles. Find the angular dispersion of the grating as a function of diffraction angle θ.

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40. Light with wavelength $\lambda = 589.0 nm$ falls normally on a diffraction grating with period $d = 2.5 \mu m$, comprising $N = 10000$ lines. Find the angular width of the diffraction maximum of second order.

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41. Demonstrate that when light falls on a diffracting grating at right angles, the maximum resolving power of the grating cannot exceed the value l / λ, where l is the width of the grating and λ is the wavelength of light.

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42. Using a diffraction grating as a example, demonstrate that the frequency difference of two maxima resolved according to Rayleigh's criterion is equal to the reciprocal of the difference of propagation times of the exterme interfering oscillations, i.e. $\delta v = 1 / \delta t$.

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43. Light composed of two spectral lines with wavelength 600.00 and $600.050nm$ falls normally on a diffraction grating $10.0mm$ wide. At a centain diffraction angle θ these lines are close to being resolved (according to Rayleigh's criterion). Find θ.

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44. Light falls normally on a transparent diffraction grating of width $l = 6.5cm$ with 200 lines per millimetre. The spectrum under inverstigation includes a spectral line with $\lambda = 670.8nm$ consisting of two components differing by $\delta\lambda = 0.015nm$. Find:

(a) in what order of the spectrum these components will be resolved,

(b) the least difference of wavelength that can be resolved by this grating in a wavelength region $\lambda \approx 670nm$.

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45. With light falling normally on a transparent diffraction grating $10mm$ wide, it was found that the components of the yellow line of sodium $(589.0$ and $589.6nm)$ are resolved beginning with the fifth order of the spectrum. Evaluate:

(a) the period of this grating,

(b) what must be the width of the grating with the same period for a double $\lambda = 460.0nm$ whose components differ by $0.13nm$ to be resolved in the third order of the spectrum.

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46. A transparent diffraction grating of a quartz spectrograph is $25mm$ wide and has 250 lines per millimetre. The focal length of an objective in whose focal plane a photographic plate is located is equal to $80cm$. Light falls on the grating at right angles. The spectrum under investigating includes a doublet with components of wavelength 310.154 and $310.184nm$. Determine:

(a) the disatnce on the photographic plate between the components of this doublet in the spectra of the first and the second order,

(b) whether these components will be resolved in these orders of the spectrum.

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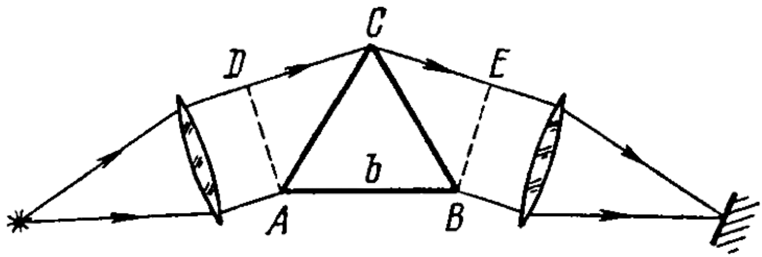
47. The ultimate resolving power $\lambda / \delta\lambda$ of the spectrograph's trihedral prism is determined by diffraction of light at the prism edges (as in the case of a slit). When the prism is oriented to the least deviation angle in accordance with Rayleigh's criterion,

$\lambda / \delta\lambda = b|dn / d\lambda|,$

where b is the width of the prism's base (Fig.) and $dn / d\lambda$ is the dispersion of its material. Derive this formula.



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48. A spectrograph's trihedral prism is manufactured from glass whose refractive index varies with wavelength as $n = A + B/\lambda^2$, where A and B are constats, with B being equal to

$0.010 \mu m^2$. Making use of the formula from the foregoing problem, find:

(a) how the resolving power of the prism depends on λ, calculate the value of $\lambda / \delta\lambda$ in the vicinity of $\lambda_1 = 434 nm$ and $\lambda_2 = 656 nm$ if the width of the prism's base is $b = 5.0 cm$,

(b) the width of the prism's base capacble of resolving the yellow doublet of sodium $(589.0$ and $589.6 nm)$.

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49. How wide is the base of a trihedral prism which has the same resolving power as a diffraaction grating with 10000 lines in the second order of the spectrum if $|dn/d\lambda| = 0.10\mu m^{-1}$?

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50. There is a telescope whose objective has a diameter $D = 5.0cm$. Find the resolving power of the objective and the minimum separation between two points at a distance $l = 3.0km$ from the telescope, which it can resolve (assume $\lambda = 0.55\mu m$).

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51. Calaculate the minimum spearation between two points on the Moon which can be resolved by a reflecting telescope with mirror diameter $5m$. The wavelength of light is assumed to be equal to $\lambda = 0.55 \mu m$.

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52. Determine the minimum multiplication of a telescope with diameter of objetive $D = 5.0 cm$

with which th resolving power of the objective is totally employed if the diameter of the eye's pupi is $d_0 = 4.0mm$.

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53. There is a microscope whose objective's numerical aperture is $\sin\alpha = 0.24$, where α is the half-angle subtended by the objective's rim. Find the minimum spearation resolved by this microscope when an object is illuminated by light with wavelength $\lambda = 0.55\mu m$.

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54. Find the minimum magnification of a microscope, whose objective's numerical apertune is $\sin \alpha = 0.24$, at which the resolving power of the objective is totally employed if the diameter of the eye's pupil is $d_0 = 4.0mm$.

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55. A beam of X-rays with wavelength λ falls at a glancing angle 60.0° on a linear chain of scattering centres with period a. Find the angles of incidence corresponding to all diffraction maxima if $\lambda = 2a/5$.

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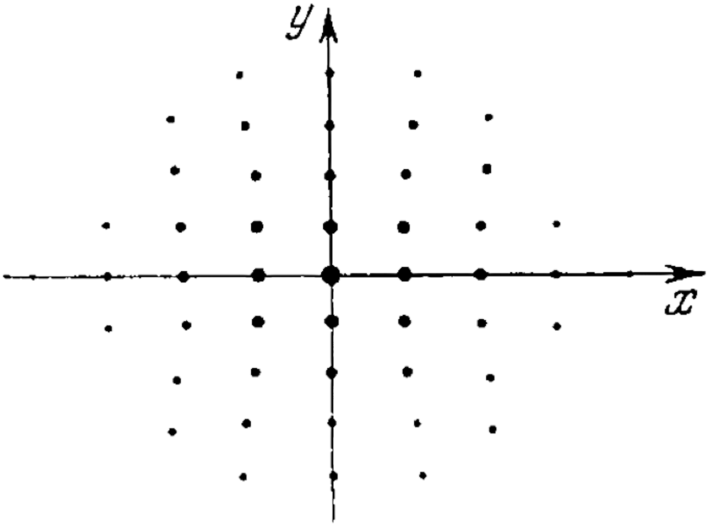
56. A beam of X-rays with wavelength $\lambda = 40 \pm$ falls normally on aplne rectangular array of scattering centres and produces a system of diffraction maxima (Fig.) on a plane screen removed from the array by a distance $l = 10cm$. Find the array periods a and b along the x and y axes if the distance between symmetrically located maxima of second order are equal to $\Delta x = 60mm$

(along the x axis) and $\Delta y = 40mm$ (along the y axis).



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57. A beam of X-rays impinges on a three-dimensional rectangular array whose periods are $a, b,$ and c. The direction of the incident beam coincides with the direction along which the array period is equal to a. Find the directions to the diffraction maxima and the wavelength at which these maxima will be observed.

