Light & Optics Review Sheet

Wave Optics

Wave properties of light

- The colors in a rainbow are ROY G. BIV (Red, orange, yellow, green, blue, indigo, violet).
- White light is a combination of all colors
- Black is the absence of light
- Wavelength determines color ("red is stretch and spread, blue is close you, and green is in between")
- Humans can see light with wavelengths between 400nm (violet) – 700nm (red)
- Amplitude determines brightness
- Light is a transverse wave. This is proved by polarization

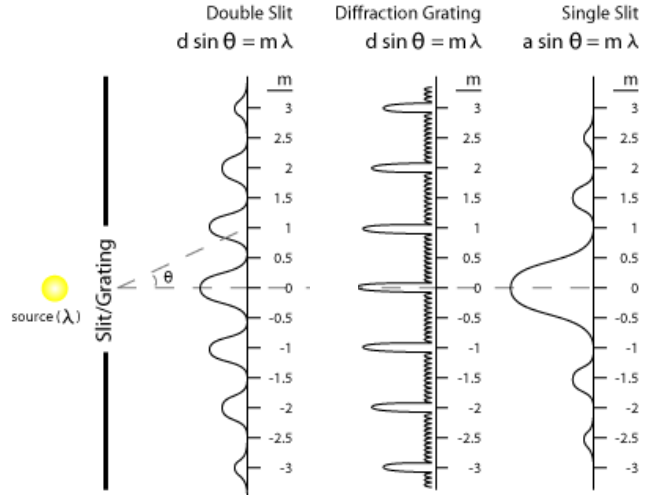
Electromagnetic waves

- Light is part of a wave family called the Electromagnetic Spectrum
- Electromagnetic waves, from lowest to highest energy (and frequency), are:
  - Radio waves
  - Microwaves
  - Infrared waves
  - Visible light waves
  - Ultra violet waves
  - X-rays
  - Gamma waves
- All electromagnetic waves travel at the same speed (c) which is 3.0×10^8 m/s
- Electromagnetic waves do not require a medium to travel through. (However, they can travel though a medium like air or glass or water too. They just don't *need* a medium. Sound is different. Sound *needs* a medium to propagate.)

The length of the most effective transmitting antenna is equal to one–fourth the wavelength of the broadcast wave. If a radio station has an antenna 4.5 meters long then what is the broadcast frequency of the radio station?
A) 1.4×10^{-8} Hz B) 6.0×10^{-8} Hz C) 1.7×10^{7} Hz
D) 6.7×10^{7} Hz E) 3.0×10^{8} Hz

Interference and diffraction

- double slit or diffraction grating
  - → $d \sin\theta = m\lambda$
  - → $d \sin\theta$ is the path difference
  - → $x \approx \frac{m\lambda L}{d}$ (small angle approximation)
  - → bright fringes/constructive interference at m=0,1,2,3..
  - → dark areas/destructive interference at m=0.5,1.5,2.5..
  - → constructive interference occurs when the path difference is an integer # of wavelengths
  - → destructive interference occurs when the path difference is half integer # of wavelengths
  - → diffraction grating has narrower/sharper fringes than double slit (see diagram)
- single slit
  - → $d \sin\theta = m\lambda$
  - → $x \approx \frac{m\lambda L}{d}$ (small angle approximation)
  - → bright fringes/constructive interference at m=0,1.5,2.5,...
  - → dark areas/destructive interference at m=1,2,3..
  - → Has wider central max than double slit (see diagram)



In Young's double slit experiment, the second order bright band of one light source overlaps the third order band of another light source. If the first light source has a wavelength of 660 nm, what is the wavelength of the second light source?
A) 1320 nm B) 990 nm C) 495 nm D) 440 nm E) 330 nm

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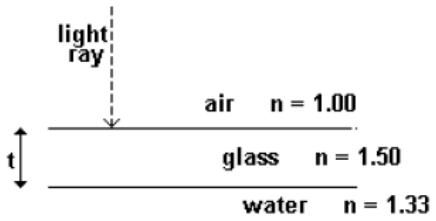
In a Young's double-slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed to

A) $D/2$ B) $\frac{D}{\sqrt{2}}$ C) $\sqrt{2}D$ D) $2D$ E) $4D$

Thin film interference

- $2T = m\lambda_n$
- T is the thickness of the film, λ is the wavelength in the film: $\lambda_n = \lambda/n$
- 180° phase change if reflect off slower medium (higher n)
- no phase change when reflect off faster medium (lower n)
- if TWO phase changes
  - → constructive: m=0,1,2,3..
  - → destructive: m=0.5,1.5,2.5..
- if ONE phase change
  - → constructive: m=0.5,1.5,2.5..
  - → destructive: m=0,1,2,3..
- Frequency is constant in a new medium!



