Topic 1 – Simple Oscillations and their Description

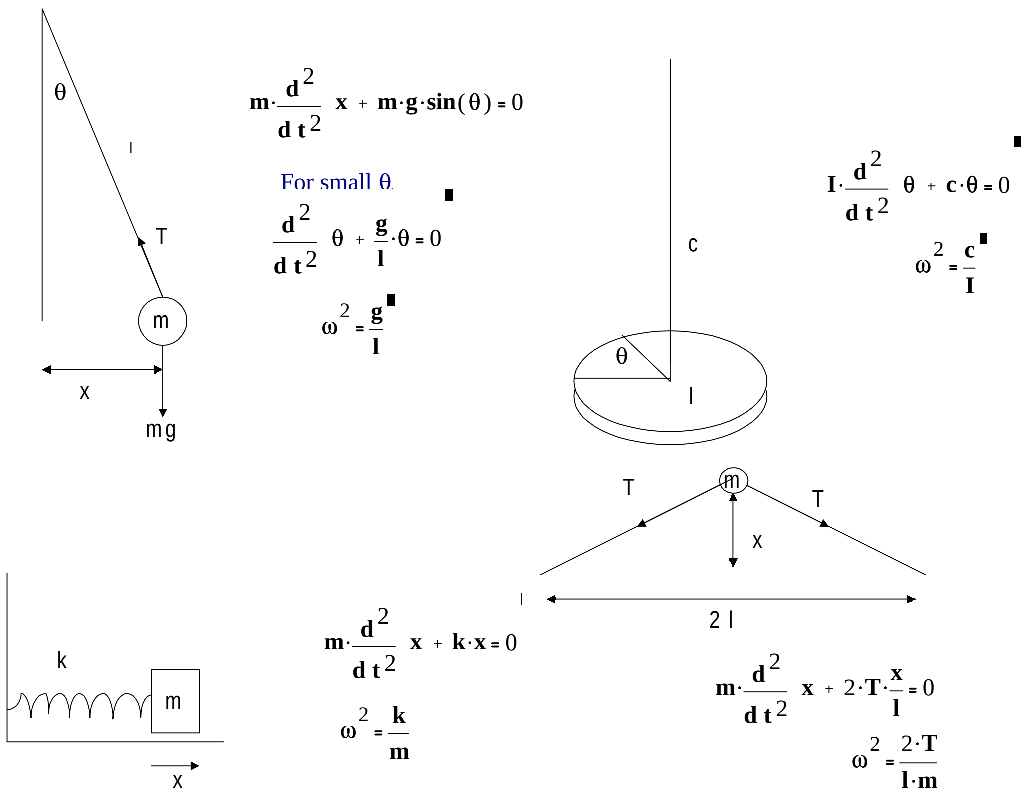
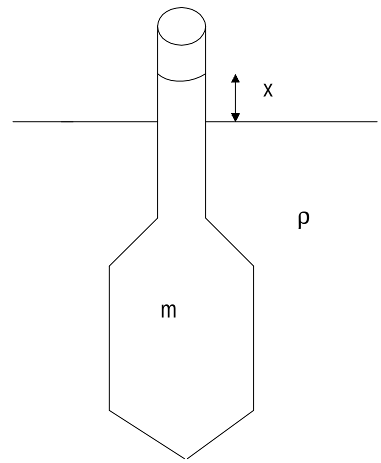
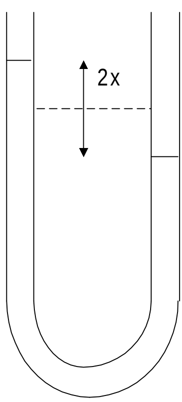


Figure 0.1: A selection of simple harmonic oscillators.





$$\rho \cdot l \cdot \frac{d^2}{dt^2} x + 2 \cdot \rho \cdot g \cdot x = 0$$

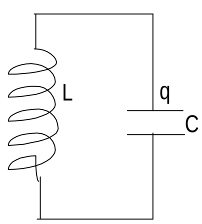
where l is the length of the fluid column

$$\omega^2 = 2 \cdot \frac{g}{l}$$

$$m \cdot \frac{d^2}{dt^2} x + A \cdot \rho \cdot g \cdot x = 0$$

where A is the cross-sectional area of the tube

$$\omega^2 = \frac{A \cdot \rho \cdot g}{m}$$



$$L \cdot \frac{d^2}{dt^2} q + \frac{q}{C} = 0$$

$$\omega^2 = \frac{1}{L \cdot C}$$

Figure 0.2: A further selection of simple harmonic oscillators.

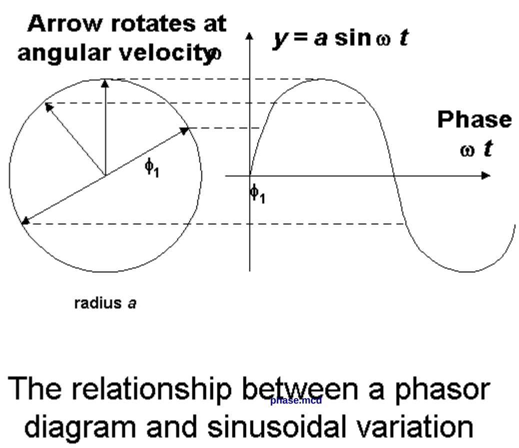


Figure 0.3: Relationship between a rotating vector and simple harmonic motion.

Topic 2 – Complex Numbers; Energy of Oscillators

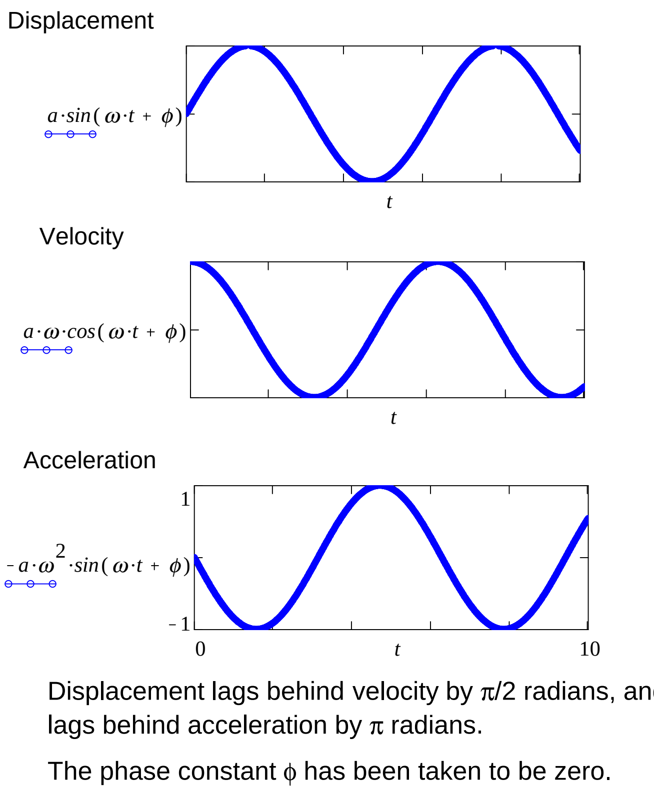


Figure T2.4: Relationship between a rotating vector and simple harmonic motion.

Topic 3 – Combinations of Oscillations

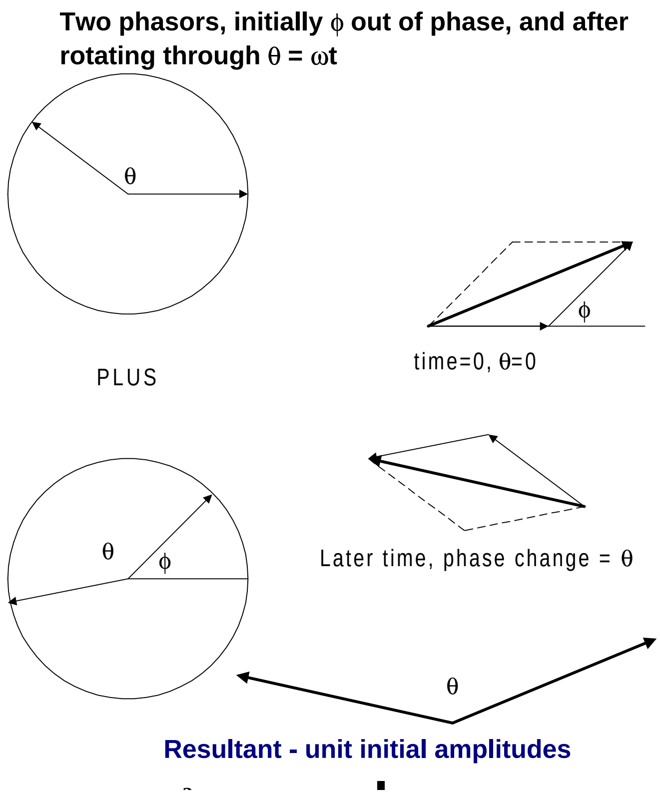


Figure T3.5: Addition of two phasors.

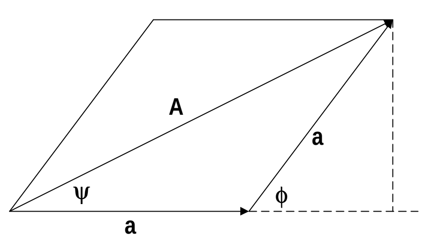


Figure T3.6: Addition of two phasors of equal amplitude.

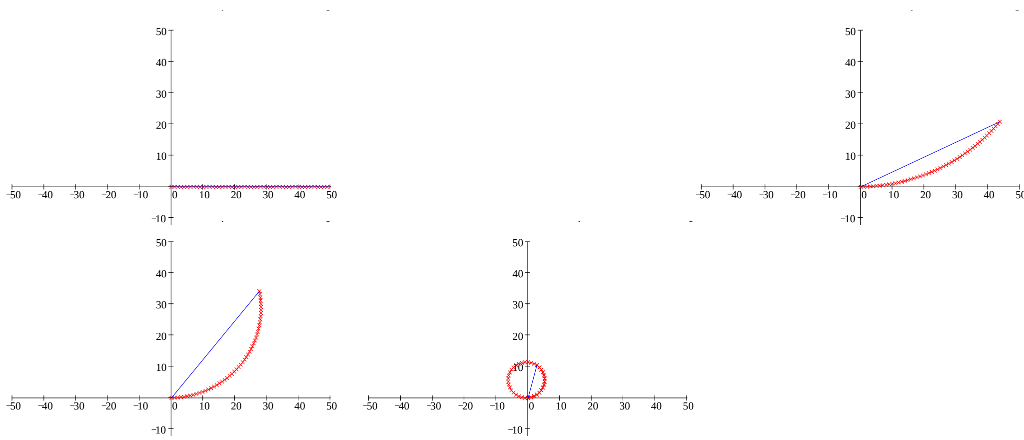


Figure T3.7: Addition of many phasors of equal amplitude: 50 phasors with relative phase difference 0 (top), 1 degree, 2 degrees and 10 degrees (bottom).

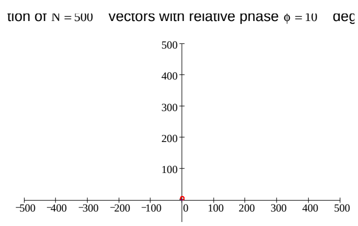


Figure T3.8: Addition of many phasors of equal amplitude: 500 phasors with relative phase difference 10 degrees.

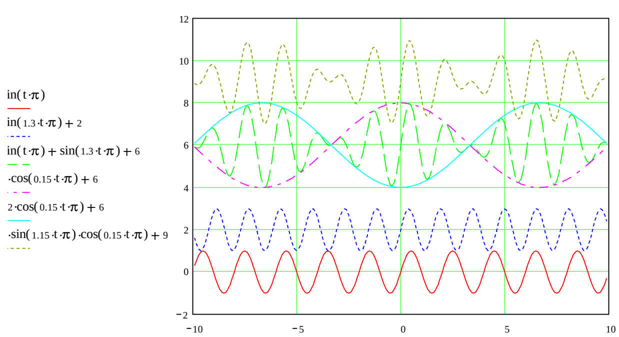


Figure T3.9: Superposition of two signals with different frequencies, showing the phenomenon of beats.

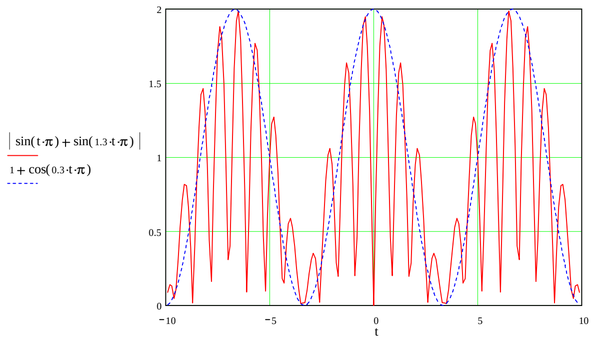


Figure T3.10: Superposition of two signals with different frequencies, giving beats. Here we are plotting the absolute value of the signal. The variation of the loudness has twice the frequency of the envelope function of the signal.

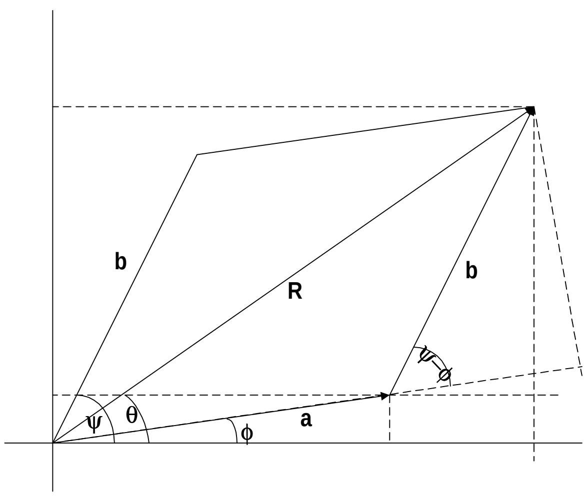


Figure T3.11: Addition of two phasors of different amplitudes.

Topic 4 - The Wave Equation – Basic Properties

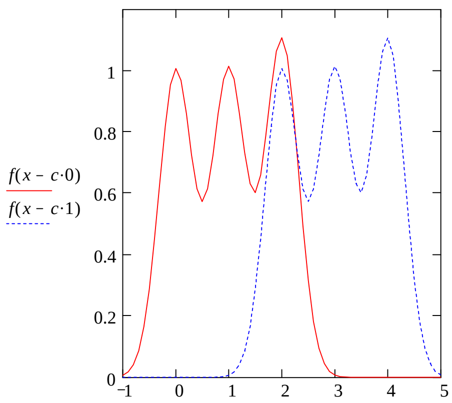
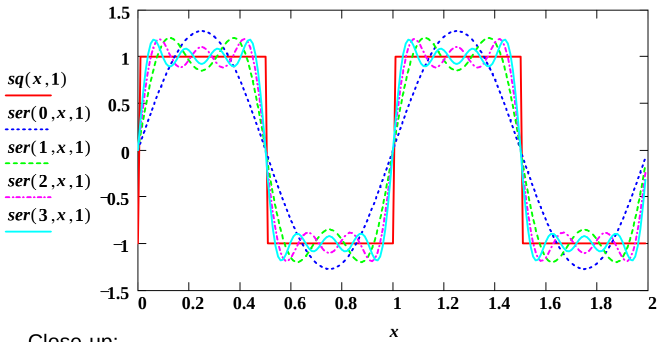
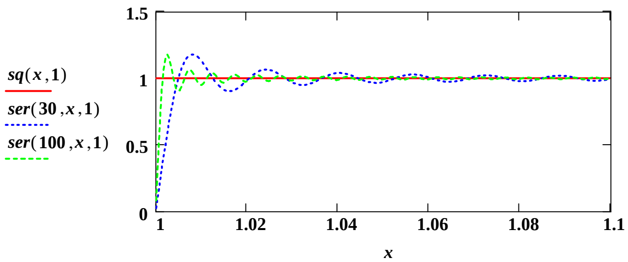


Figure T4.12: The propagation of a general wave pulse.