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58. A narrow beam of X-rays impinges on the natural facet of a $NaCI$ single srystal, whose density is $hro = 2.16g/cm^3$ at a galancing angle $\alpha = 60.0^\circ$. The mirror reflection from this facet produces a maximum of seond order. Find the wavelength of radiation.

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59. A beam of $X-$rays with wavelength $\lambda = 174 \pm$ falls on the surface of a single crystal rotating about its axis which is parallel let to its surface and perpendicular to the direction of the incident beam. In this case the direction to the maxima of second and third order from the system of planes parallel to the surface of the single crystal from an angle $\alpha = 60^{\circ}$ between them. Find the corresponding interplanar disatnce.

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60. On transmitting a bem of Xrays with wavelength $\lambda = 17.8 \pm$ through a polycrystalline specimen a system of diffraction rings is produced on a screen located at a distance $l = 45$ cm fom the specimen. Determine the radius of the bright rind corresponding to second order of reflection from the system of planes with interplanar distance $d = 155 \pm$

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Polarization Of Light

1. A plane monochromatic wave of natural light with intensity I_0 falls normally on a screen composed of two touching Polaroid half-planes. The principle direction of one Polaroid is parallel,and of the other perpendicular, to the boundary between them. What kind of diffraction pattern is formed behind the screen? What is the intensity of light behind the screen at the points of the plane perpendicualr to the screen and passing through the boundary between the Polaroids?

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2. A plane monochromatic wave of natural light with intensity I_0 falls normally on an opaque screen with round hole corresponding to the first Fresnel zone for the observation point P. Find the intensity of light at the point P after the hole was converd with two identical Polaroids whose principle directions are mutually perpendicular and the boundary beween them passes

(a) along the diameter of the hole,

(b) along the circumference of the circle limiting the first half of the fresnel zone.

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3. A beam of plane-polarized light falls on a polarizer which rotates about the axis of the ray with angular velocity $\omega = 21 rad / s$. Find the energy of light passing through the Polarizer per one revolution if the flux of energy of the incident ray is equal to $\Phi_0 = 4.0 mW$.

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4. A beam of natural light falls on a system or $N = 6$ Nicolprisms whose transmission planes are turned each through an angle $\varphi = 30^\circ$ with respect to that of the foregoing prism. What fraction of luminous flux passes through this system ?

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5. Natural light falls on a system of three identical in-line Polaroids the principle direction of the middle Polaroid forming an angle $\varphi = 60^\circ$ with those of two other Polaroids. The maximum transmission coefficient of each Polaroid is equal to $\tau = 0.81$ when plane-polarized light falls on them. How many times will the intensity of the light decrease after its passing through the system?

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6. The degree of polarization of partially polarized light is $P = 0.25$. Find the ratio of intensities of the polarized component of this light and the natural component.

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7. A Nicol prism is placed in the way of partially polarized beam of light. When the prism is turned from the position of maximum transmission through an angle $\varphi = 60^\circ$, the intensity of transmitted light decreased by a factor of $\eta = 3.0$.

Find the degree of polarization of incident light.

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8. Two identical imperfect polarizers are placed in the way of a natural beam of light. When the polarizers' planes are parallel, the system transmits $\eta = 10.0$ times more than in the case of crossed planes. Find the dergee of polarization of light produced

(a) by each polarizer separately,

(b) by the whole system when the planes of the polarizers are parallel.

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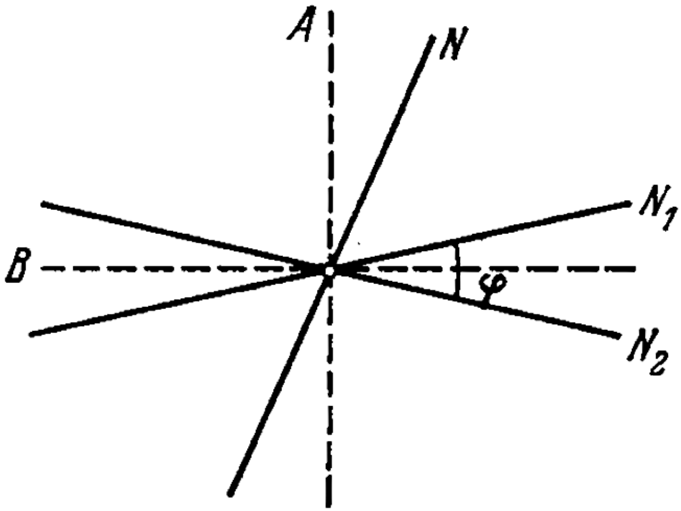
9. Two parallel plane-polarized beams of light of equal intesity whose oscillation planes N_1 and N_2 from a small angle φ between them (Fig.) fall on a Nicol prism. To equalize the intensities of the beams emerging behind the prism, its principle direction N must be aligned along the bisecting line A or B. find the value of the angle φ at which the rotation of the Nicol prism through a small angle $\delta\varphi << \varphi$ from the position A results in the fractional change of intensities of the beams $\Delta I / I$ by the value $\eta = 100$ times exceeding that resulting due to rotation through the same angle from the position B.



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10. Resorting to the Fresnel equations, demonstrate that light reflected from the surface of dielectric will be totally polarized if the angle of incidence θ_1 satisfies the condition $\tan\theta_1 = n$, where n is the refractive index of the dielectric. What is in this case the angle between the reflected and refracted rays?

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11. Natural light falls at the Brewster angle on the surfcae of glass. Using the Fresnel equations, find

(a) the reflection coefficient,

(b) the degree of polarization of refracted light.

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12. A plane beam of natural light with intensity I_0 falls on the surface of water at the Brewster angle. A fraction $\rho = 0.039$ of luminous flux is reflected. Find the intensity of the refracted beam.

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13. A beam of plane-polarized light falls on the surface of water at the Brewster angle. The polarization plane of the electric vector of the electromagnetic wave makes an angle $\varphi = 45^\circ$ with the incidence plane. Find the reflection coefficient.

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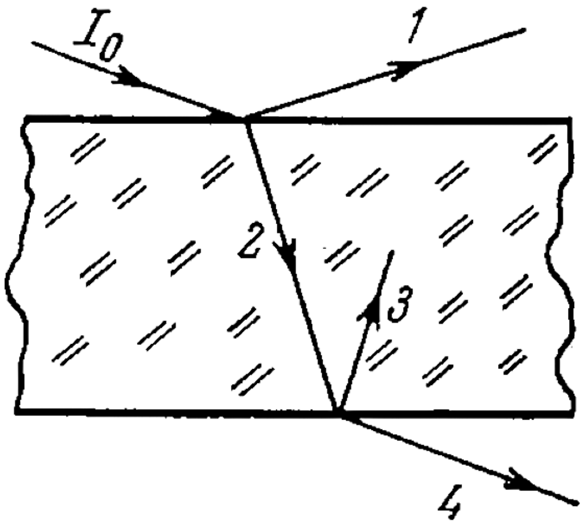
14. A narrow beam of natural light falls on the surface of a thick transparent plane-parallel plate at the Brewster angle. Its top surface. Find the degree of polarization of beams $1-4$ (Fig.)



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15. A plane beam of natural light with intensity I_0 falls on the surface of water at the Brewster angle. A fraction $\rho = 0.039$ of luminous flux is reflected. Find the intensity of the refracted beam.

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16. A narrow beam of natural light falls on a set of N thick plane-parallel glass plates at the Brewster angle. Find:

(a) the degree P of polarization of the transmitted beam,

(b) what P is equal to when $N = 1, 2, 5,$ and 10.