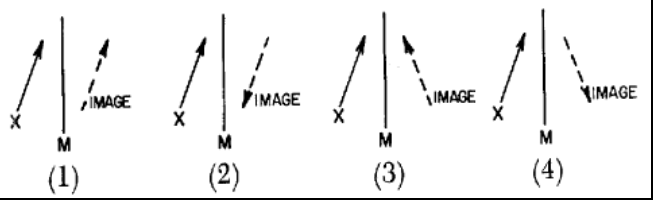
A light ray is incident normal to a thin layer of glass. Given the figure, what is the minimum thickness of the glass that gives the reflected light an orangish color (λ(air) orange light = 600nm)
A) 50 nm
B) 100 nm
C) 150 nm
D) 200 nm
E) 500 nm

Ray Optics

Reflection

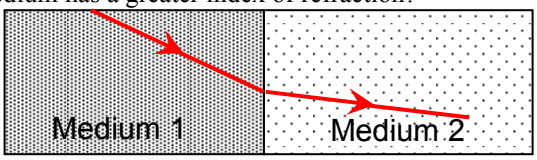
- Law of reflection: Incident angle equals reflected angle
- The image from a plane mirror is virtual, and has the same orientation, size, and distance from the mirror as the object

97 Which diagram correctly shows the image of object X produced by plane mirror M?



Refraction

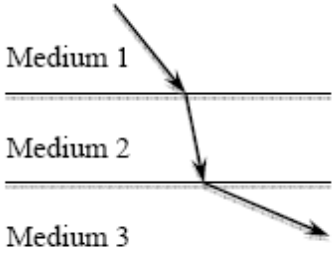
- Light changes speed in different media as determine by the *index of refraction (n)*
- $v = \frac{c}{n}$
- $n_{air}=1$, $n_{water}=1.33$, $n_{glass}=1.5$, $n_{diamond}=2.41$
- When light changes speeds, it also changes direction.
- The farther it bends from the normal line, the faster it travels. Which medium has a greater speed of light? Which medium has a greater index of refraction?



- $n_1 \sin\theta_1 = n_2 \sin\theta_2$ - Snell's law relates incident and reflected angle
- Total internal reflection can occur when going from slower to faster medium, and refracted angle is 90 degrees.
- The incident angle is called the critical angle in this case.

The diagram below shows the path taken by a monochromatic light ray traveling through three media. The symbols v_1, λ_1, and f_1 represent the speed, wavelength, and frequency of the light in Medium 1, respectively. Which of the following relationships for the light in the three media is true?

(A) $\lambda_1 < \lambda_3 < \lambda_2$
(B) $v_2 < v_3 < v_1$
(C) $f_2 < f_1 < f_3$
(D) $v_3 < v_1 < v_2$
(E) $\lambda_2 < \lambda_1 < \lambda_3$



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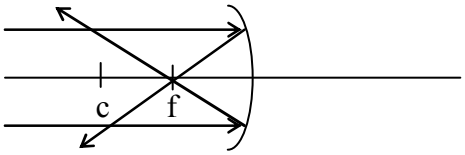
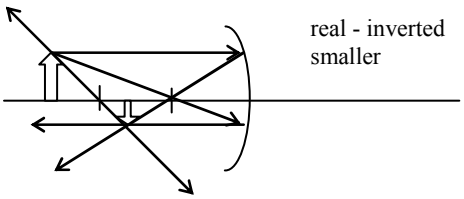
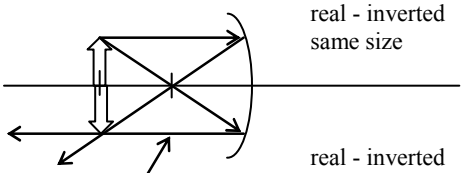
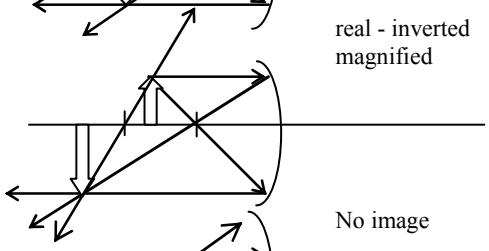
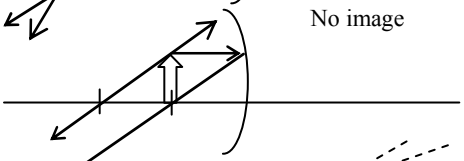
Concave Mirrors