Close-up:

$x := 1.0001, 1.0005$



The Gibbs phenomenon is the concentration of the 'overshoot' of the sudden rise into a region close to the edge of the step.

Figure T4.13: Demonstration of Fourier's theorem: sine waves are being superposed to make a square wave.

Topic 5 - Single-Frequency Waves and Dispersion

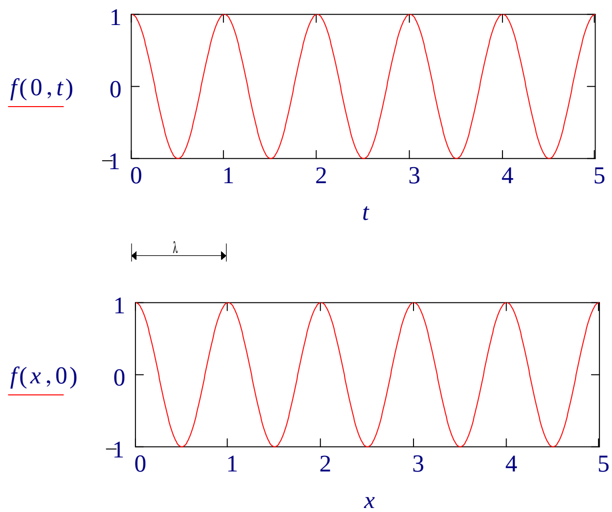


Figure T5.14: The propagation of a sinusoidal wave, the real part of $e^{i(kx-\omega t)}$, as a function of time (top) and position (bottom).

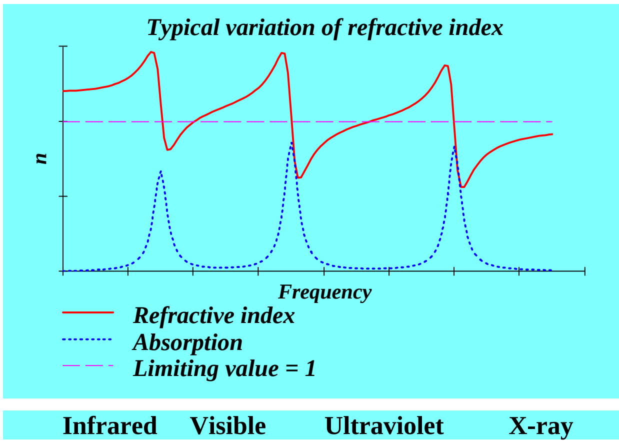


Figure T5.15: Schematic variation of refractive index and associated absorption with frequency.

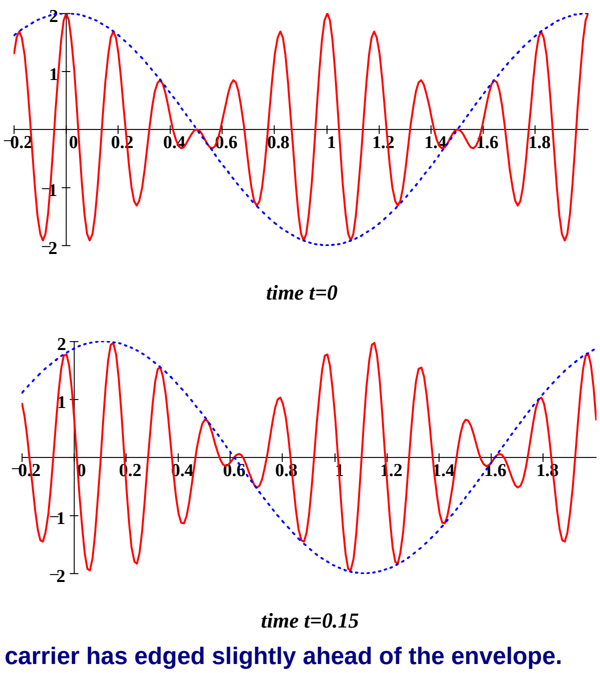


Figure T5.16: Two superposed sine waves, showing the carrier and envelope.

Topic 6 - Dispersion (continued)

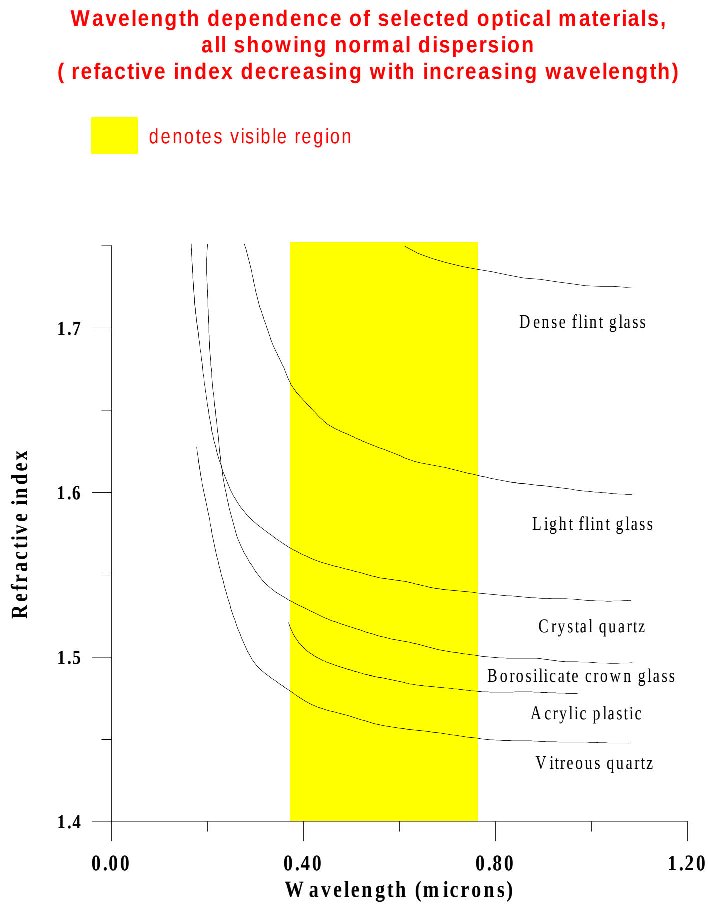


Figure T6.17: Typical variation of refractive index with frequency.

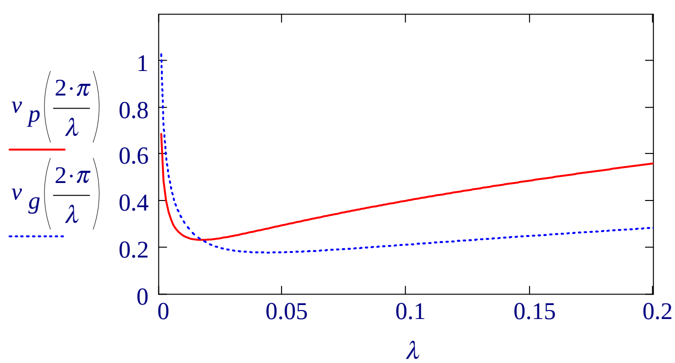


Figure T6.18: Dispersion of a surface wave on a deep fluid.

Topic 7 - Derivation of Wave Equation - Beaded String

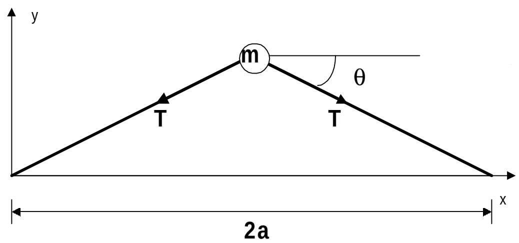


Figure T7.19: A single bead on a stretched wire acting as a simple harmonic oscillator.

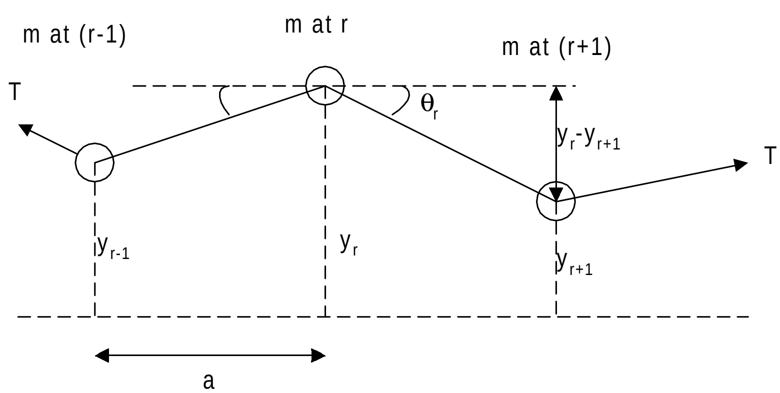
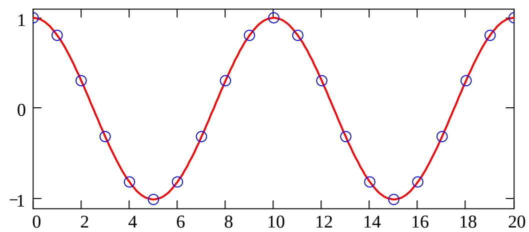


Figure T7.20: Displacements on a regularly beaded string.

$$k := \frac{2 \cdot \pi}{10 \cdot a}$$



$$k := \frac{2 \cdot \pi}{6 \cdot a}$$

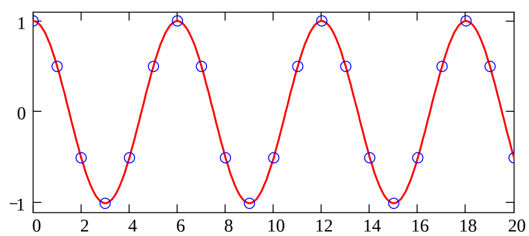


Figure T8.21: A single-frequency wave on a beaded string.

$$k := \frac{2 \cdot \pi}{2 \cdot a}$$

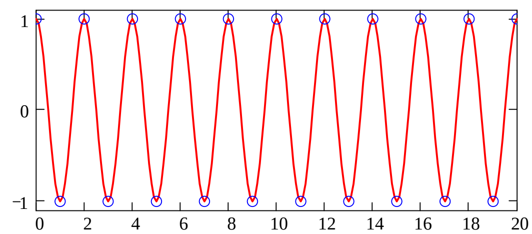


Figure T8.22: The minimum wave-length wave on a beaded string.

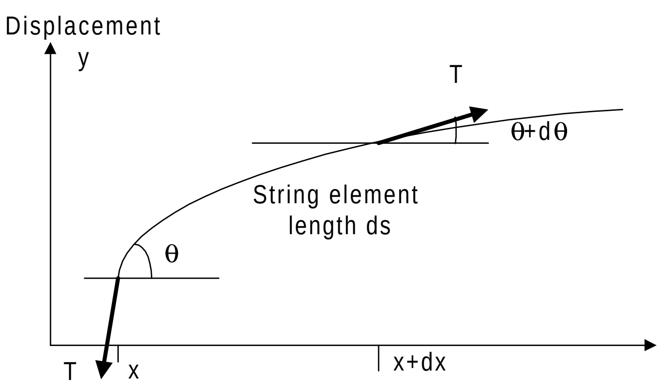


Figure T8.23: Forces on an element of a stretched string.

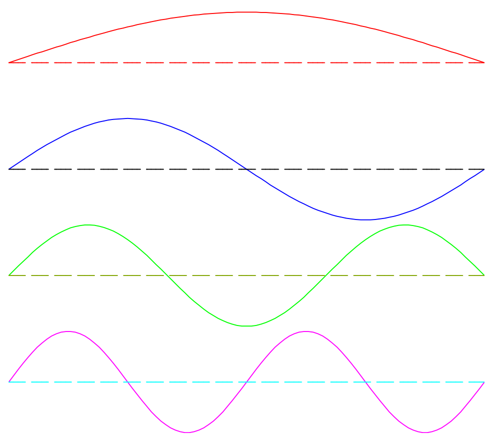


Figure T8.24: The displacements in the four lowest-frequency normal modes of transverse vibration of a stretched string with fixed ends.

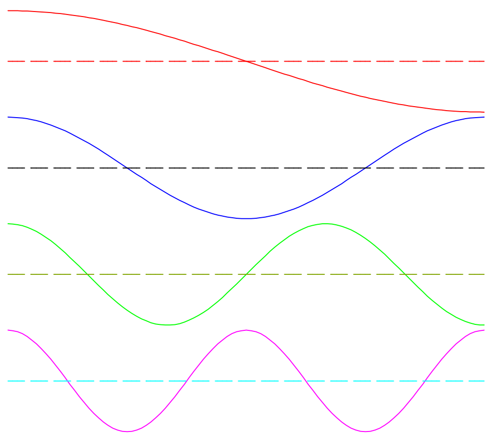


Figure T8.25: The displacements in the four lowest-frequency normal modes of transverse vibration of a stretched string with ends supported with no transverse force.

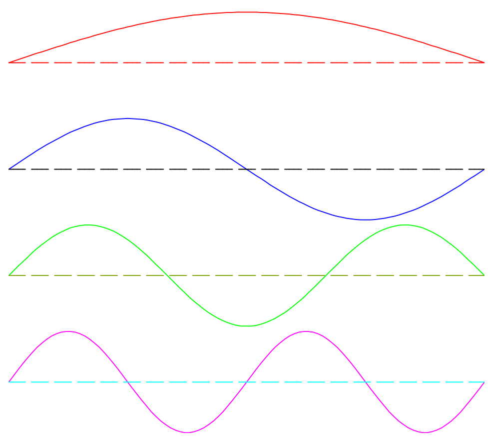


Figure T8.26: The displacements in the four lowest-frequency normal modes of transverse vibration of a stretched string with fixed ends.

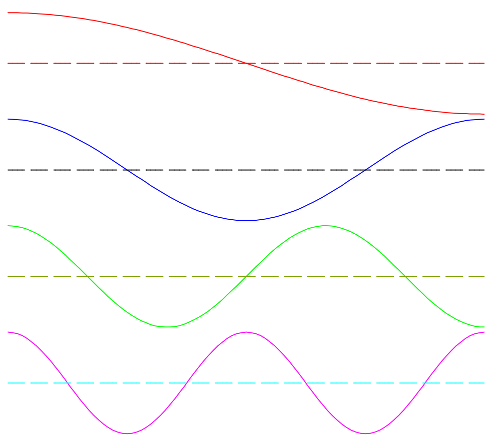


Figure T8.27: The displacements in the four lowest-frequency normal modes of transverse vibration of a stretched string with ends supported with no transverse force.