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17. Using the Fresnel equations, find:

(a) the reflection coefficient of natural light falling normally on the surface of glass,

(b) the relative loss of luminous flux due to reflections of a paraxial ray of natural light passing through an aligned aoptical system comprising five glass lenses (secondary reflections o flight are to be neglected).

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18. A light wave falls normally on the surface of glass coated with a layer of transparent substance. Neglecting secondary reflections, demonstrate that the amplitudes of light waves reflected from the two surfaces of such a laver will be equal under the condition $n' = \sqrt{n}$, where n' and n are the refractive indiced of the layer and the glass respectively.

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19. A beam of natural light falls on the surface of glass at an angle of 45°. Using the Fresnel equations, find the degree of polarization of

(a) reflected light,

(b) refracted light.

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20. Using Huygens's principle, construct the wavefronts and the propegation directions of the ordinary and extraordinary rays in a positive uniaxial crystal whose optical axis

(a) is perpendicualr to the incidence plane and parallel to the surfcae of the crystal,

(b) lies in the incidence plane and is parallel to the surface of the crystal,

(c) lies in the incidence plane at an angle of 45° to the surface of the crystal, and light falls at right angles to the optical axis.

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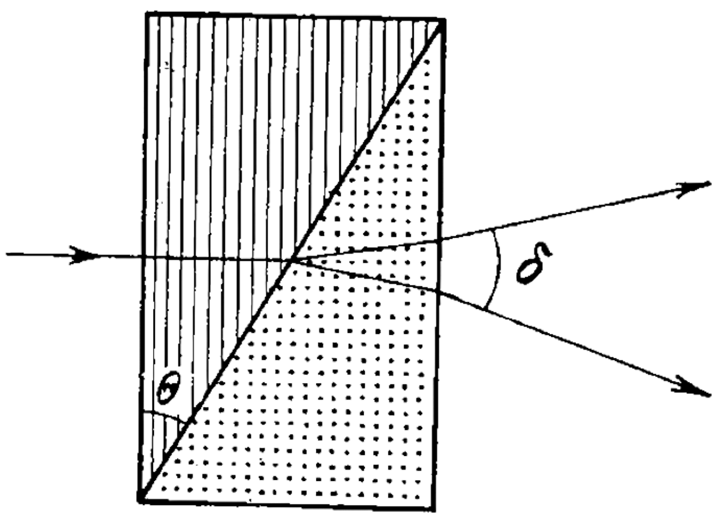
21. A narrow beam of natural light with wavelength $\lambda = 589nm$ falls normally on the surface of a Wollaston polarizing prism made of Iceland spar as shown in Fig. The optical axes of the two parts of the prism are mutually perpendicualr. Find the angle δ between the directions of the beams behind the prism if the angle θ is equal to 30°.



22. What kind of polarizations has a plane electromagetic wave if the projections of the vector E on the x and y axes are perpendicular to the propagation direction and are defind by the following equations:

(a) $E_x = E\cos(\omega t - kz), E_y = E\sin(\omega t - kz)$,

(b)

$E_x = E\cos(\omega t - kz), E_y = E\cos(\omega t - kz + \pi/4)$

(c)

$E_x = E\cos(\omega t - kz), E_y = E\cos(\omega t - kz + \pi)$?

23. One has to manufacture a quartz plate cur parallel to its optical axis and not exceeding $0.50mm$ is thickness. Find the maximum thickness of the plate allowing plane-polarized light with wavelength $\lambda = 589nm$

(a) to experience only rotation of polarization plane,

(b) to acquire circular polarization after passing through that plane.

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24. A quartz plate cur parallel to the optical axis placed between two crossed Nicol prisms. The angle between the principal directions of the Nicol prism and the plate is equal to 45°. The thckness of the plate is $d = 0.50mm$. At what wavelengths in the interval from 0.50 to $0.60\mu m$ is the intensity of light which passed through that system independent of rotation of the rear prism? The difference of refractive indices for ordinary and extraordinary rays in that wavelength interval is assumed to be $\Delta n = 0.0090$.

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25. White natural light falls on a system of two crossed Nicol prisms having between them a quartz plate $1.50 mm$ thick, cut parallel to the optical axis. The axis of the plate froms an angle of 45° with the principle directions of the Nicol prism. The light transmitted through that system was split into the spectrum. How many dark fringes will be observed in the wavelength interval from 0.55 to $0.66 \mu m$? The difference of refractve indices for ordinary and extraordianry rays in that wavelength interval is assumed to be equal to 0.0090.

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26. A crystalline plate cut parallel to its optical axis is $0.25mm$ thick and serves as a quarter-wave plate for a wavelength$\lambda = 530nm$. At what other wavelength of visible spectrum will it also serve as a quarter-wave plate? The difference of refractive indices for extraordinary and ordianry rays is assumed to the constant and equal to $n_e - n_0 = 0.0090$ at all wavelength of the visible spectrum.

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27. A quartz plate cut parallel to its optical axis is placed between two corssed Nicol prisms so that principle directions form an angle of 45° with the optical axis of the plate. What is the minimum thickness of that plate transmitting light of wavelength $\lambda = 643 nm$ with maximum intensity while greatly reducing the intensity of transmitting light of wavelength $\lambda_2 = 564 nm$? The difference of refractive indieces indices for extroardianry and ordinary rays is assumed to be equal to $n_e - n_0 = 0.0090$ for both wavelengths.

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28. A quartz wedge with refracting angle $\Theta = 3.5$ is inserted between two crossed Polaroids. The optical axis of the wedge is parallel to its edge and forms an angle of 45° with the principal directions of the Polaroids. On transmittion of light with wavelength $\lambda = 550nm$ through this system, an interference fringe pattern is formed. The width of each fringe is $\Delta x = 1.0mm$. Find teh difference of refractive indices of quartz for ordinary and extraodianry rays at the wavelength indicated above.

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29. Natural monochromatic light of intensity I_0 falls on a system of two Polaroids between which a crystalline plate is inserted,cut parallel to its optical axis. The plate introduces a phase difference δ between the ordinary and extraodianry rays. demonstrate that the intensity of light transmitted through that sysytem is equal to

$$I = \frac{1}{2} I_0 \left[\cos^2(\varphi - \varphi') - \sin 2\varphi . \sin 2\varphi' \sin^2(\delta/2)\right]$$

,

where φ and φ' are the angles between the optical axis of the crystal and the principle directions of the Polaroids. In particular, consider the cases of crossed and parallel Polaroids.

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30. Monochromatic light with circular polarization falls normally on a crystalline plate cut parallel to the optical axis. Behind the plate there is a Nicol prism whose principle direction froms an angle φ with the optical axis of the plate. Demonsrate that the intensity of light transmitted through that system is equal to

$$I=I_0(1+\sin 2\varphi . \sin \delta),$$

where δ is the phase difference between the ordianry and extraordinary rays which is introduced by the plate.

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31. Explain how, using a Polaroid and a quarter-wave plate made of positive uniaxial crystal $(n_e > n_0)$, yo distinguish

(a) light with left-hand circualr polarization from that with right-hand polarization,

(b) natural light from light with circualr polarization and from the compoitive of natural light and that with circular polarization.