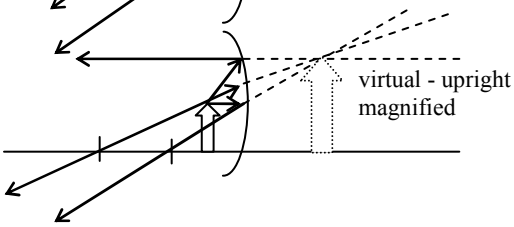






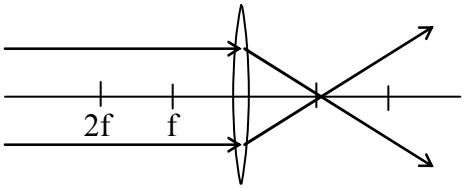


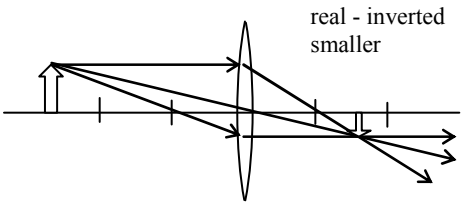


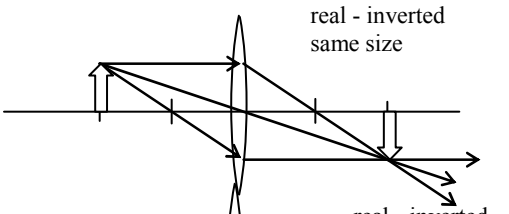


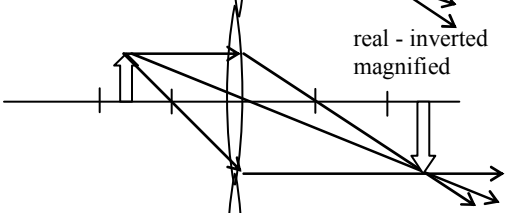
- distant objects create parallel rays
- "f" stands for focal point
- "c" stands for center of curvature (c=2f)
- 3 rules
  - In parallel, out focus
  - In focus, out parallel
  - In center, out center
- images formed where reflected rays converge
- *virtual* images are upright, *real* images are inverted
- as object gets closer, image gets further
- at "c" object and image are same size and distance
- image magnified when object is between c and f
- NO IMAGE is formed at f because reflected rays are parallel
- Inside "f" only *virtual* images formed
- $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}$ "If I do, I die"
- $\frac{h_i}{h_o}=\frac{d_i}{d_o}$

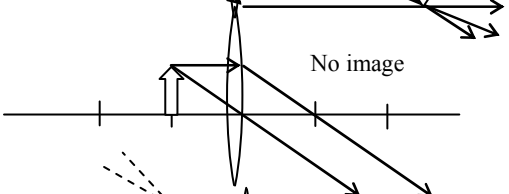
Convex Lens

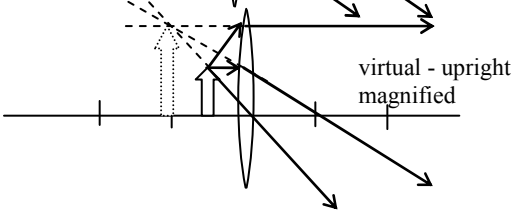












- distant objects create parallel rays
- "f" stands for focal point
- Treat "2f" like "c" for curved mirrors
- 3 rules
  - In parallel, out focus
  - In focus, out parallel
  - In center, out center
- images formed where refracted rays converge
- *real* images are inverted and on opposite side
- *virtual* images are upright and on same side
- as object gets closer, image gets further
- at "2f" object and image are same size and distance
- image magnified when object is between 2f and f
- NO IMAGE is formed at f because refracted rays are parallel
- Inside "f" only *virtual* images formed
- $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}$ "If I do, I die"
- $\frac{h_i}{h_o}=\frac{d_i}{d_o}$

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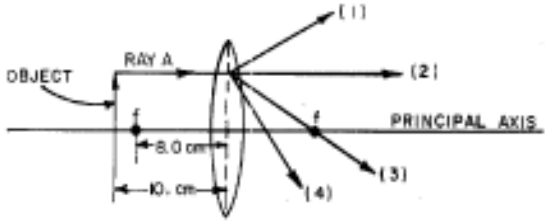
Base your answers to questions 76 through 79 on the diagram below which represents a converging crown glass lens with a focal length of 8.0 centimeters. Ray A represents one of the light rays incident upon the lens.