Topic 10 - Acoustic Waves

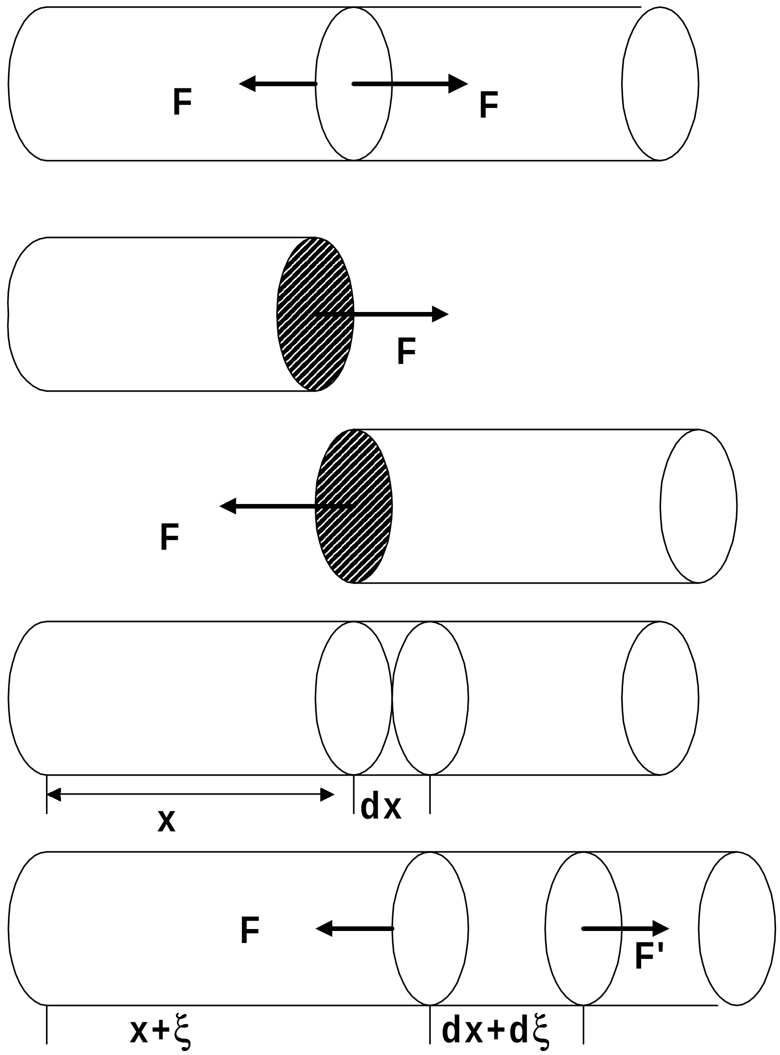


Figure T10.28: The displacement and associated force in a rod supporting a wave.

Figure T10.29: Waves in action: the earth's structure as revealed by the propagation of seismic waves; the destructive effects of an earthquake; ultrasound used for nondestructive testing of a pipe; the image of a foetus revealed by ultrasound.

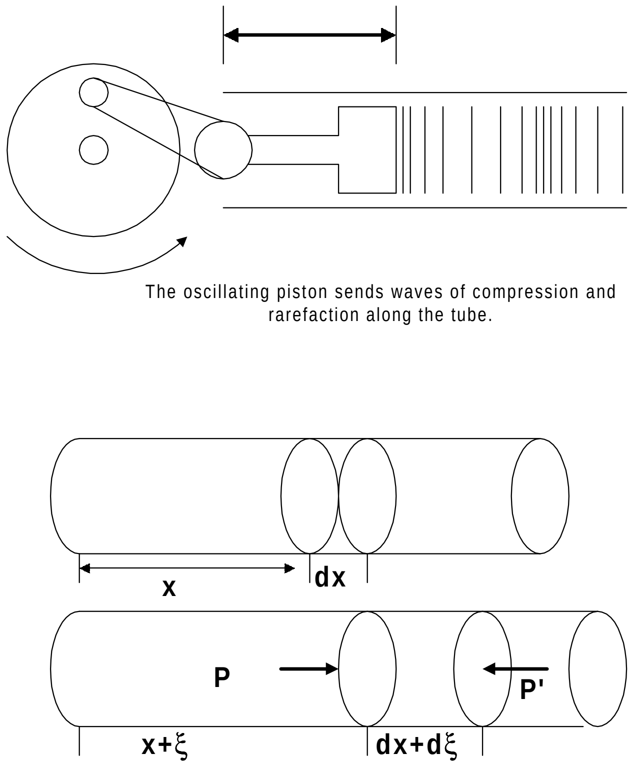


Figure T11.30: The propagation of a wave in a gas.

Topic 12 - Impedance and Energy Transport in Waves

Topic 13 - Impedance and Energy Transport in Waves (concluded) — Reflection and Transmission at Interfaces

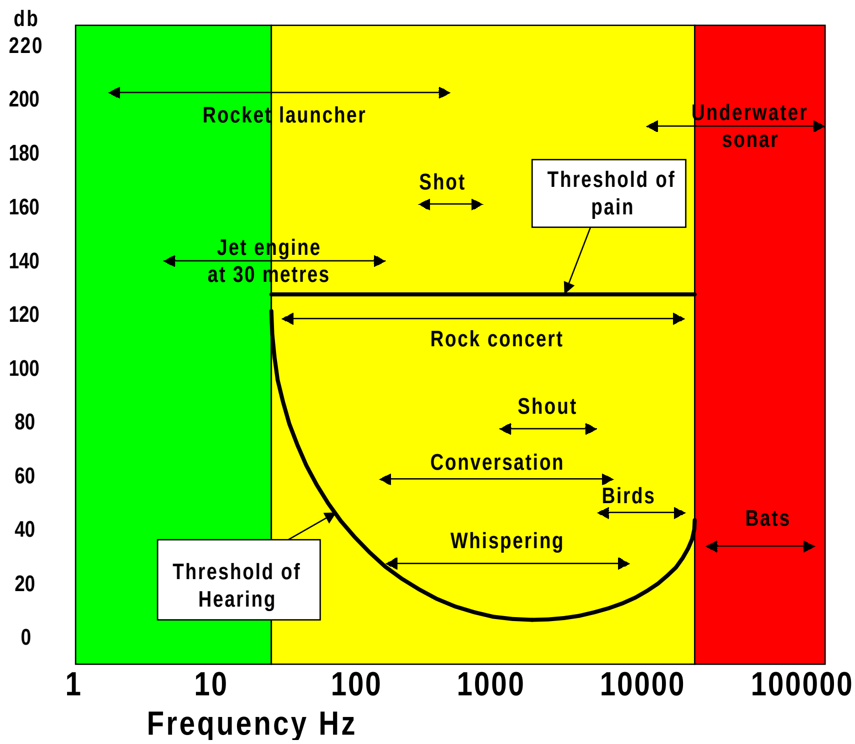


Figure T13.31: Examples of sound intensities.

Topic 14 — Reflection and Transmission at Interfaces (concluded)

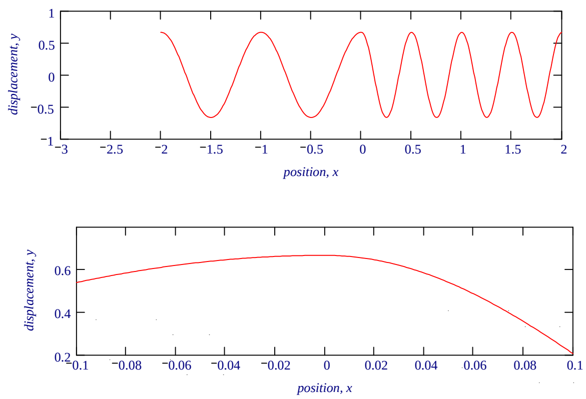


Figure T14.32: A wave encountering the join between two strings: the lower figure is a close-up near the join, showing the smoothness of the displacement.

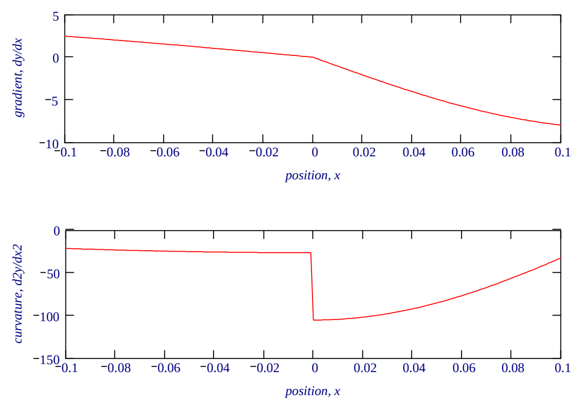


Figure T14.33: The slope and curvature of the wave near the join.

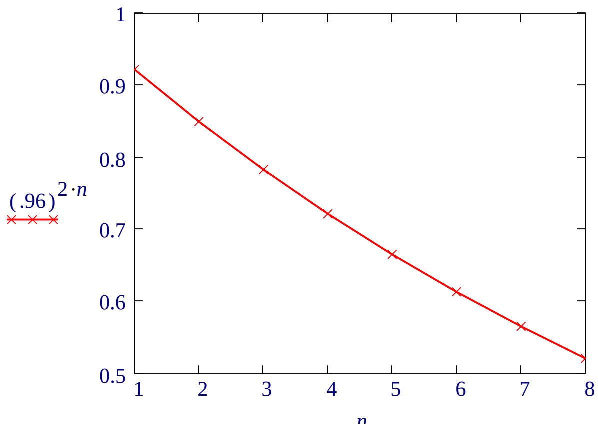


Figure T15.34: Decrease of transmitted energy as light propagates through a series of (air/glass/air) interfaces, assuming 96 percent transmission at each interface.

Topic 16 — Impedance Matching: II

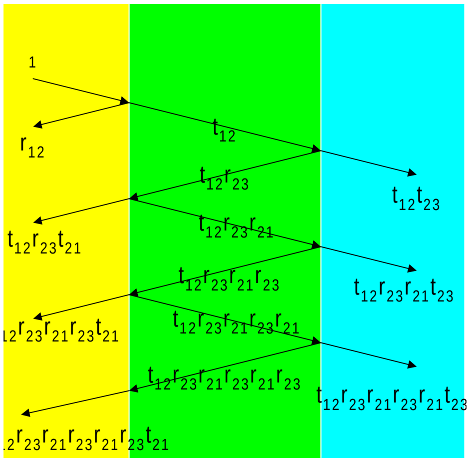


Figure T16.35: Multiple reflections in a coating. Note that only the amplitudes are shown here: when the separate reflections or transmissions are added to give the totals, appropriate phase factors must be included to account for the distance travelled in the layer.

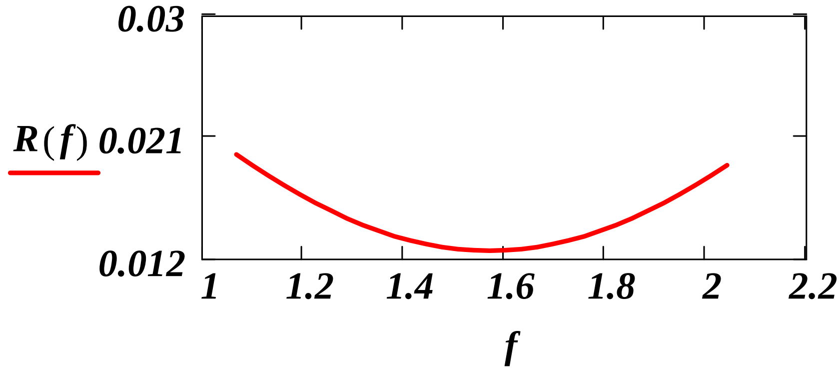


Figure T16.36: The reflected power from an air/glass interface coated with a quarter-wave layer of magnesium fluoride. The parameter f is $4\pi l/\lambda$, where l is the coating thickness and λ is the wavelength. The factor of 2 in wavelength shown would be enough to span the visible spectrum, with reflectivity optimised in the green.

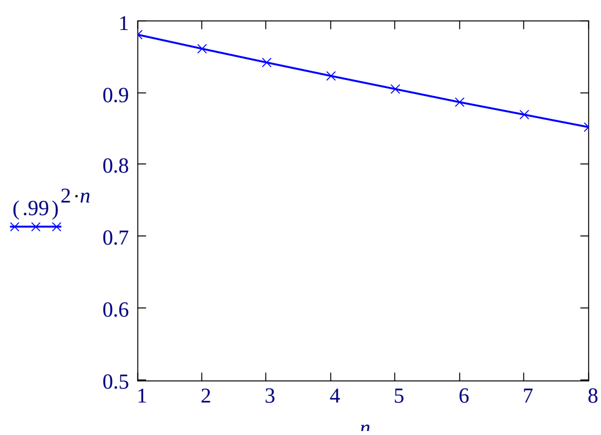


Figure T16.37: Decrease of transmitted energy as light propagates through a series of (air/glass/air) interfaces, assuming 99 percent transmission at each interface.

Topic 17 — - Waves in more than one dimension *FGT377, AF769-772*

Figure T17.38: Planes of constant phase in a plane wave in three dimensions are parallel planes (figure omitted to save file space).

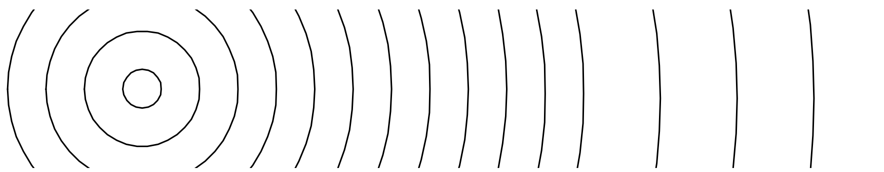


Figure T17.39: A wave spreading away from a point source, showing that at large distances a small section of the wavefront looks almost flat.

Topic 18 — Standing Waves and Waveguides

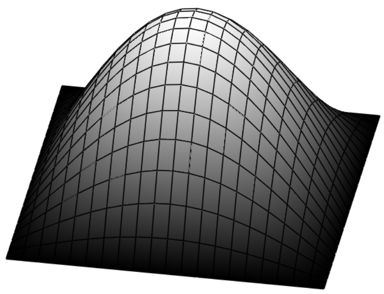


Figure T18.40: The lowest mode of vibration of a square membrane.

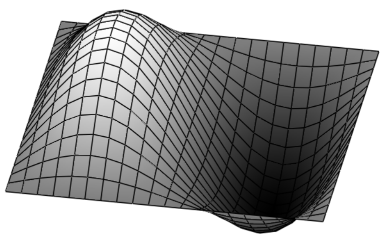


Figure T18.41: A second mode of vibration of a square membrane.

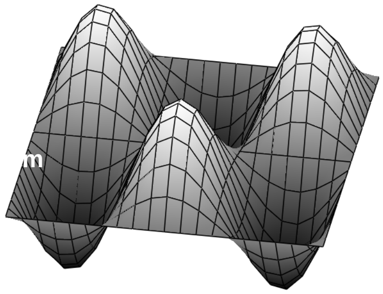


Figure T18.42: A third mode of vibration of a square membrane.

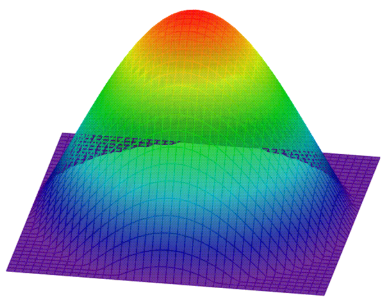


Figure T18.43: The lowest mode of vibration of a circular membrane.

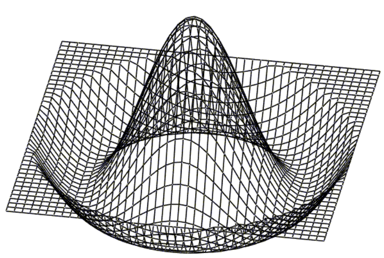


Figure T18.44: A mode of vibration of a circular membrane, showing one radial node but maintaining circular symmetry.

A Guided Wave System

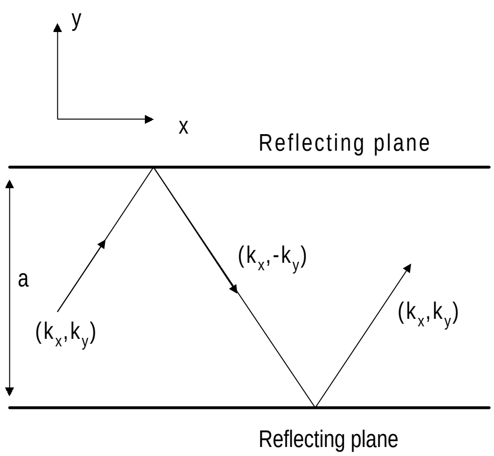


Figure T18.45: A pair of reflecting planes, forming a wave-guide.