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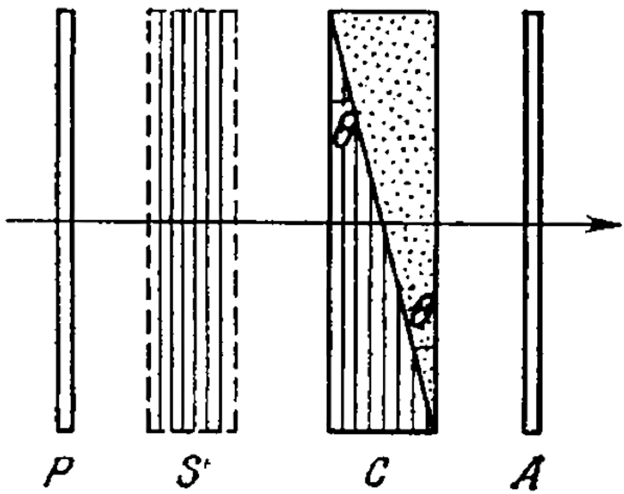
32. Light with wavelength λ falls on a system of crossed polarizer P and analyzer A between which a Babinet compesator C is inserted (Fig.). The compensator consists of two q2uartz wedges with the optical axis of one of them being parallel to the edge, and of the other, perpendicular to it. The principal directions of the polarizer and the analyser from an angle of 45° with the optical axes of the compensator. The refracting angle of the wedges is equal to $\Theta(\Theta < < 1)$ qand the difference of refractive indices of quartz is $n_e - n_0$. The insertion of investigated birefringent sample S , with the optical axis oriented as shown in the figure, results in displacement of the fringe upward by $\delta x mm$. Find:

the width of the fringe Δx,

(b) the magnitude and the sign of the optical path difference of ordinary and extraordianry rays, which appears due to the sample S.



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33. Using the tables of the Appendix, calculate the difference of refractive indices of quartz for light wavelength $\lambda = 589.5nm$ with right-hand and left-hand circular polarizations.

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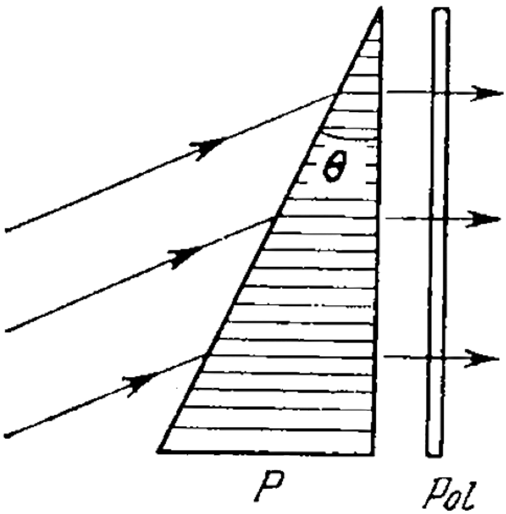
34. Plane-polarized light of wavelength $0.59\mu m$ falls on a trihedral quartz prism P (Fig.) with refracting angle $\Theta = 30^\circ$. Inside the prism light propagates along the optical axis whose direction is shwon by hatching. Behind the Polaroid Pol an interference pattern of bright and dark fringes of width $\Delta x = 15.0mm$ is pbserved. Find the specific rotation constant of quartz and the distribution of intensity of light behind the Polaroid.



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35. Natural monochromatic light falls on a system of two crossed Nicol prisms between to its optical axis is insered. Find the minimum thickness of the plate at which this system will transmit $\eta = 0.30$ of luuminous flux if the specific rotation constant of quartz is equal to $\alpha = 17 angdeg / mm$.

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36. Light passes through a system of two crossed Nicol prisms between which a quartz plate cut at right angles to its optical axis is placed. Determine the minimum thickness of the plate which allows light of wavelength $436 nm$ to be complately cut off by the system and transmits half the light of wavelength $497nm$. The specific rotation constant of quartz for these wavelength is equal to 41.5 and 31.1 angualr degress per mm respectively.

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37. Plane-polarized light of wavelength $589nm$ propagates along the axis of a concentration $500g/l$. Viewing from the side, one can see a system of helical fringes, with $50cm$ between neighbouring dark fringes along the axis. Explain the emergence of the fringes and determine the specific rotation consatnt of the solution.

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38. A Kerr cell is positioned between two crossed Nicol prisms so that the direction of electric field E in the capacitor forms an angle of 45° with the principle directions of the prisms. The capacitor has the length $l = 10cm$ and is falled up with nitrobenzence. Light of wavelength $\lambda = 0.50\mu m$ passes through the system. Taking into account that in this case the kerr constant is equal to $B = 2.2.10^{-10} cm / V^2$, find:

(a) the minimum strength of electric field E in the capacitor at which the intensity of light that passes through this syetm is independent of rotation of the rear prism,

(b) how many times per second light will be interrupted when a sinusoidal voltage of frequecny $v = 10MHz$ and strength amplitude $E_m = 50kV / cm$ is applied to the capacitor.

Note. The Kerr constant is the coefficient B in the equation $n_e = n_0 = B\lambda E^2$.

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39. Monochromatic plane-polarized light with angular frequency ω through a certain substance along a unifrom magnetic field h. Find the difference of refractive indices for right-hand and left-hand components of light beam with circular polarization if the verdet consatnt is equal to V.

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40. A certain substance is placed in a longitudinal magnetic field of a solenoid located between two Polaroids. The length of the tube wity substance is equal to $l = 30cm$. Find the verdet constant if at a field strength $H = 56.5kA/m$, the angle of rotation of polarization plane is equal to

$\varphi_1 = +5^\circ 10'$ for one direction of the field and to

$\varphi_2 = -3^\circ 20,'$ for the opposite direction.

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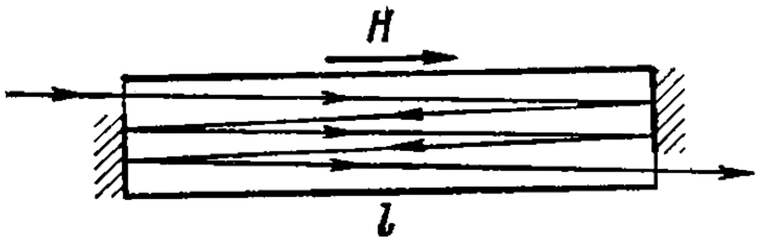
41. A narrow beam of plane-polarized light passes through dextrorotatory positive compound placed into a longitudinal magnetic field as shown in Fig. Find the angle through which the polarization plane of the transmitted beam will turn if the length of the tube with the componed is equal to l, the specific rotation constant of the compound is equal to α, the verder constant is V, and the magnetic field strength is H.



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42. A tube of length $l = 26cm$ is filled with benzence and placed in a longitudinal magnetic field of a solenoid positioned between two Polaroids. The angle between the principle

directions of the Polaroids is equal to 45°. Find the minimum strength of the magnetic field at which light of the wavelength $589nm$ propagates through that system only in one direction (optical value). What happens if teh idrection of the given magnetic field is changed to the opposite one?

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43. Experience shows that a body irradiated with light with circular polarization acquires a torque. This happens because such a light possesses an angular momentum whose flow density in vacuum is equal to $M = I/\omega$, where I is the intensity o flight, ω is the angualr oscillation frequacny. Suppose light with circualr polarization and wavelength $\lambda = 0.70\mu m$ falls normally on a uniform black disc of mass $m = 10mg$ which can freely rotate about its axis. How soon will its angualr velocity become equal to $\omega_0 = 1.0 rad/s$ provided $I = 10W/cm^2$?

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Dispersion And Absorption Of Light

1. A free electron is located in the field of a monochromatic light wave. The intensity of light is $I = 150W/m^2$, its frequency is $\omega = 3.4.\ 10^{15}s^{-1}$.

Find:

(a) the electron's oscillation amplitude and its velocity amplitude,

(b) the ratio F_m/F_e, where F_m and F_e are the amplitudes of forces with which the magnetic and electric components of the ligth wave field act on the electron, demonstrate that the ratio is equal to $\frac{1}{2}v/c$, where v is the electron's velocity amplitude and c is the velocity of light.