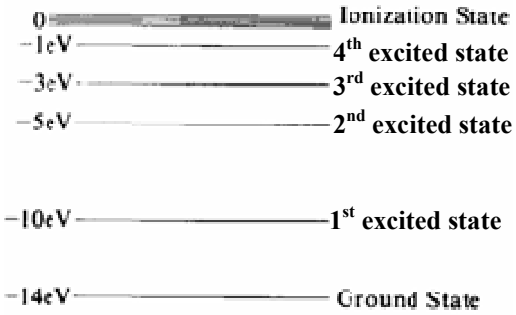
76 Which ray best represents the path of ray *A* after it emerges from the lens?
(1) 1 (3) 3
(2) 2 (4) 4

77 The image of the object formed by the lens is
1 virtual and erect 3 real and erect
2 virtual and inverted 4 real and inverted

78 How far from the lens is the image formed?
(1) 18 cm (3) 40 cm
(2) 2 cm (4) 80 cm

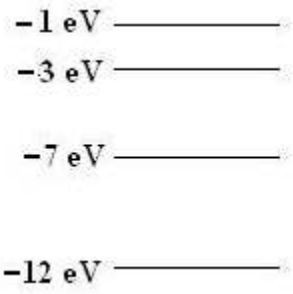
79 Which phenomenon best explains why the lens produces an image?
1 diffraction 3 reflection
2 dispersion 4 refraction

Atoms and Photons

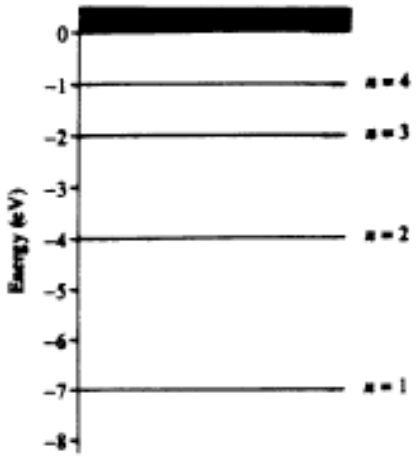


- Electrons are found outside the nucleus, but only at specific distances from the nucleus, called shells, orbitals, energy levels, or states.
- Electrons cannot exist between these energies
- The energy level closest to the nucleus is called the ground state and has the lowest energy.
- All states have negative energy (remember: we can set PE to be zero anywhere)
- Electron-volts (eV) is commonly used as a unit of energy because we're dealing with electrons.
- Electrons get excited to higher energy levels by absorbing photons
- Photon absorption indicated by upward arrows on energy-level diagrams
- electrons emit photons when they fall back down to lower energy levels.
- Photon emission indicated by downward arrows on energy-level diagrams.
- The larger the gap between energy levels, the higher the photon's frequency, and vice versa.
- An electron can become ionized (break away from the nucleus) if it absorbs enough energy.
- The energy of a photon can be calculated using $E=hf$ (h = 4.14E-15 eV-s)
- f can be replaced using the speed of a wave equation:

$$E = hf = \frac{hc}{\lambda} \qquad (hc = 1240 \text{ eV-nm})$$



The diagram shows the lowest four energy levels for an electron in a hypothetical atom. The electron is excited to the −1 *eV* level of the atom and transitions to the lowest energy state by emitting only two photons. Which of the following energies could not belong to either of the photons?
(A) 2 *eV* (B) 4 *eV* (C) 5 *eV* (D) 6 *eV* (E) 9 *eV*



Which of the following transitions will produce the photon with the longest wavelength?
(A) n = 2 to n = 1
(B) n = 3 to n = 1
(C) n = 3 to n = 2
(D) n = 4 to n = 1
(E) n = 4 to n = 3

Light & Optics Review Sheet

Nuclear Decay

- Charge is conserved in any nuclear reaction
- Alpha decay: 2 protons and 2 neutrons (Helium nucleus) released from nucleus
- Beta decay:
  - → Beta minus: electron released from nucleus, neutron turns into proton
  - → Beta plus: positron released from nucleus, proton turns into neutron
- Gamma decay: high energy electromagnetic radiation emitted

What does the ? represent in the nuclear reaction

$$^{2}H_{1} + {}^{2}H_{1} \rightarrow {}^{3}He_{2} + ?$$

A) an alpha B) a beta C) a gamma D) a neutron E) a proton

During a particular kind of radioactive decay, a particle is emitted from the nucleus of an atom and the atom's atomic number increases by one. This decay necessarily involves the emission of _____ from the nucleus

A) an alpha particle B) a beta particle C) a gamma ray D) a proton E) a neutron