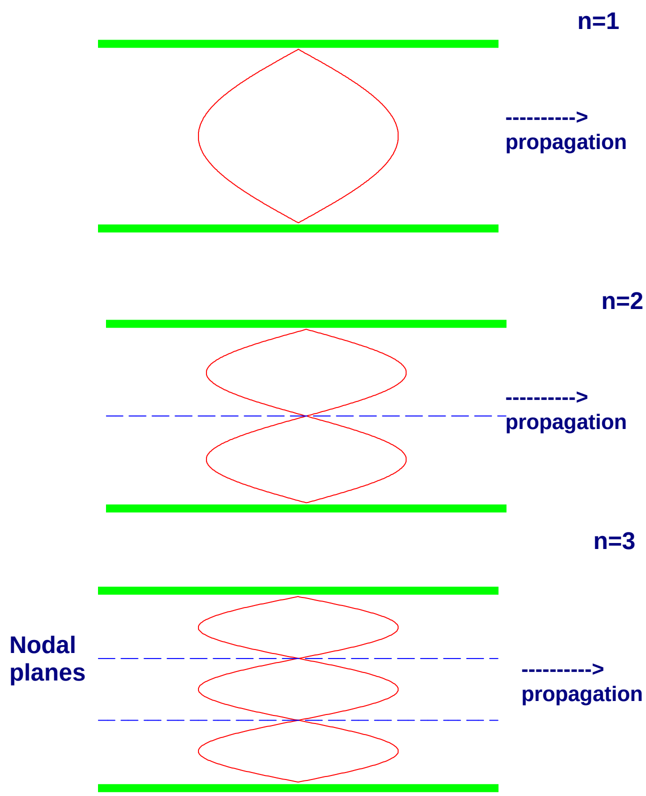


Figure T18.46: The nodal planes in a two-dimensional wave guide.

Topic 19 — The Doppler Effect: Moving sources and Receivers

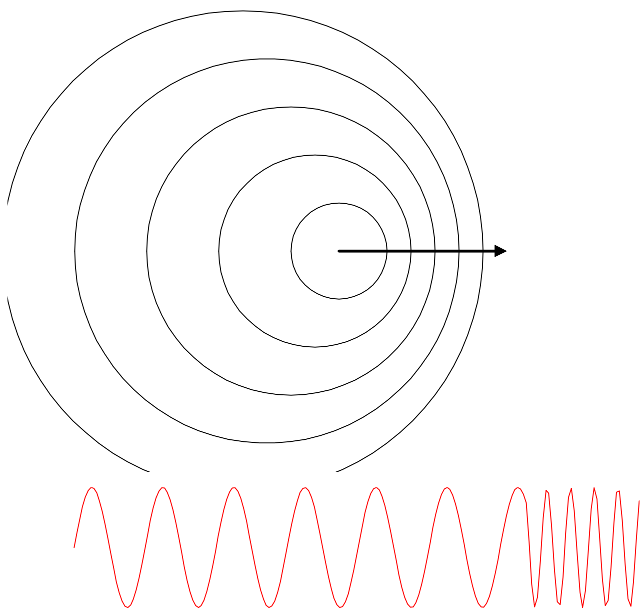


Figure L19.47: The waves spreading out from a moving source, showing the wavelengths compressed in front of the source, extended behind it.

Topic 20 — Light: Some Basic Properties

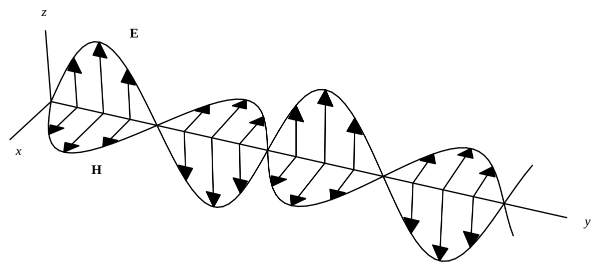


Figure L20.48: An electromagnetic wave, made up of interdependent electric and magnetic fields.

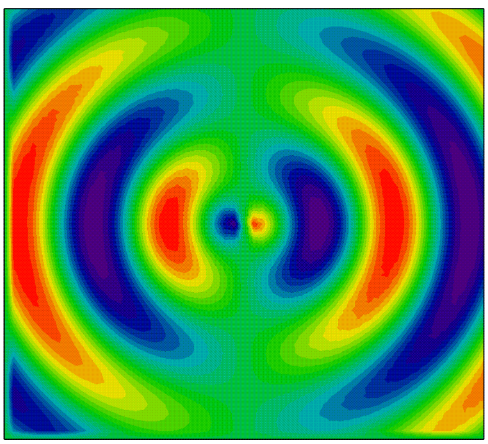


Figure L20.49: The radiation pattern from a dipole source: the dipole is pointing up the page, and does not radiate along that direction. In the diagram, red represents positive field, blue represents negative field, and green is zero.

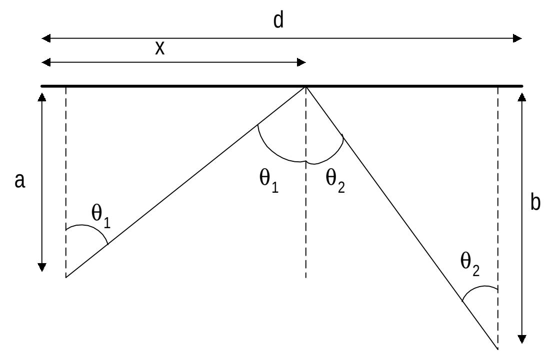


Figure L20.50: The application of Fermat's principle to reflection from a plane surface.

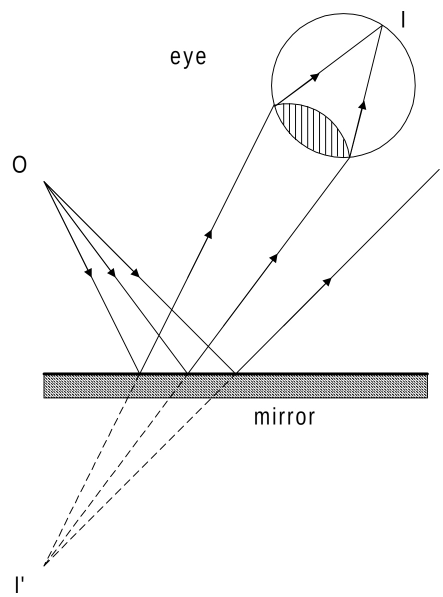


Figure L20.51: The image in a plane mirror is a *virtual* image, as the rays do not pass through the image.

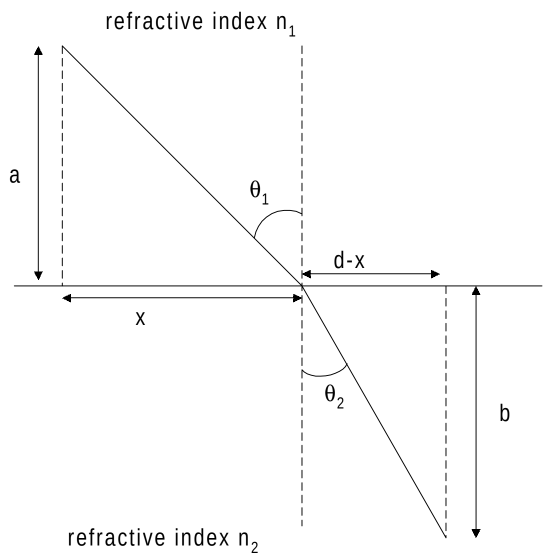


Figure L20.52: The propagation of a general wave pulse.

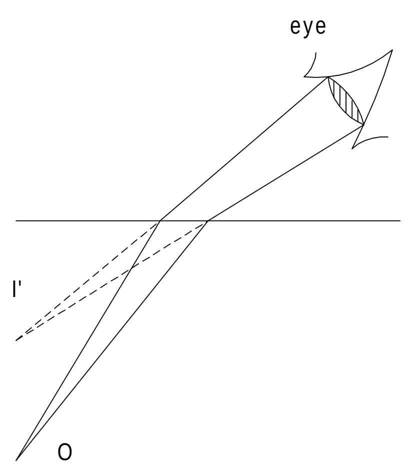


Figure L20.53: The image formed by refraction at a plane surface..

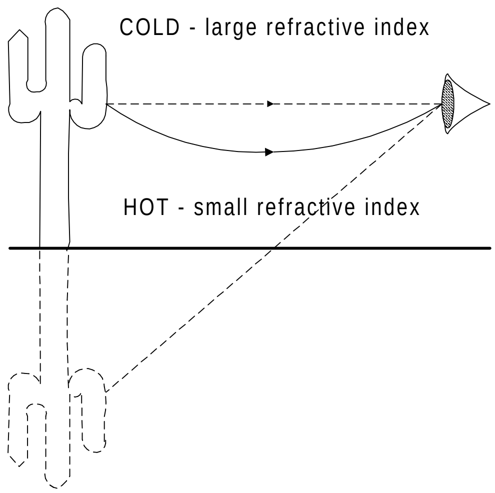


Figure L20.54: The mirage effect, formed by refraction at a layer of hot, less dense air.

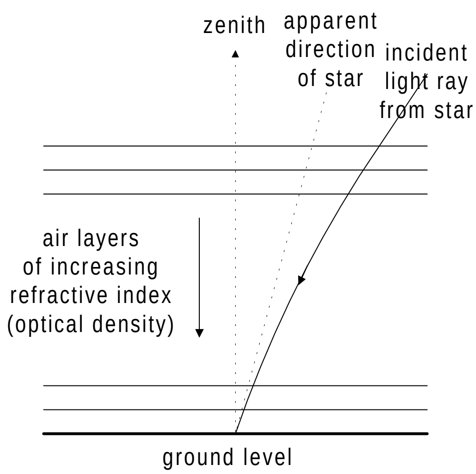


Figure L20.55: The effect of atmospheric density variation on the apparent positions of stars.

Topic 21 — Interference - Basic phenomena

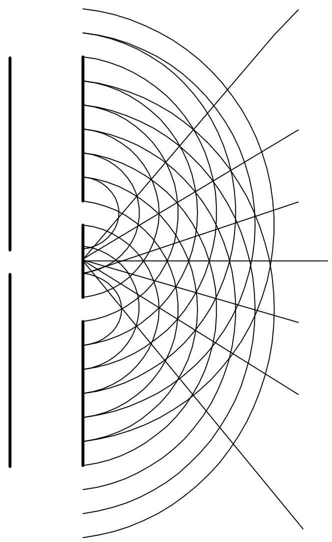


Figure L21.56: The pattern of peaks in waves from Young's slits, showing the directions in which they reinforce each other.

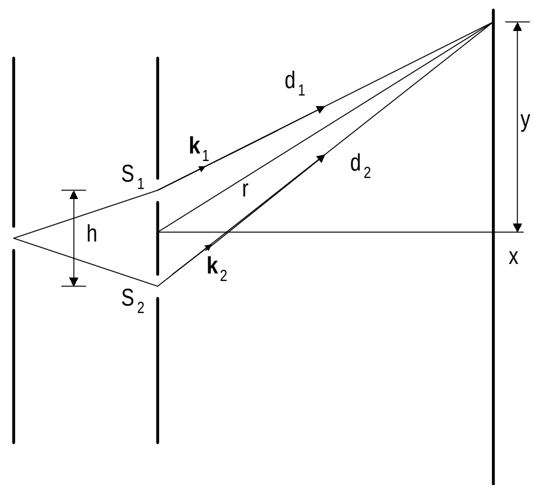


Figure L21.57: The geometry for calculating the path length difference in Young's experiment.

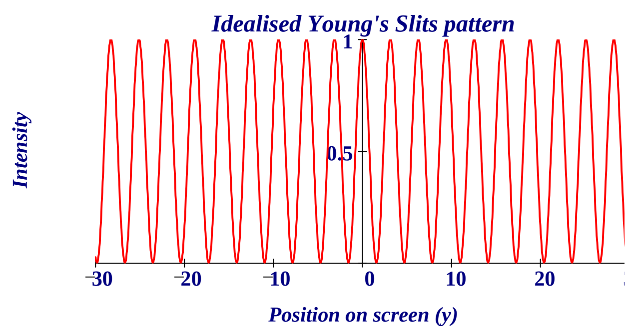


Figure L21.58: The (ideal) pattern of intensities in Young's experiment.

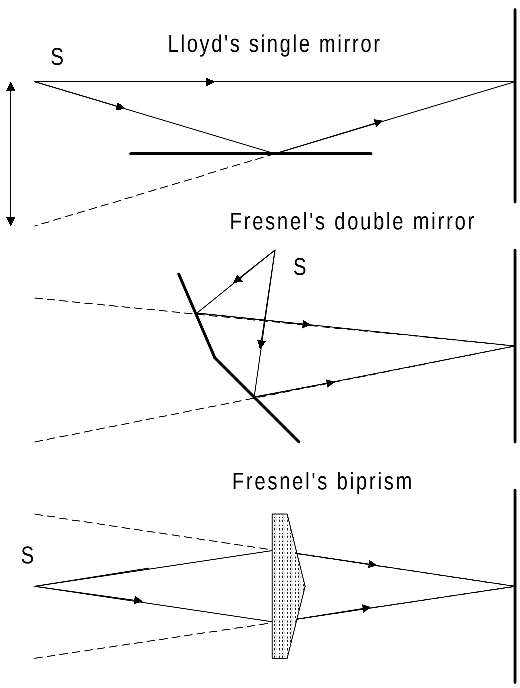


Figure L21.59: Alternative methods of dividing the wave-front for interference experiments.

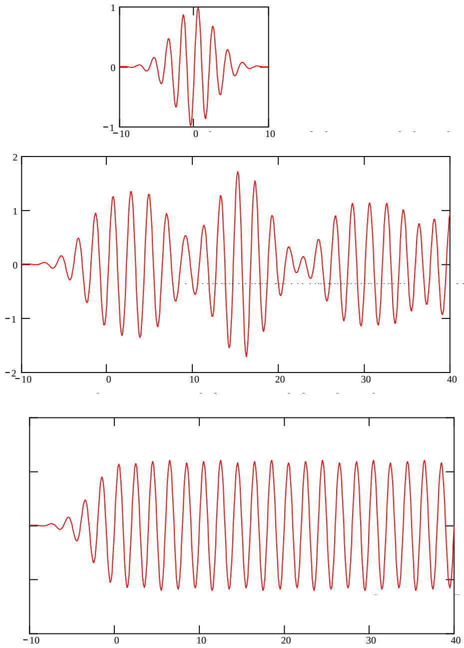


Figure L21.60: In light from, for example, a sodium flame, each atom sends out a short pulse of light (top). If all the atoms radiated 'in step' the result would be as shown in the middle graph. In reality, the atoms 'fire' at random, giving the irregular wave shown at the bottom.

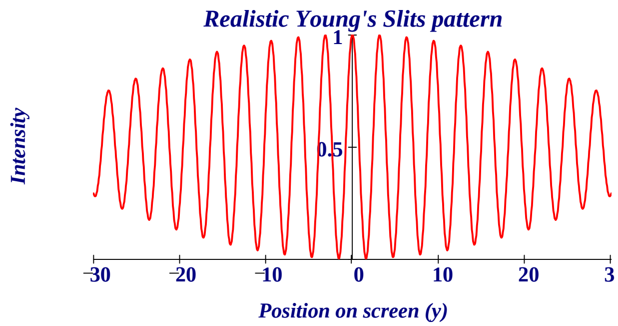


Figure L21.61: The fading of the fringe pattern at larer angles in Young's experiment, as a result of the finite coherence length of the light.

Topic 22 — Interference of Several Sources
FGT1051-1053, AF914-917

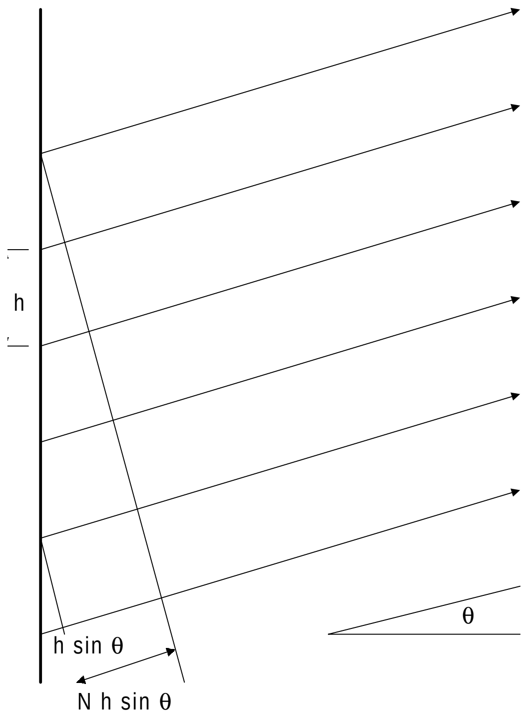


Figure L22.62: The geometry of several interfering sources.