Instruction. The action of the magnetic field component can be disregarded in the equation of motion of the electron since the calculations shown it to be negligible.

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2. An electromagnetic wave of frequency ω propagates in dilute plasma. The free electron concentration in plasma is equal to n_0. Neglecting the interaction of the wave and plasma ions, find:

(a) the frequency dependence of plasma permittivity,

(b) how the phase velocity of the electromagnetic wave depends on its wavelength `lambda in plasma.

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3. Find the free electron concentration in ionsphere if its refractive index is equal to $n = 0.90$ for radiowaves of frequency $v = 100MHz$.

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4. Assuming electrons of substance to be free when subjected to hard X-rays, determine by what magnitude the refractive index of graphite differs from unity in the case of $X-$rays whose wavelength in vaccume is equal to $\lambda = 50 \pm$.

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5. An electron experiences a quasi-elastic force kx and a "friction force" yx in the field of electromagnetic radiation. The Ecomponent of the field varies as $E = E_0 \cos \omega t$. Neglecting the action of the magnetic component of the field, find,

(a) the motion equation of the electron,

(b) the mean power absorbed by the electron, the frequency at which that power is maximum and the expression for the maximum mean power.

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6. In some cases permittivity of substance turns out to be a complex or a negative quantity, and refractive index, respectively, a complex $(n' = n + ix)$ or an imaginary $(n' = ix)$ quantity. Write the equation of a plane wave for both of these cases and find out the physical meaning of such refractive indices.

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7. A sounding of dilute plasma by radiowaves of various frequencies reveals that rediowaves with wavelength exceeding $\lambda_0 = 0.75m$ experience total internal reflection. Find the free electron concentration in that plasma.

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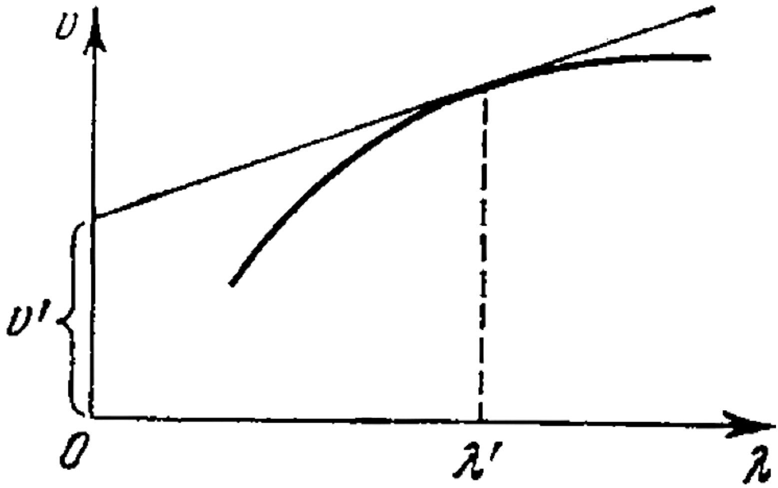
8. Using the definition of the group velocity u, derive Rayleigh's fromula $(5.5d)$. Demonstrate that in the vicinity of $\lambda = \lambda'$ the velocity u is equal to the segment v' cut by the tangent of the curve

$v(\lambda)$ at the point λ' (Fig.)



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9. Find the relation between the group velocity u and phase velocity v for the following disperison laws:

(a) $v \propto 1/\sqrt{\lambda_1}$,

(b) $v \propto k$,

(c) $v \propto 1/\omega^2$,

Here λ, k, and ω are the wavelength, wave number, and angular frequancy.

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10. In a certain medium the relationship between the group and phase velocities of an electromagnetic wave has the form $uv = c^2$, where c is the velocity of light in vaccume. Find the dependence of permittivity of that medium on wave frequency, $\varepsilon(\omega)$.

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11. The refractive index of carbon dioxide at the wavelengths $509, 534$ and $589nm$ is equal to $1.647, 1.640,$ and 1.630 respectively. Calculate the phase and group velocities of light in the vicinity of $\lambda = 534nm.$

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12. A train of plane light waves propagates in the medium where the phase velocity v is a linear function of wavelength: $v = 1 + b\lambda$, where a and b

are some positive constants. Demonstrate that in such a medium the shape of an arbitary train of light waves is restroed after the time interval $\tau = 1/b$.

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13. A beam of natural light of intensity I_0 falls on a system of two crossed Nicol prisms between which a tube filled with certain solution is placed in a longitudinal magnetic field of strength H. The length of the tube is l, the coefficient of linear absorption of solution is x, and the verder constant is V. Find the intensity of light transmitted through that system.

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14. A plane monochromatic light wave of intensity I_0falls normally on a plane-parallel plate both of whose surfaces have a reflection coeffiecient ρ. Taking into account multiple reflections, find the intensity of the transmitted light if

(a) the plate is perfectly transparent, i.e the absorption is absent,

(b) teh coefficient of linear absorption is equal to x, and the plate thickness is d.

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15. Two plates, one of thickness $d_1 = 3.8mm$ and the other oof thickness $d_2 = 9.0mm$, are manufactured from a certain substance. When placed alternately in the way of monichromatic light, the first trasmits $\tau_1 = 0.84$ fraction of luminous flux and that substance. Light falls at right angles to the plates. The secondary reflections are to be neglected.

16. A beam of monochromatic light passes through a pile of $N = 5$ identical plane-parallel glass plates each of thickness $l = 0.50cm$. The coefficient of reflection at each surface of the plates is $\rho = 0.050$. The ratio of the intensity of light transmitted through the pile of plates to the intensity of incident light is $\tau = 0.55$ Neglecting the secondary reflections of light, find the absorption coefficient of the given glass.

17. A beam of monichromatic light falls normally on the surfcae of a plane-parallel plate of thickness l. The absorption coefficient of the substance the plate is made of varies linearly along the normal to its surfcae from x_1 to x_2. The coefficient of reflection at each surface of the plate is equal to ρ. Neglecting the secondary reflections, find the transmission coefficient of such a plate.

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18. A beam of light of intensity I_0 falls normally on a transparent plane-parallel plate of thickness l.

The beam contains all the wavelengths in the interval from λ_1 to λ_2 of equal spectral intensity. Find the intensity of the transmitted beam if in this wavelength interval the absorption coefficient is a linear function of λ, with exterme values x_1 and x_2. The coefficient of reflection at each surfcae is equal to ρ. The secondary reflections are to be neglected.

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19. A light filter is a plate of thickness d whose absorption coefficient depends on wavelength λ as

$x(\lambda) = \alpha(1 - \lambda/\lambda_0)^2 cm^{-1},$

where α and λ_0 are constants. Find the passband $\Delta\lambda$ of this light filter, that is the band at whose edge the attenuation of light is η times that at the wavelength λ_0. The coefficient of reflection from teh surfaces of the light filter is assumed to be the same at all wavelengths.

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20. A point source of monochromatic light emitting a lumninous flux Φ is positioned at the cnetre of a spherical layer of substance. The inside radius of the layer is a, the outside one is b. The coefficient of linear absorption of the substance is equal to x, the reflection coefficient of the surfcaes is equal to ρ. Neglecting the secondary reflections, find the intensity of light taht passes through that layer.

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21. How many times will the intensity of a narrow X-ray beam of wavelength $20\pm$ decrease after passing through a lead plate of thickness $d = 1.0mm$ if the mass absorption coefficient for the given radiation wavelength is equal to $\mu/\rho = 3.6cm^2/g$?