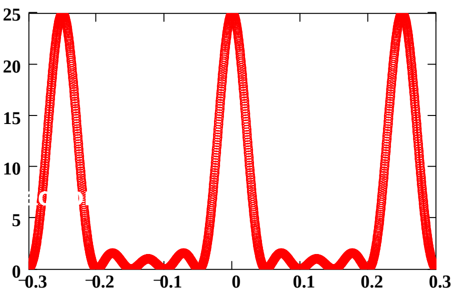


Figure L22.63: The interference pattern produced by five line sources, showing intensity plotted as a function of angle in radians.

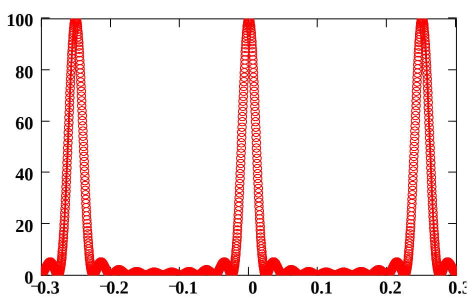


Figure L22.64: The interference pattern produced by ten line sources, showing intensity plotted as a function of angle in radians.

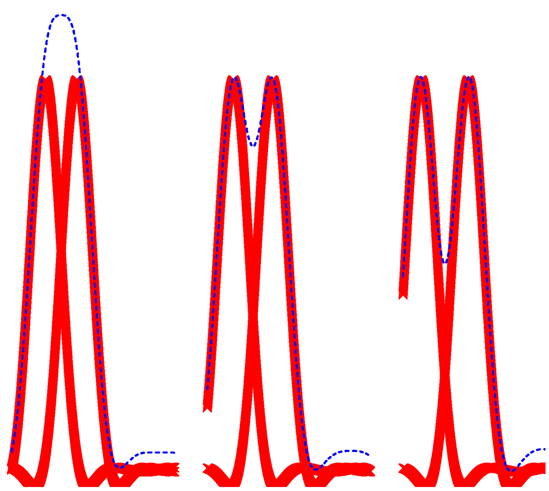


Figure L22.65: The Rayleigh criterion for distinguishing between two interference peaks.

Topic 23 — Resolution of Grating and Diffraction

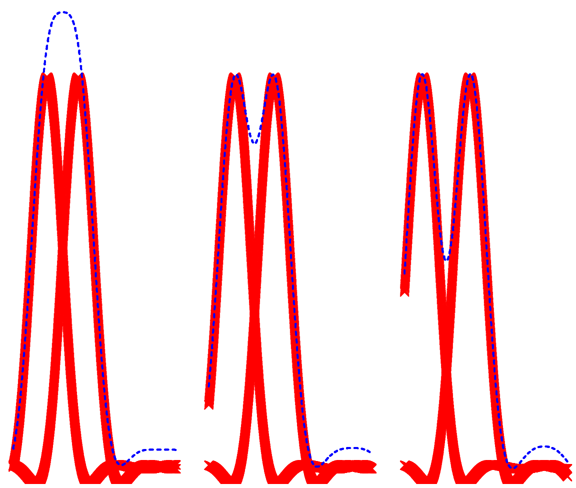


Figure L23.66: Rayleigh's criterion for two lines to be distinguishable, illustrated with pairs of lines separated by 0.8, 1.0 and 1.2 times the Rayleigh criterion.

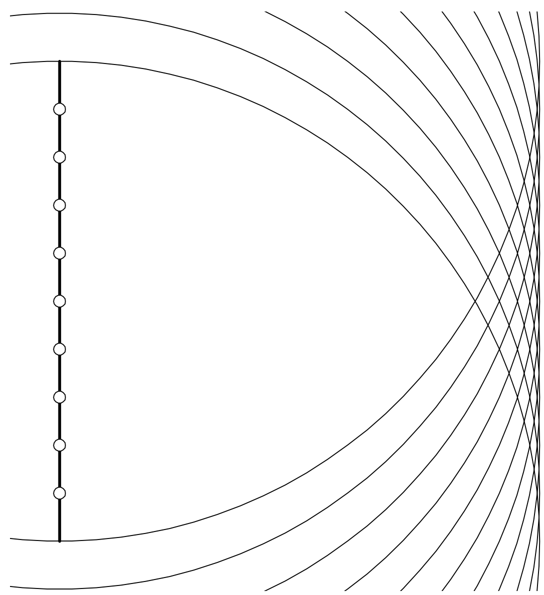


Figure L23.67: Huygens's principle applied to the propagation of a plane wave. The dots on the primary wave front represent the secondary sources, and the circular arcs are the secondary waves. The envelope is another plane wave.

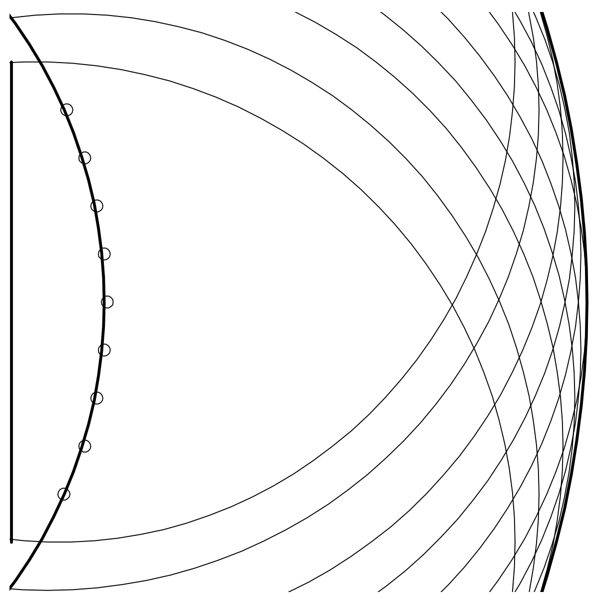


Figure L23.68: Huygens's principle applied to the propagation of a cylindrical wave. The dots on the primary wave front represent the secondary sources, and the circular arcs are the secondary waves. The envelope is another cylindrical wave, with larger radius of curvature.

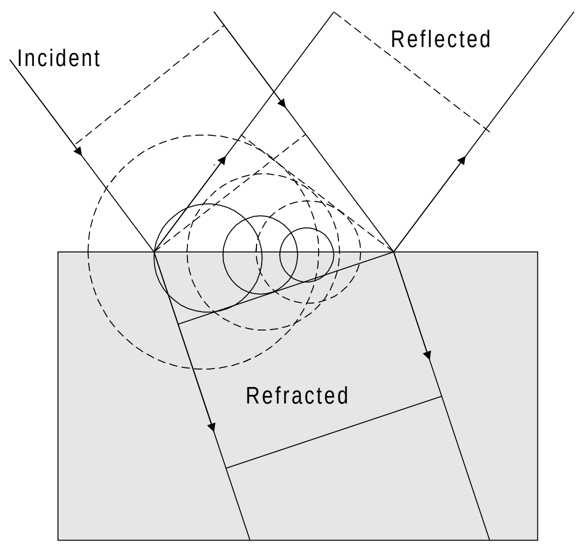


Figure L23.69: Huygens's principle applied to the reflection and refraction of a plane wave at an interface. The circles are drawn with different radii representing the different speeds in the two media and the different times at which the wave arrive at the interface.

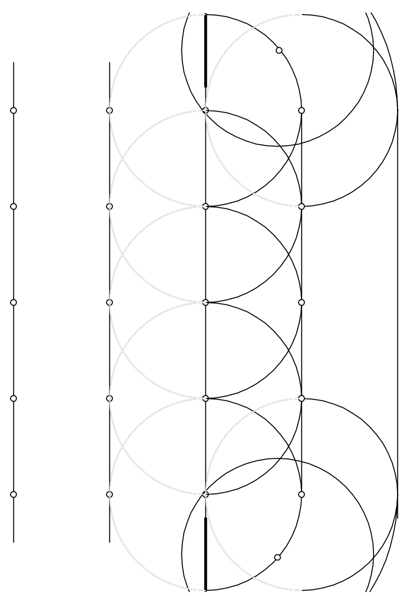


Figure L23.70: Huygens's principle applied to the passage of a plane wave through an aperture. The envelope function shows the wave spreading outwards from the aperture *in a way that is independent of the wavelength.*

Topic 24 — Diffraction

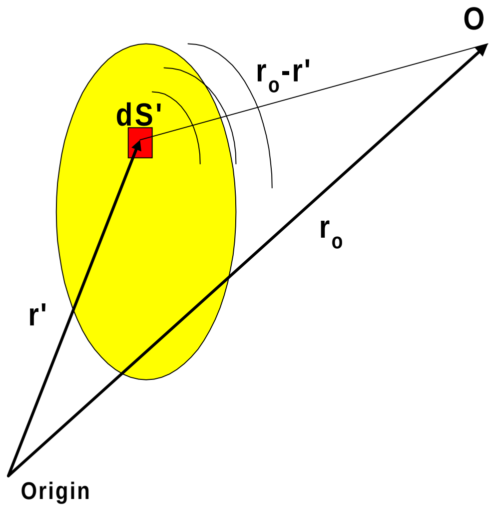


Figure L24.71: Diffraction of a wave through an aperture. Each element dS' of the aperture contributes to the total field at the observation point O.

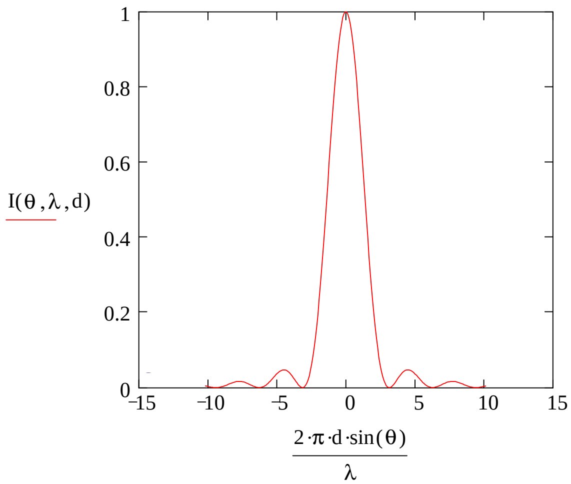


Figure L24.72: The variation of intensity with angle in the diffraction pattern of a narrow slit.

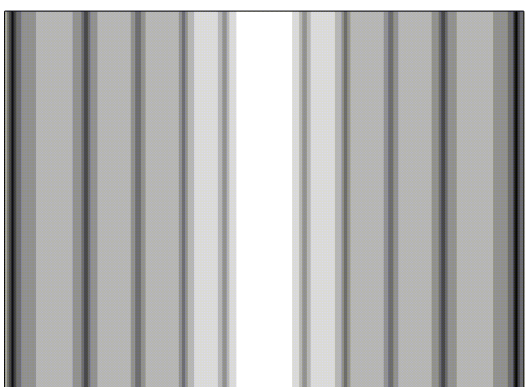


Figure L24.73: The light and dark bands in the diffraction pattern of a narrow slit.

Topic 25 — Diffraction and Resolution

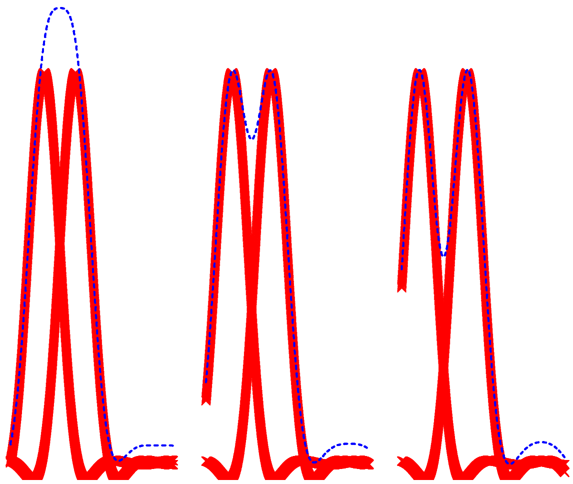


Figure L25.74: Rayleigh's criterion for the distinguishability of two diffraction peaks, illustrated by peaks separated by 0.8, 1.0 and 1.2 times the Rayleigh distance.

Diffraction pattern - slit and circular aperture

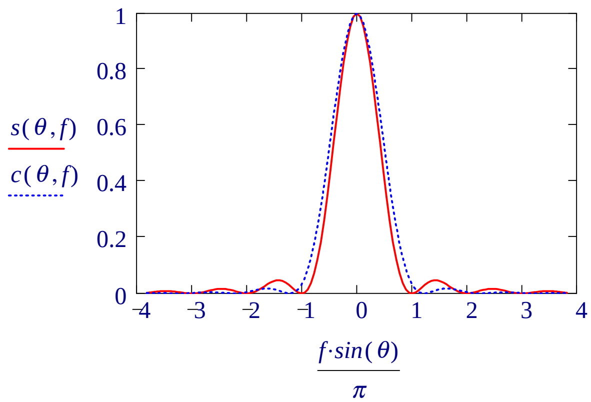


Figure L25.75: The diffraction pattern $c(f,\theta)$ of a circular aperture compared with $s(f,\theta)$ for a slit, where f is $\pi d/\lambda$. The wavelength is λ and d is the width of the slit or the diameter of the circular aperture.

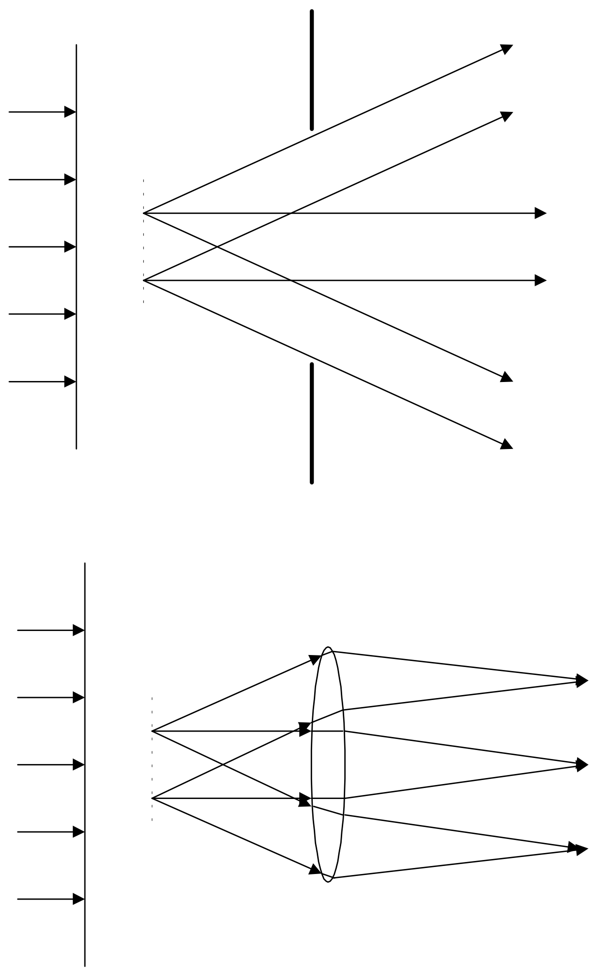


Figure L25.76: The lowest-order diffraction maxima of a grating passing through a finite aperture, such as the objective lens of a mircoscope. The upper diagram shows a simple aperture, whereas the lower diagram shows the focusing effect of the lens.