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22. A narrow beam of $X-$ray radiation of wavelength $62 \pm$ penetrates an aluminium screen $2.6cm$ thick. How thick must a lead screen be to attenuate the beam just as much? The mass absorption coefficients of aluminium and lead for this radiations are equal to 3.48 and $72.0cm^2/g$ respectively.

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23. Find the thickness of aluminium layer which reduces by half the intensity of a narrow monochromatic X-ray beam if the corresponding mass absorption coefficient is $\mu/\rho = 0.32 cm^2/g$.

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24. How many 50% absorption layers are there in the plate reducing the intensity of a narroe X-ray beam $\eta = 50$ times?

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Optics Of Moving Sources

1. In the Fizeau experiment on measurement of the velocity of light the distance between the gear wheel and the mirror is $l = 7.0km$, the number of teeth is $z = 720$. Two successive disappearances of light are observed at the folllowing rotation velocities of the wheel: $n_1 = 283rps$ and $n_2 = 313$ rps. Find the velocity of light.

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2. A source of light moves with velocity v relative to a receiver. Demonstrate that for $v < < c$ the fractional variation of frequency of light is defined by Eq.

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3. One of the spectral lines emitted by excited He^{+} ions has a wavelength $\lambda = 410 nm$. Find the soppler shift $\Delta\lambda$ of that line when observed at an angle $\theta = 30^{\circ}$ to the beam of moving ions possessing kinetic energy $T = 10 MeV$.

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4. When a spectral line of wavelength $\lambda = 0.59 \mu m$ is observed in the directions to the opposite edges of the solar disc along its equator, there is a difference in wavelengths equal to $\delta\lambda = 8.0 \pm$. Find the period of the sun's revolution about its own axis.

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5. The Doppler effect has made it possible to discover the doubles stars which are so distance that their resolution by means of a telescope is impossible. The spectral lines of such stars periodically become doublets indicating that the radiations does come two stars revolving about their centre of mass. Assuming the masses of the two stars to be equal, find the distance between them and their masses if the maximum splitting of the spectral lines is equal to $(\Delta\lambda/\lambda)_m = 1.2.10^{-4}$ and occurs every $\tau = 30$ days.

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6. A plane electromagnetic wave of frequency ω_0 falls normally on the surface of a mirror approching with a relativistic velocity V. Making use of the Doppler formula, find the frequency of the reflected wave. Simplify the obtained expression for the case $V < < c$.

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7. A radar operates at a wavelength $\lambda = 50.0cm$. Find the velocity of an approaching aircraff if the beat frequency between the transmitted signal and the signal reflected form the aircraft is equal to $\Delta v = 1.00kHz$ at the radar location.

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8. Taking into account that the wave phase $\omega t - kx$ is an invariant, i.e. it retains its value on transition from one interial frame to another, determine how the frequency ω and the wave number k entering the expression for the wave phase are transformed. Examine the unidimensional case.

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9. How fast does a certain nebula recede if the hydrogen line $\lambda = 434nm$ in its spectrum is displaced by $130nm$ toward longer wavelengths?

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10. How fast should a car move for the driver to perceiver a red traffic light $(\lambda \approx 0.70\mu m)$ as a green one $(\lambda' \approx 0.55\mu m)$?

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11. An observer moves with velocity $v_1 = \frac{1}{2}c$ along a straight line. In front of him a source of monochromatic light moves with velocity $v_2 = \frac{3}{4}c$ in the same direction and along the same straight line. The proper frequency of light is equal to ω_0. Find teh frequency of light registered by the observer.

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12. One of the spectral lines of atomis hydrogen has the wavelength $\lambda = 656.3nm$. Find the Doppler shifl $\Delta\lambda$ of that line when observed at right angles to the beam of hydrogen atoms with kinetic enegry $T = 1.0 Mev$(the transverse Doppler effect).

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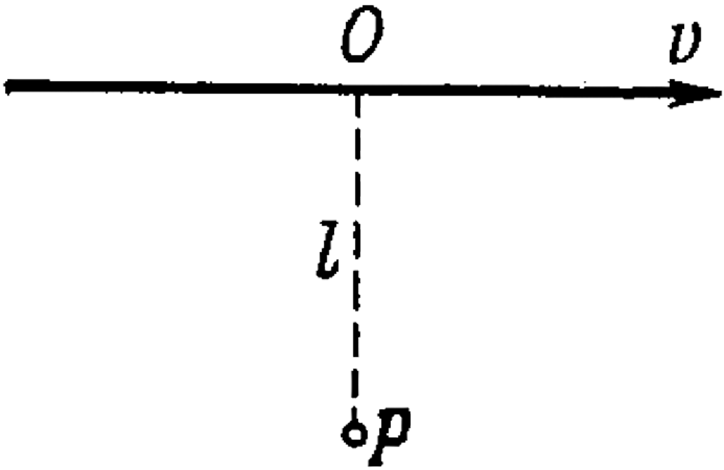
13. A source emitting electromagnetic signals with proper frequency $\omega_0 = 3.0.10^{10} s^{-1}$ moves at a constant velocity $v = 0.80c$ along a stright line separated from a stationary observer P by a distance l (Fig.) Find the frequency of the singnals perceived by the observer at the moment when

(a) the source is at the point O,

(b) the observer sees it at the point O.



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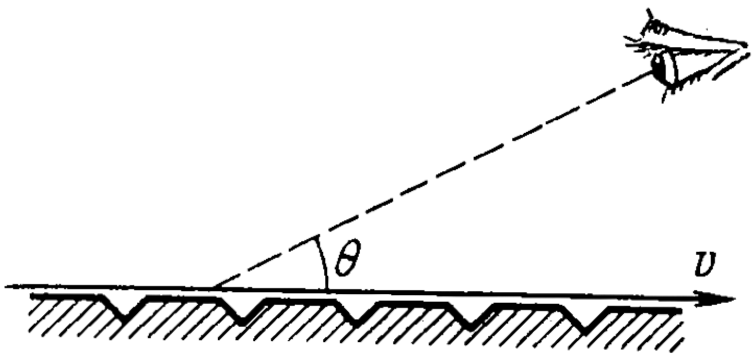
14. A narrow beam of electrons passes immediately over the surface of a metallic mirror with a diffraction grating with period $d = 2.0 \mu m$ inscribed on it. The electrons move with velocity v, comparable to c, at right angles to the lines of the grating. The trajectory of the electrons can be seen in the from of a strip, whose colouring depends on the observation angle θ (Fig.) Interpret this phenomenon. Find the wavelength of the radiations observed at an angle $\theta = 45^\circ$.



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15. A gas consists of atoms of mass m being in thermodynamic equilibrium at temperature T. Suppose ω_0 is the natural frequency of light emitted by the stoms.

(a) Demonstrate that the spectral distribution of the emitted light is defined by the formula

$I_\omega = I_0 e^{-a(1-\omega/\omega_0)^2}$,

(I_0 is the spectral intensity corresponding to the frequency ω_0, $a = mc^2/2kT$).

(b) Find the relative width $\Delta\omega/\omega_0$ of a given spectral line. i.e. the width of the line between the frequencies at which $I_\omega = I_0/2$.

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16. A plane electromagnetic wave propagates in a medium moving with constant velocity $V < < c$ relative to an interial frame K. Find the velocity of that wave in the frame K if the refractive index of the medium is equal to n and the propagation direction of the wave coincides with that of the medium.

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17. Aberration of light is the apparent displacement of stars attributable to the effect of the orbital motion of the Earth. The direction to a star in the ecliptic plane varies periodically and the star performs apparent oscillations within an angle $\delta\theta = 41''$. Find teh orbital velocity of the Earth.