Topic 26 — Diffraction (concluded)

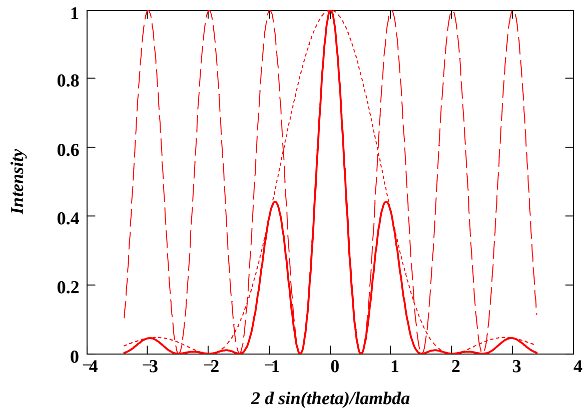


Figure L26.77: Young's slits pattern as modified by a finite slit width. In this figure the slit widths are half of the separation between the slits. Note that the even orders of diffraction are missing.

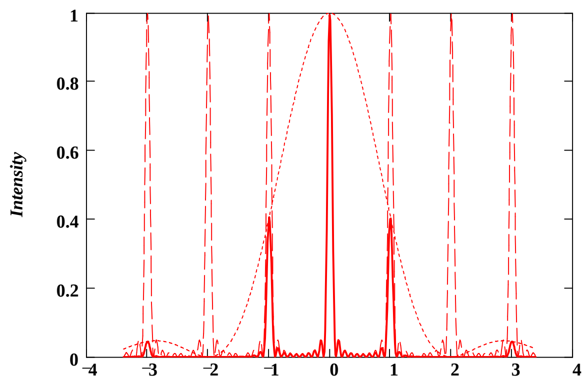


Figure L26.78: The modification of the diffraction pattern of a grating, shown for an unrepresentatively small number of slits (ten), each half as wide as the slit spacing.

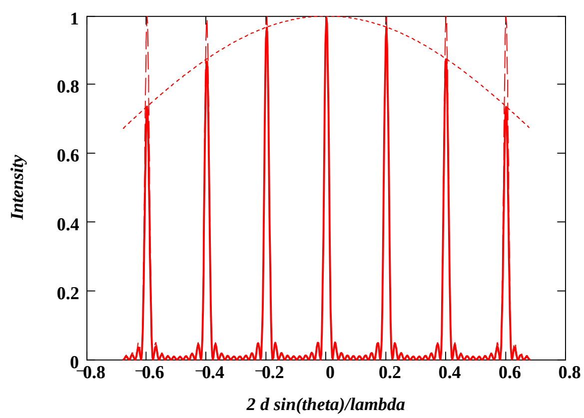


Figure L26.79: The modification of the diffraction pattern of a grating, shown for an unrepresentatively small number of slits (ten), each one tenth as wide as the slit spacing.

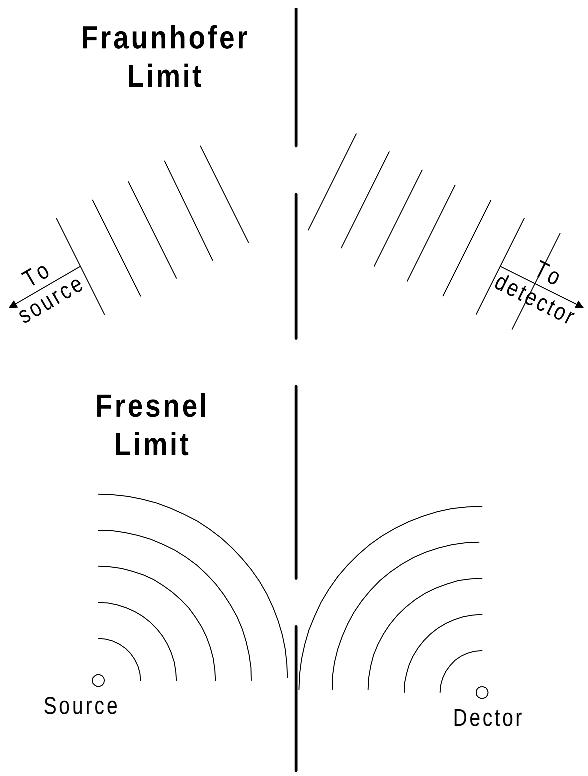


Figure L26.80: The difference between Fraunhofer and Fresnel diffraction.

Topic 27 — Interference - Various Phenomena

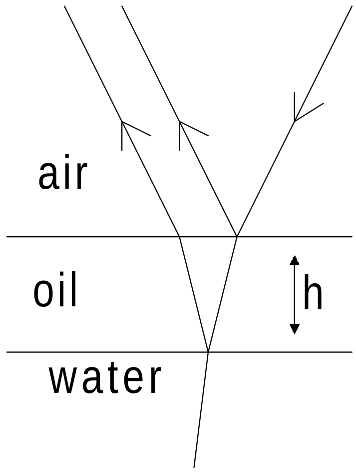


Figure L27.81: The geometry of fringe formation in an oil film.

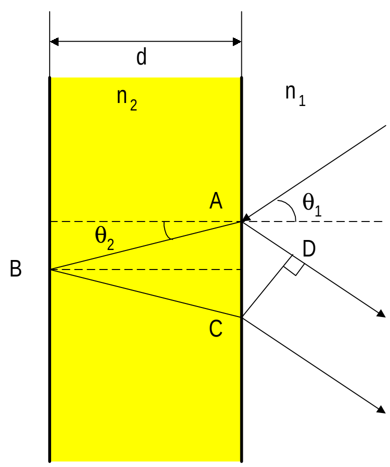


Figure L27.82: The geometry of fringe formation by a layer at non-normal incidence.

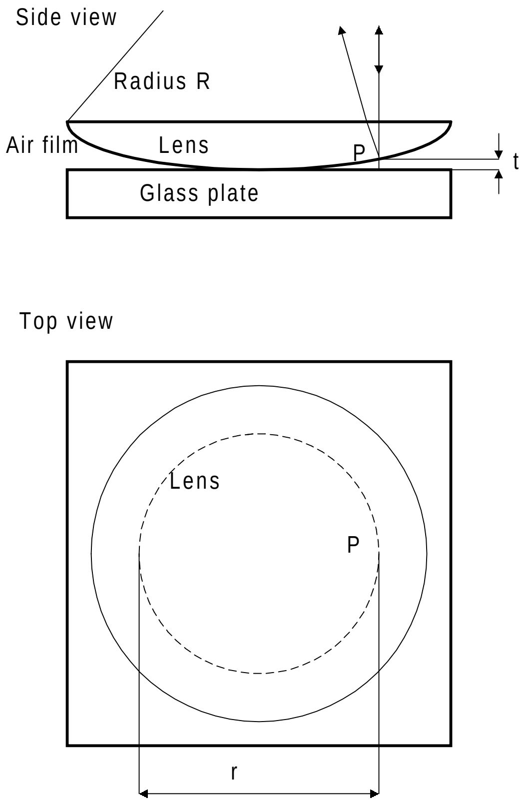


Figure L27.83: The set-up of a Newton's rings experiment.

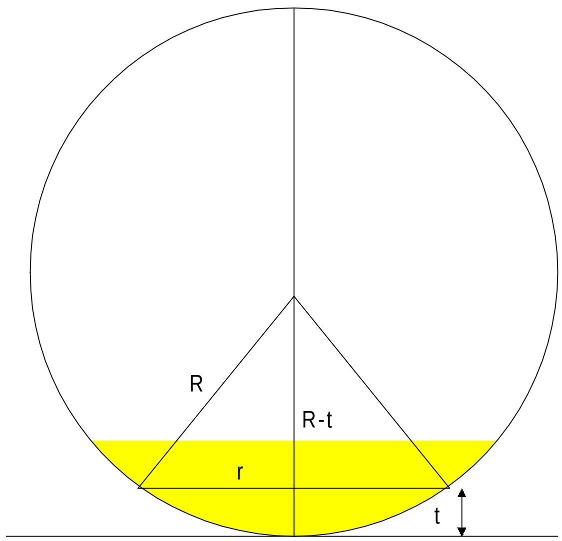


Figure L27.84: The geometry of the Newton's rings experiment.

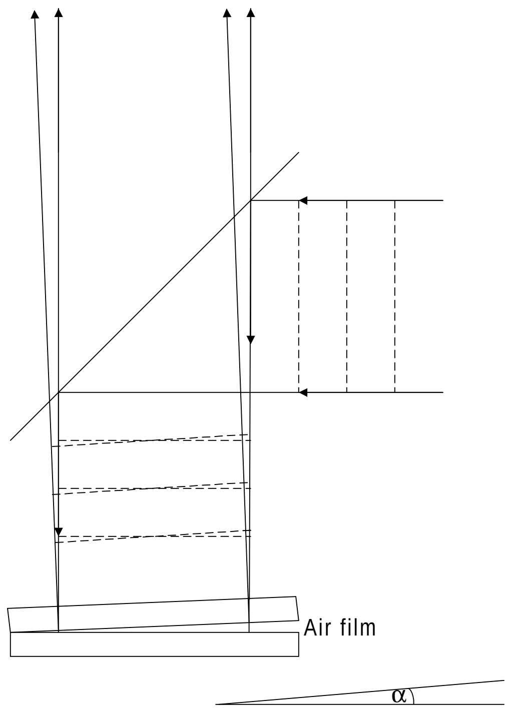


Figure L27.85: The formation of fringes in a wedge.

Topic 28 — The Michelson Interferometer

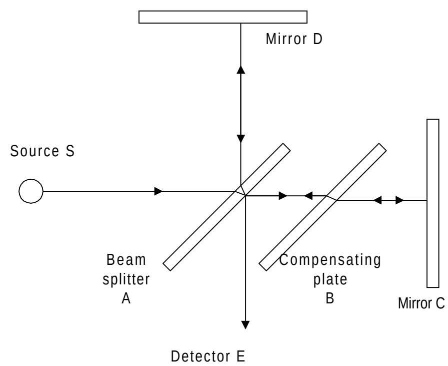


Figure L28.86: The Michelson interferometer: see the text for a detailed description.

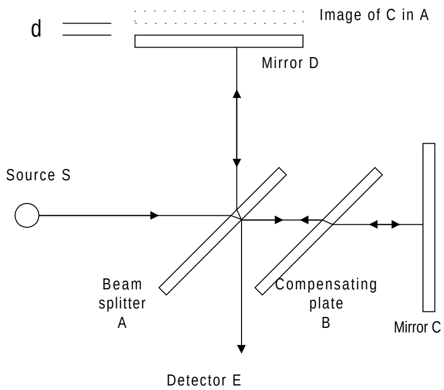


Figure L28.87: The relative positions of the mirrors in the Michelson interferometer are best thought of by thinking of the relative position of the mirrors in terms of the image of the movable mirror in the beam splitter.

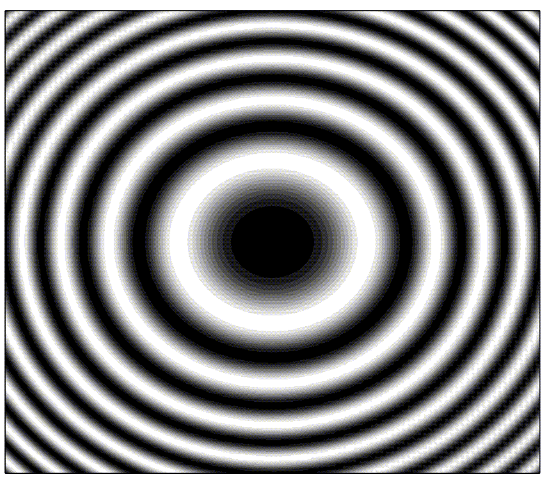


Figure L28.88: The pattern of circular fringes produced in the Michelson interferometer with both mirrors perpendicular to the beams and with a spacing of 100 wavelengths.

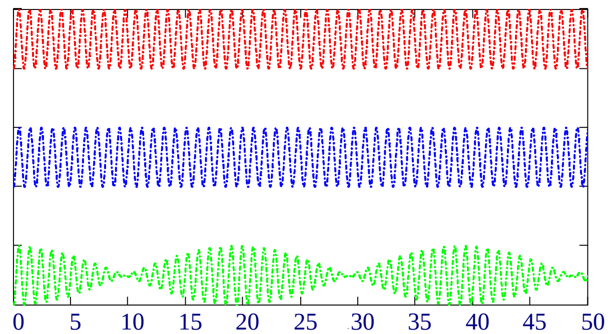


Figure L28.89: The variation of fringe intensity with distance for (top) a wavelength λ, (centre) a wavelength of 1.05λ and (bottom) a doublet source containing both wavelengths.

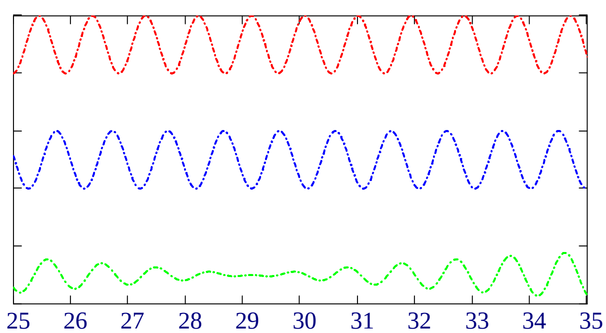


Figure L28.90: Close-up of the variation of fringe intensity with distance for (top) a wavelength λ, (centre) a wavelength of 1.05λ and (bottom) a doublet source containing both wavelengths.

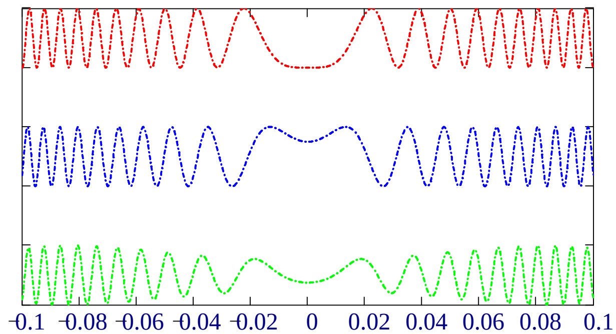


Figure L28.91: The variation of fringe intensity with angle for (top) a wavelength λ, (centre) a wavelength of 1.05λ and (bottom) a doublet source containing both wavelengths, at a mirror spacing of 1000 wavelengths.

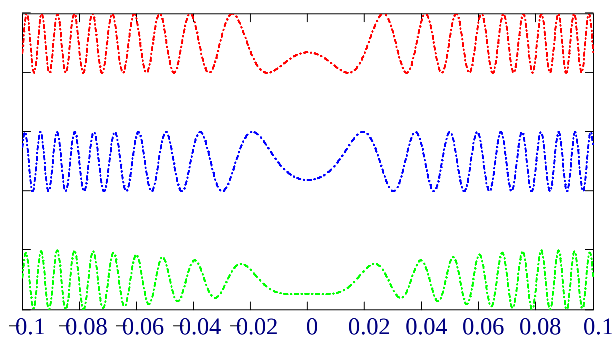


Figure L28.92: The variation of fringe intensity with angle for (top) a wavelength λ, (centre) a wavelength of 1.05λ and (bottom) a doublet source containing both wavelengths, at a mirror spacing of 1000.1 wavelengths.

Topic 29 — The Fabry-Perot Interferometer *FGT1040*

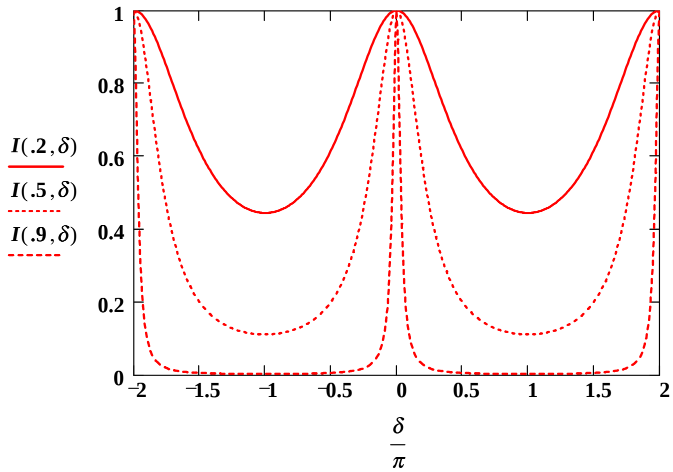


Figure L29.93: The variation of the Airy function with the reflectivity coefficient R, plotted as a function of the phase shift δ.