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18. Demonstrate that the angle θ between the propegation direction of light and the x axis transfroms on transition from the reference frame K to K' according to the formula

$$\cos\theta' = \frac{\cos\theta - \beta}{1 - \beta\cos\theta},$$

where $\beta = V/c$ and V is the velocity of the frame

K'with respect to the frame K. the x and x' axes of the reference frames coincide.

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19. Find the aperture angle of a cone in which all the stars located in the semi-sphere for a observer on the Earth will be visible if one moves relative to the Earth with relativistic velocity V differing by 1.0% from the velocity of light. Make use of the formula of the foregoing problem.

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20. Find the conditions under which a charged particle moving uniformly through a medium with refractive index n emits light (the Vavilov-Cherenkov effect). Find also the direction of that radiations.

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21. Find the lowest values o fthe kinetic energy of an electron and a proton causing the emergence of Cherenkov's radiation in a medium with refractive index $n = 1.60$. For what particles is this minimum value of kinetic enegry equal to $T_{\min} = 29.6 MeV$?

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22. Find the kinetic enegry of electrons emitting light in a medium with refractive index $n = 1.50$ at an angle $\theta = 30^\circ$ to their propagation direction.

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Thermal Equation

1. Using Wien's formula, demonstrate that

(a) the most probable radiation frequency $\omega_{pr} \propto t$,

(b) the maximum spectral density of thermal radiation $(u_{\omega})_{\max} \propto T^3$,

(c) the radiosity $M_e \propto T^4$.

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2. The temperature of one of the two heated black bodies is $T_1 = 2500K$. Find the temperature of the other body if the wavelength corresponding to its maximum emissive capacity exceeds by $\Delta\lambda = 0.50\mu m$ the wavelength corresponding to the maximum emissive capacity of the first black body.

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3. The radiosity of a black body is $M_e = 3.0W/cm^2$. Find the wavelength corresponding to the maximum emissive capacity of that body.

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4. The spectral composition of solar radiation is much the same as that of a black whose maximum emission corresponds to the wavelength $0.48\mu m$. Find the mass lost by the sun every second due to

radiation. Evaluate the time interval during which the mass of the sun diminishes y 1 per cent.

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5. Find the temperature of totally ionized hydrogen plasma of density $\rho = 0.10 g / cm^3$ at which the thermal radiation pressure is equal to the gas kinetic pressure of the particles of plasma. Take into account that the thermal radiation pressure $p = u / 3$, where u is the space density of radiation enegry, and at high temperatures all substances obey the equation of state of an ideal gas.

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6. A copper ball of diameter $d = 1.2cm$ was placed in an evacuated vessel whose walls are kept at the absolute zero temperature. The initial temperatures of the ball is $T_0 = 300K$. Assuming the surface of the ball to be absolutely balck, find how soon its temperature decreases $\eta = 2.0$ times.

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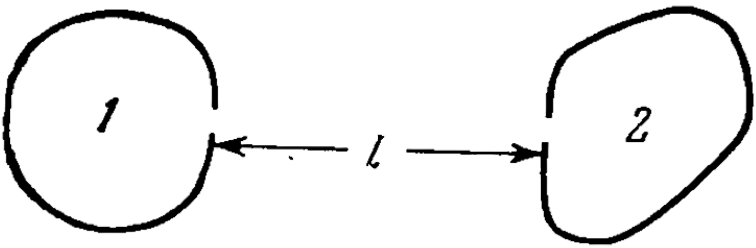
7. There are two cavities (Fig.) with small holes of equal diameters $d = 1.0cm$ and perfectly reflecting outer surfaces. The distance between the holes is $l = 10cm$. A constant temperature $T_1 = 1700K$ is maintained in cavity 1. Calculate the steady-state temperature inside cavity 2.



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8. A cavity of volume $V = 1.01$ is filled with thernal radiation at a temperature $T = 1000K$. Find:

(a) the heat capacity C_v, (b) the entropy S of that radiation.

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9. Assuming the spectral distribution of thermal radiation energy of obey wien's formula $u(\omega, T) = A\omega^3 \exp(-1\omega/T)$, where $a = 7.64 ps. K$, find for a temperature $T = 2000K$ the most probable

(a) radiation frequency, (b) radiation wavelength.

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10. Using Planck's fromula, derive the approximate expressions for the space spectral density u_ω of radiation

(a) in the range where $h\omega < \ < kT$ (Rayleigh-Jeans fromula),

(b) in the range where $h\omega > \ > kT$ (Wien's formula).

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11. Transform Planck's formula for space spectral density u_ω or radiation form the variable ω to the variables v (linear frequency) and λ (wavelength).

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12. Using Planck's formula, find the power radiated by a unit area of a black body within a narrow wavelength interval $\Delta\lambda = 1.0nm$ close to the maximum of spectral radiation density at a temperature $T = 3000K$ of the body.

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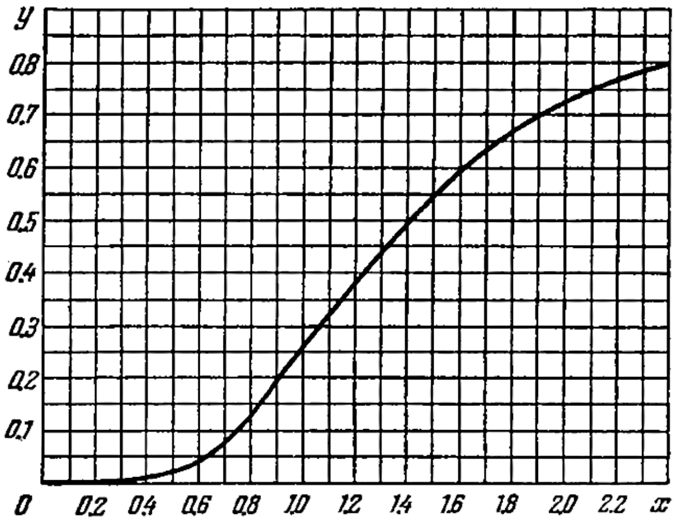
13. Fig. shows the plot of the function $y(x)$ representing a fraction of the total power of thermal radiation falling within the spectral interval from 0 to x. Here $x = \lambda / \lambda_m (\lambda_m$ is the wavelength corresponding to the maximum of spectral radiation density).

Using this plot, find:

(a) the wavelength which divides the radiation spectrum into two equal (in terms of energy) parts at the temperature $3700K$,

(b) the fraction of the total radiation power falling within the visible range of the spectrum $(0.40 - 0.76 \mu m)$ at the temperature $5000K$,

(c) how manu times the power radiated at wavelengths exceeding $0.76 \mu m$ will increase if the temperature rises form 3000 to $5000 K$.



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14. Making use of Planck's formula, derive the expressions determining the number of photons per $1cm^3$ of a cavity at a temperature T in the spectral intervals $(\omega, \omega + d\omega)$ and $(\lambda, \lambda + d\lambda)$.

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15. An isotropic point source emits light with wavelength $\lambda = 589nm$. The radiation power of the source is $P = 10W$. Find:

(a) the mean density of the flow of photons at a distance $r = 2.0m$ from the osurce,

(b) the distance between the source and the point at which the mean concentration of photons is equal to $n = 100cm^{-3}$.

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16. From the standpoint of the corpuscular theory demostrate that the momentum transferred by a beam of parallel light rays per unit time does not depend on its spectral composition but depends only on the enegry flux Θ_e.