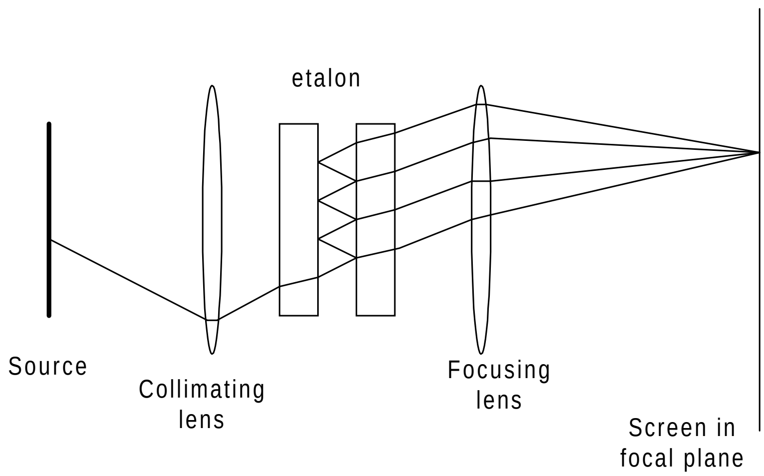


Figure L29.94: The Fabry-Perot interferometer.

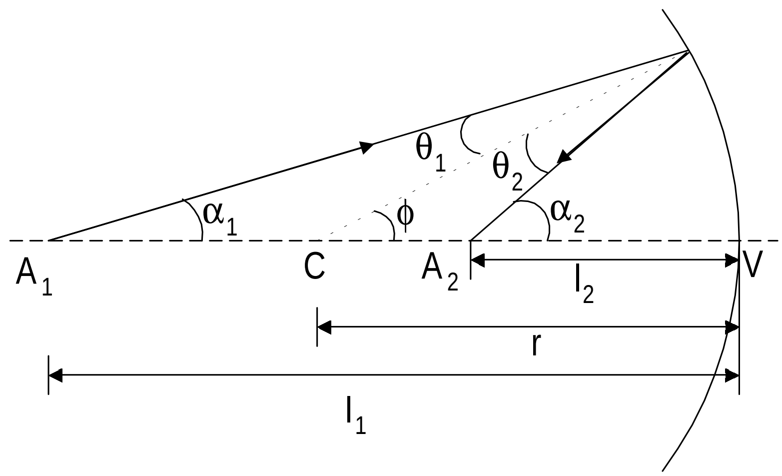


Figure T30.95: Reflection in a concave spherical mirror.

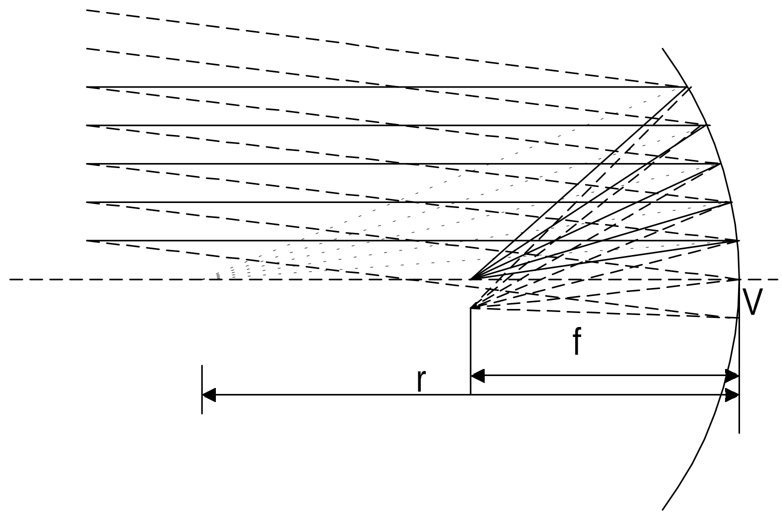


Figure T30.96: The focal length of a concave spherical mirror.

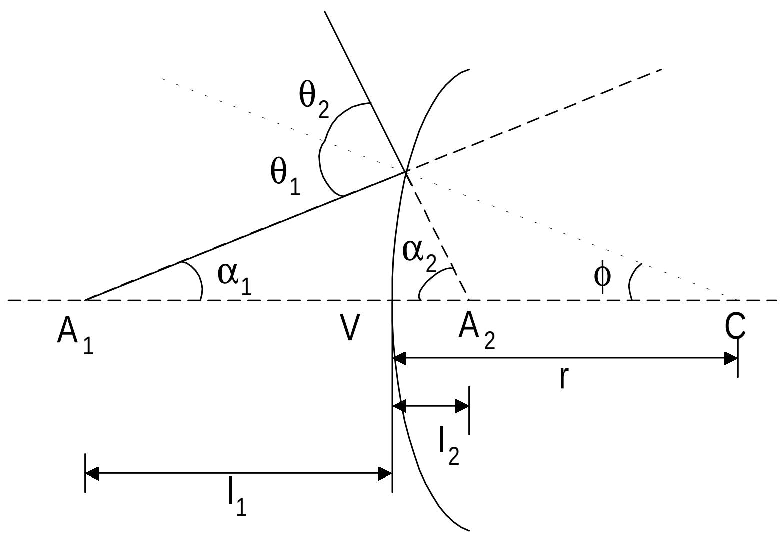


Figure T30.97: Reflection in a convex spherical mirror.

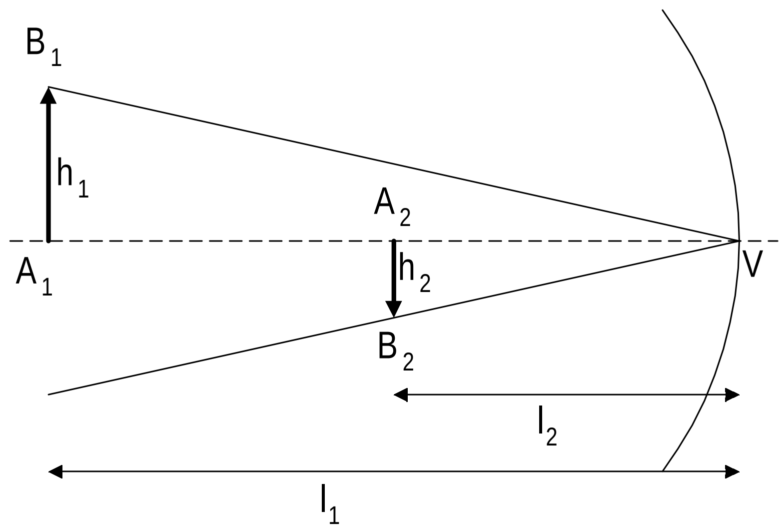


Figure T30.98: Magnification of the image reflected in a concave spherical mirror.

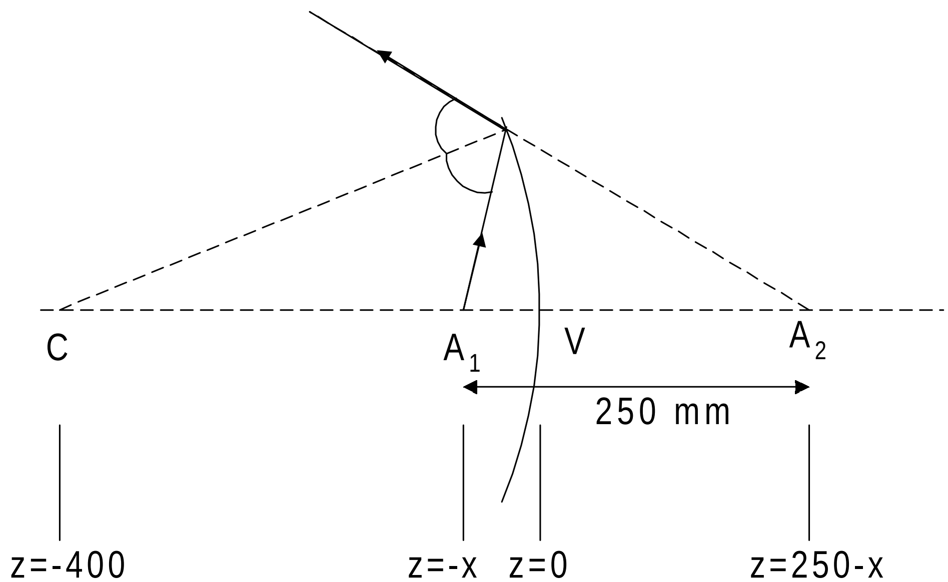


Figure T30.99: A concave spherical mirror used as a make-up or shaving mirror.

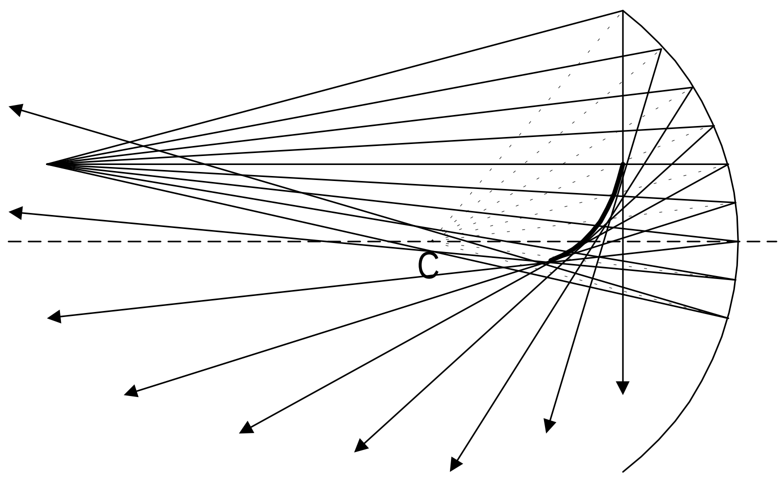


Figure T30.100: Spherical aberration of a concave spherical mirror.

Topic 31 — Applications of Refraction I

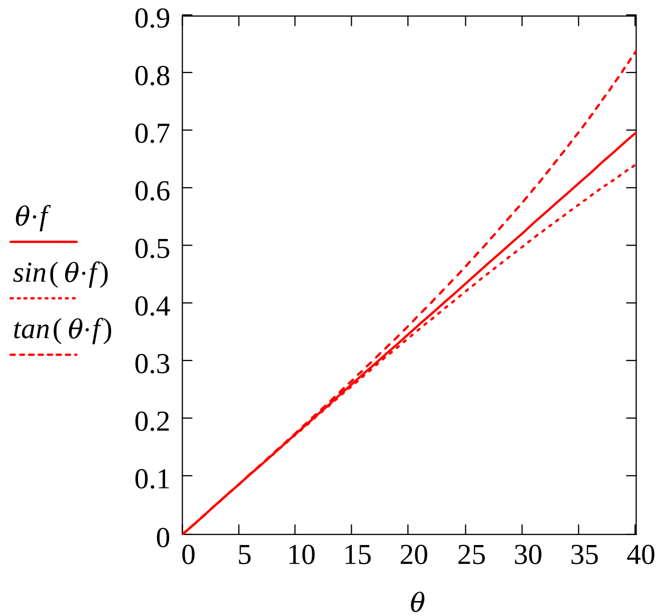


Figure L31.101: Illustration of the approximation $\theta \approx \sin(\theta) \approx \tan(\theta)$ for small angles. Note that although θ on the horizontal axis is given in degrees, on the vertical axis the factor $f = \pi/180$ converts θ to radians.

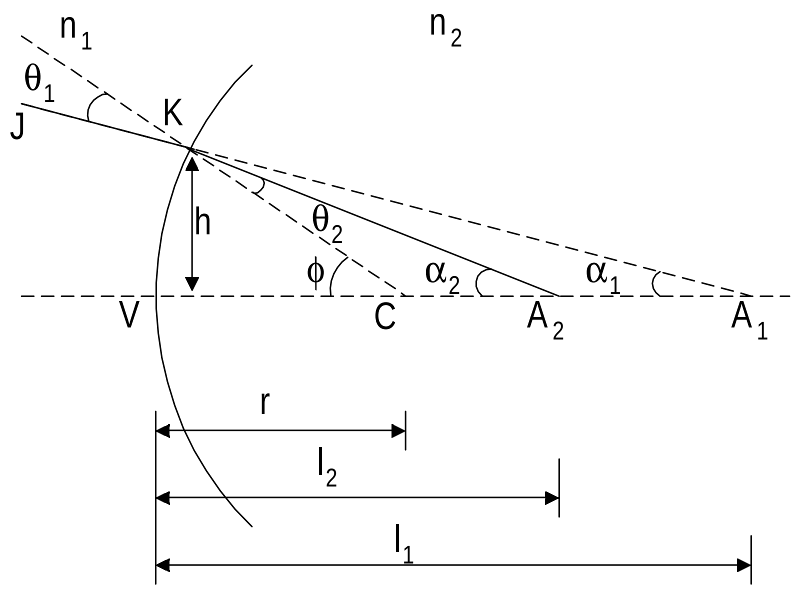


Figure L31.102: Refraction of light at a convex spherical interface.

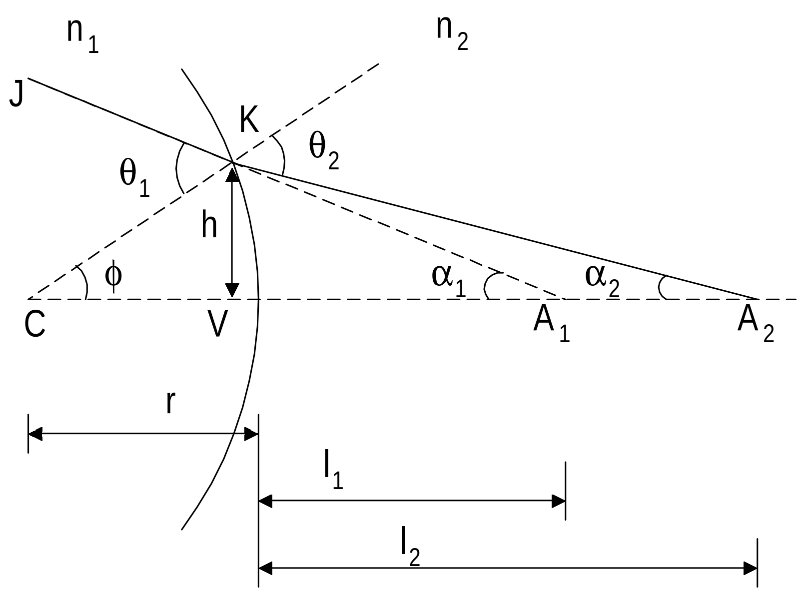


Figure L31.103: Refraction of light at a concave spherical interface.

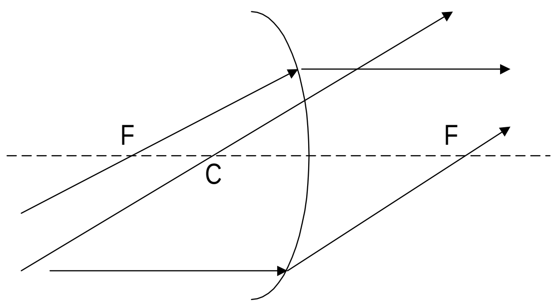


Figure L31.104: The principal rays at a curved interface: these are the two rays through the foci, which enter or leave the system parallel to the optical axis, and the one ray which passes through the system undeviated (in this case, the ray through the centre of curvature of the interface).

Topic 32 — Applications of Refraction II

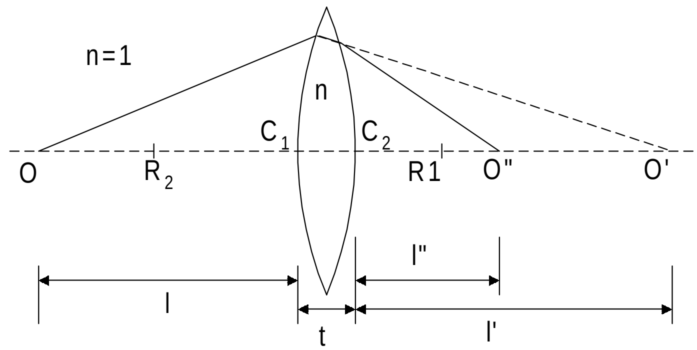


Figure L32.105: The refraction of light by a thin lens.

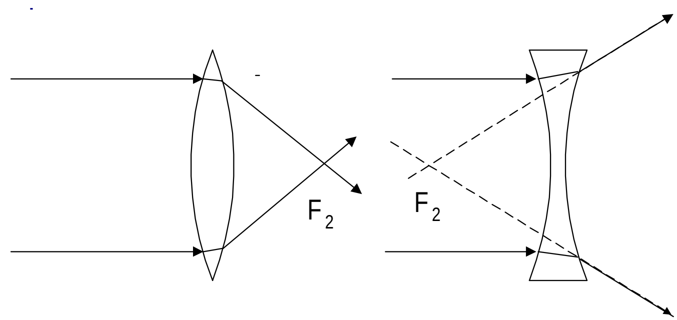


Figure L32.106: The principal rays for a thin lens: rays incident through the first principal focus and exiting parallel to the optical axis.

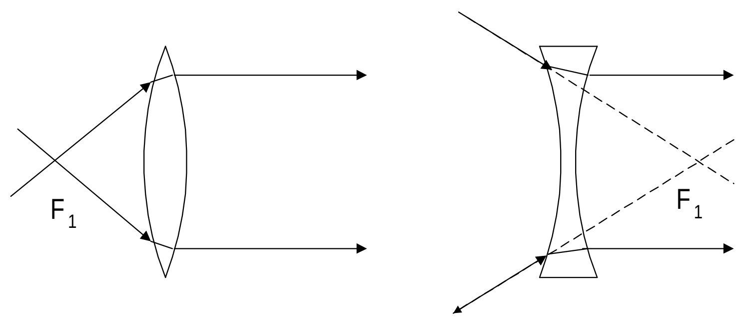


Figure L32.107: The principal rays for a thin lens: rays incident parallel to the axis and exiting through the second principal point.

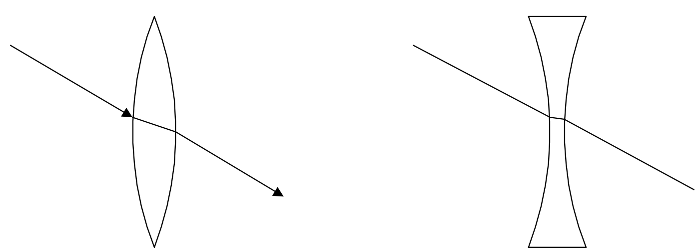


Figure L32.108: The principal rays for a thin lens: rays passing undeviated through the centre of the lens.

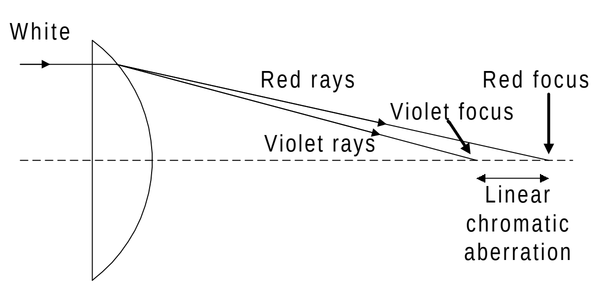


Figure L32.109: Chromatic aberration by a thin lens.

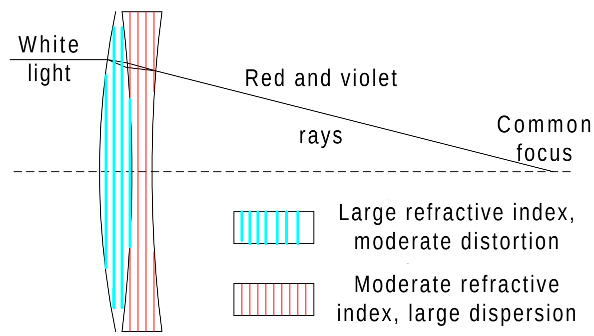


Figure L32.110: Correction of chromatic aberration by an achromatic doublet.

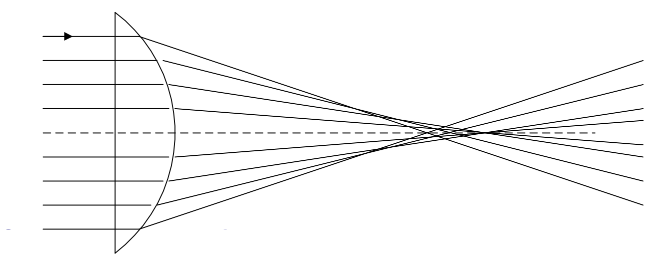


Figure L32.111: Spherical aberration in a large-aperture lens.

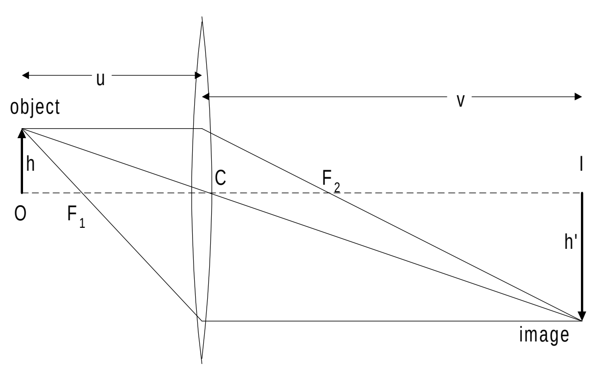


Figure L32.112: The formation of an image by a converging lens.

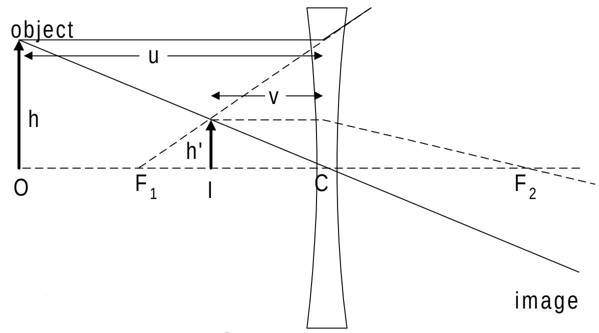


Figure L32.113: The formation of an image by a diverging lens.

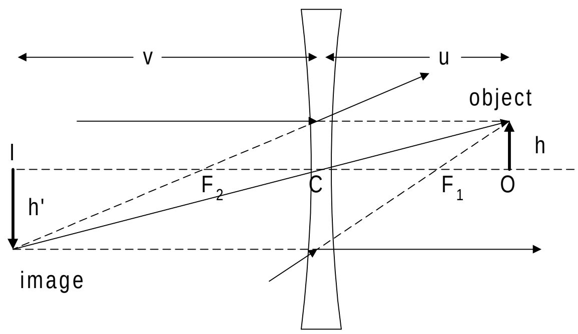


Figure L32.114: The formation of an image of a virtual object in a concave lens.

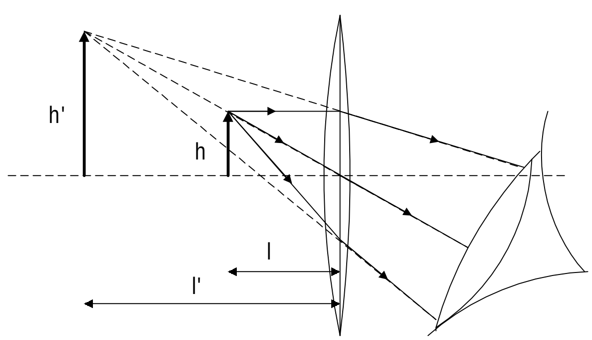


Figure L32.115: The simple lens used as a magnifying glass.

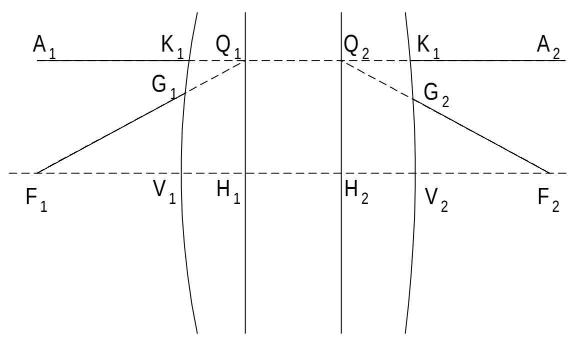


Figure L32.116: The key features of a thick lens system.

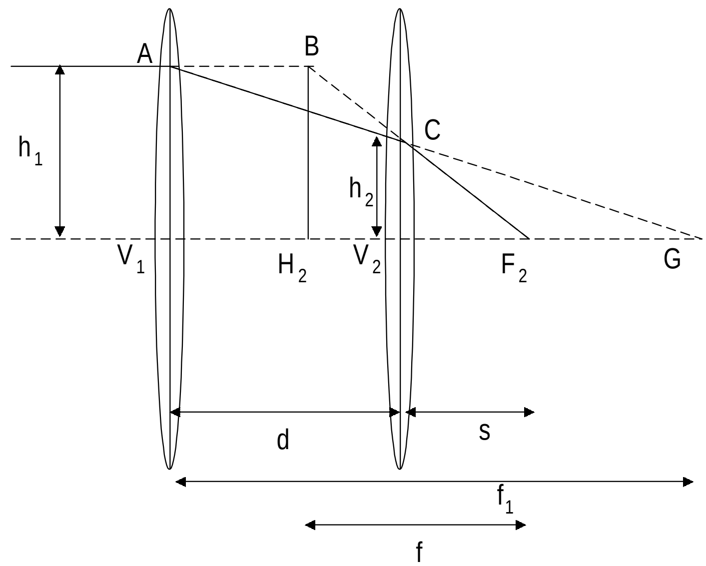


Figure L33.117: The geometry of a two-lens system.

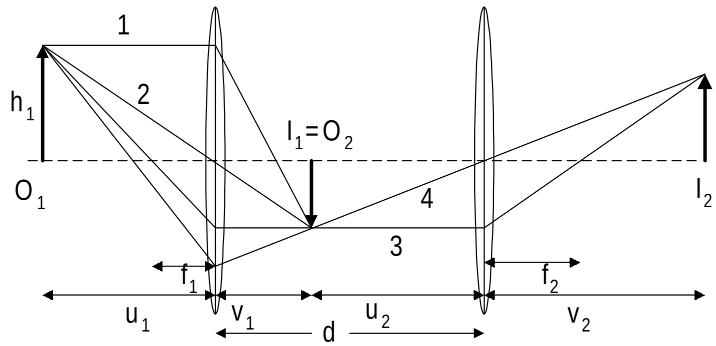


Figure L33.118: An example of a system with two lenses.

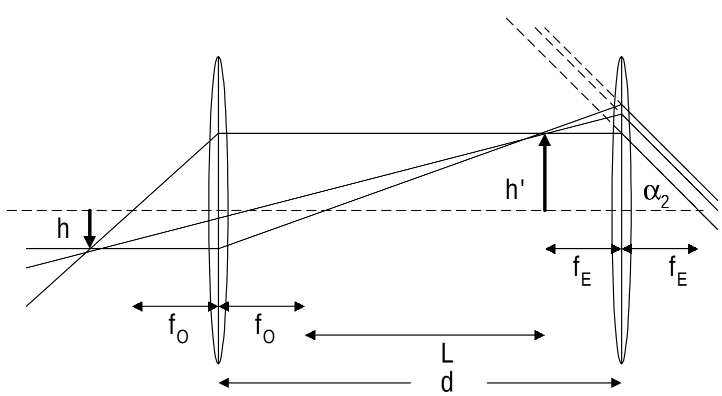


Figure L33.119: The compound microscope.

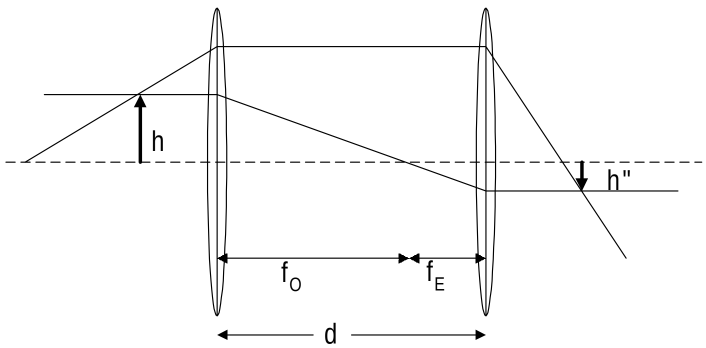


Figure L33.120: The astronomical telescope: linear magnification.

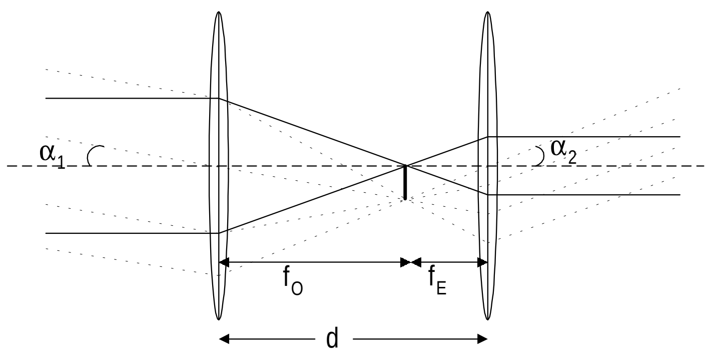


Figure L33.121: The astronomical telescope: angular magnification.

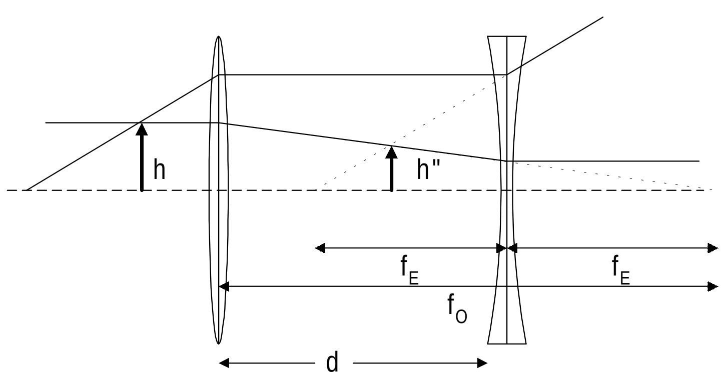


Figure L33.122: The Galilean telescope: linear magnification.

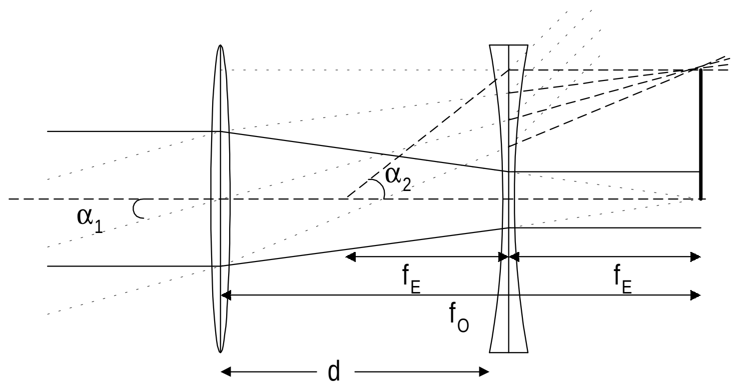


Figure L33.123: The Galilean telescope: angular magnification.