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17. A laser emits a light pulse of duration $\tau = 0.13ms$ and energy $E = 10J$. Find the mean pressure extered by such a light pulse when it is focussed into a spot of diameter $d = 10 \mu m$ on a surface perpendicualr to the beam and possessing a reflection coefficient $\rho = 0.50$.

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18. A short light pulse of enegry $E = 7.5 J$ falls in the form of a narrow and almost parallel beam on a mirror plate whose reflection coefficient is $\rho = 0.60$. The angle of incidence is 30°. In terms of the corpuscular theory find the momentum transfered to the plate.

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19. A plane light wave of intensity $I = 0.20W / cm^2$ falls on a plane mirror surface with reflection coefficient $\rho = 0.8$. The angle of incidence is 45°. In terms of the corpuscular theory find the magnitude of the normal pressure extered by light on that surface.

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20. A palne light wave of intensity $I = 0.70W / cm^2$ illuminates a sphere with ideal mirror surface. The radius of the sphere is $R = 5.0cm$. From the standpoint of the corpuscular theory find the force that light exerts on the sphere.

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21. An isotropic point source of radiation power P is located on the axis of an ideal mirror plate. The distance between the source and the plate exceeds the radius of the plate $\eta-$ fold. In terms of the corpuscular theory find the force that light exterts on the plate.

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22. In a reference frame Ka photon of frequency ω falls normally on a mirror approaching it with relativistic velocity V. Find the momentum inparted to the mirror during the reflection of the photon

(a) in the reference frame fixed to the mirroe,

(b) in the frame K.

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23. A small ideal mirror of mass $m = 10mg$ is suspended by w weightless theard of length $l = 10cm$. Find the angle through which the thread will be deflected when a short laser pulse angles enegry $E = 13J$ is shot in the horizontal direction at right angles to the mirror. Where does the mirror get its kinetic energy?

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24. A photon of frequency ω_0 is emitted from the surface of a star whose mass is M and radius R. Find the gravirational shift of frequency $\Delta\omega / \omega_0$ of the photon at a very great distance from the star.

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25. A voltage applied to an X-ray tube being increased $\eta = 1.5$ times, the short-wave limit of an X-ray continuous spectrum shifts by $\Delta\lambda = 26 \pm$.

Find the initial voltage applied to the tube.

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26. A narrow X-ray beam falls on a NaCl single crystal. The least angle of incidence at which the mirror reflection from the system of crystallographic planes is still observed is equal to $\alpha = 4.1^{\circ}$. The interplaner distance is $d = 0.28nm$. How high is the voltage applied to the X-ray tube?

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27. Find the wavelength of the short-wave limit of an X-ray continuous spectrum if electrons approach the anticathode of the tube with velocity $v = 0.85c$, where c is the velocity of light.

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28. Find the photoelectric thresholdfor zinc and the maximum velocity of photoelectrons liberated form its surface by electromagnetic radiation with wavelength $250nm$.

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29. Illuminating the surface of a certain metal alternatrly with light of wavelengths $\lambda_1 = 0.35 \mu m$ and $\lambda_2 = 0.54 \mu m$, it was found that the corresponding maximum velocities of photoelectrons differ by a factor $\eta = 2.0$. Find the work function of taht metal.

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30. Up to what maximum potential will a copper ball, remote from all other bodies, be charged when irradiated by electromagnetic radiation of wavelength $\lambda = 140nm$?

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31. Find the maximum kinetic enegry of photoelectrons liberated form the surface of lithium by electromagnetic radiation whose electric component varies with time as $E = a(1 + \cos \omega t)\cos \omega_0 t$, where a is a constant, $\omega = 6.0.10^{14} s^{-1}$ and $\omega_0 = 360.10^{15} s^{-1}$.

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32. Electromagnetic radiation of wavelength $\lambda = 0.30 \mu m$ falls on a photocell operating in the saturation mode. The corresponding spectra sensitivity of the photocell is $J = 4.8 mA / W$. Find the yield of photoelectrons, i.e. the number of photoelectrons produced by each incident photon.

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33. There is a vacuum photocell whose one electrode is made of cesium and the other of copper. Find the maximum velocity of photoelectrons approaching the copper electrode when the cesium electrode is subjected to electromagnetic radiation of wavelength $0.22 \mu m$ and the electrodes are shorted outside the cell.

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34. A photoelectric current emerging in the circuit of a vacuum photocell when its zinc electrode is subjected to electromagnetic radiation of wavelength $262nm$ is cancelled if an external decelerating voltage $1.5V$ is applied. Find the magnitude and polarity of the outer contact potential difference of the given phtocell.

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35. Compose the expression for a quantity whose dimension is length, using velocity of light c, mass of a particle m, and Planck's constant h. What is that quantity?

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36. Using the conservation laws, demonstrate that a free electron cannot absorb a photon completely.

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37. Explain the following features of compton scattering of light by matter:

(a) the increase in wavelength $\Delta\lambda$ is independent of the nature of the scattering substance,

(b) the intensity of the displaced component of scattered light grows with the increasing angle of scattering and with the diminishing atomic number of the substance,

(c) the presence of a non-displaced in the scattered radiation.

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38. A narrow monochromatic X-ray beam falls on a scattering substance. The wavelengths of radiation scattered at angles $\theta_1 = 60^\circ$ and $\theta_2 = 120^\circ$ differ by a factor $\eta = 2.0$. Assuming the free electrons to be responsible for the scattering, find the incident radiation wave length.

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39. A photon with energy $h\omega = 1.00 MeV$ is scattered by a stationary free electron. Find the kinetic enegry of a compton electron if the photon's wavelength changed by $\eta = 25\%$ due to scattering.

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40. A photon of wavelength $\lambda = 6.0 \pm$ is scattered at right angles by a stationary free electron. Find:

(a) the frequency of the scattered photon,

(b) the kinetic energy of the compton electron.

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41. A photon with energy $h\omega = 250keV$ is scattered at an angle $\theta = 120^\circ$ by a stationary free electron. Find the energy of the scattered photon.

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42. A photon with momentum $p = 1.02MeV / c$, where c is the velocity of light, is scattered by a stationary free electron, changing in the process its momentum to the value $p' = 0.255MeV / c$. At what angle is the photon scattered?

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43. A photon is scattered at an angle $\theta = 120^\circ$ by a stationary free electron. As a result, the electron acquires a kinetic energy $T = 0.45 MeV$. Find the energy that the photon had prior to scattering.

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44. Find the wavelength of X-ray radiation if the maximum kinetic energy of compton electrons is $T_{\max} = 0.19 MeV$.

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45. A photon with enegry $h\omega = 0.15 MeV$ is scattered by a stationary free electron changing its wavelength by $\Delta\lambda = 3.0 \pm$. Find the angle at which the compton electron moves.

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46. A photon with energy exceeding $\eta = 2.0$ times the rest energy of an electron experienced a head-on collision with a stationary free electron. Find the curvature radius of the trajectory of the compton electron in a magnetic field $B = 0.12T$. The compton electron is assumed to mive at right angles to the direction of the field.

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47. Having collided with a relativistic electron, a photon is deflected through an angles $\theta = 60^\circ$ while the electron stops. Find the compton displacement of the wavelength of the scattered photon.

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Exercise

1. A person walks at a velocity v in a straight line forming an angle α with the plane of a mirror. Determine the velocity v_{rel} which he approaches his image, assuming that the object and its image are symmetric relative to the plane of the mirror.

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2. Two rays are incident on a spherical mirror of radius R = 5 cm parallel to its optical axis at distances $h_1 = 0.5cm$ and $h_2 = 3cm$ Determine the distance Δx between the points at which these rays intersect the optical axis after being reflected at the mirror.

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