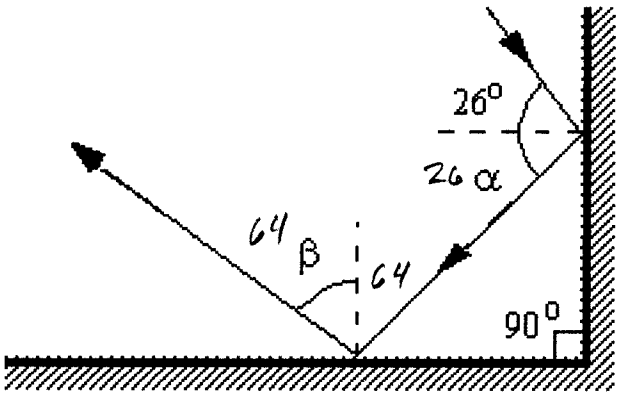
1. Light emerges from a polarizer that has its transmission axis located along the *x* axis. The light then passes through two additional sheets of polarizing material. It is desired to orient the two sheets so that, after passing through both of them, the electromagnetic wave has the maximum possible intensity and is polarized 90° with respect to the *x* axis. How should the transmission axes of the sheets be oriented? Note: the following answers give the angles that the transmission axes make with respect to the *x* axis.

	First polarizing sheet	*Second polarizing sheet*
__ A.	45° with respect to the *x* axis	45° with respect to the *x* axis
X B.	45° with respect to the *x* axis	90° with respect to the *x* axis
__ C.	90° with respect to the *x* axis	45° with respect to the *x* axis
__ D.	30° with respect to the *x* axis	60° with respect to the *x* axis
__ E.	30° with respect to the *x* axis	90° with respect to the *x* axis

ONLY B AND E POLARIZE 90° TO X AXIS. MALUS' LAW $\cos^2 30° \cos^2 60° = .1875$ (E) $\cos^2 45° \cos^2 45° = 0.25$ ✓ (B)

2. A ray of light is reflected from two plane mirror surfaces as shown in the figure. What are the correct values of α and β?



	Value of α	*Value of* β
__ A.	26°	26°
X B.	26°	64°
__ C.	38°	52°
__ D.	52°	26°
__ E.	64°	26°

ANGLE OF INCIDENCE = ANGLE OF REFLECTION AND $26 + 64$ MUST = 90 (GEOMETRY)

3. A woman stands 2.0 m in front of a convex mirror and notices that her image height is 1/4 of her actual height. Determine the radius of curvature of the mirror.

__ A. 0.67 m
X B. 1.33 m
__ C. 2.0 m
__ D. 4.0 m
__ E. 6.0 m

$M = -q/p = +1/4$ (CONVEX MIRROR → UPRIGHT IMAGE)

$p = 2.0$ SO $q = -0.5$ (VIRTUAL IMAGE, q IS −)

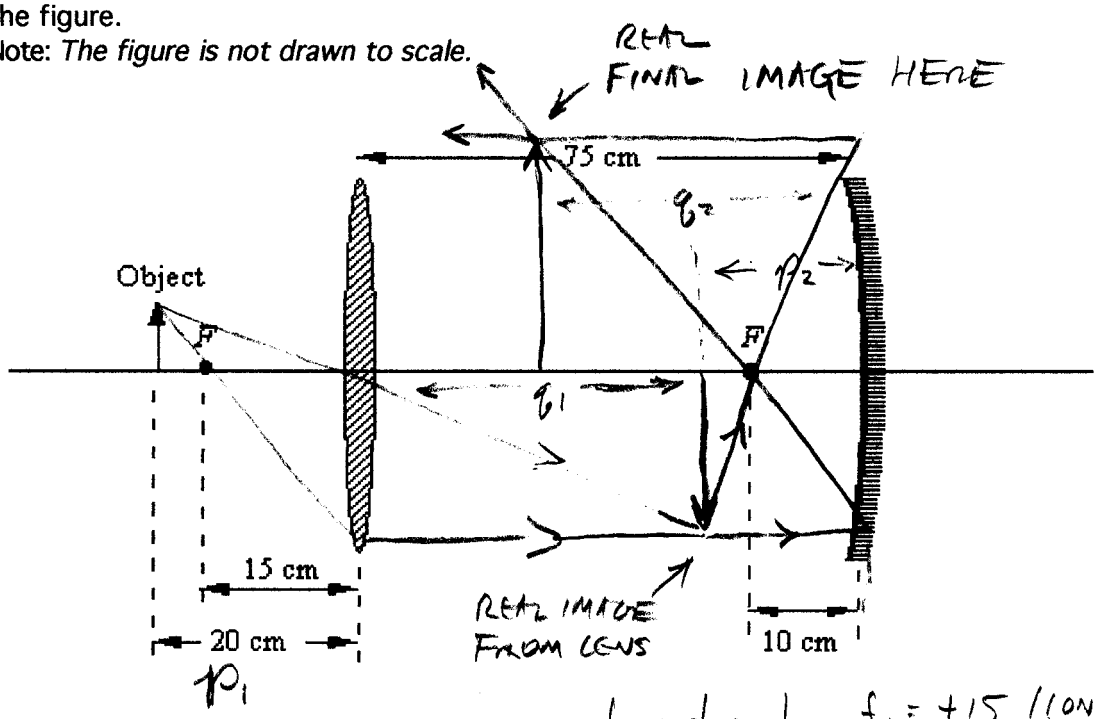
$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{2} - \frac{1}{0.5} = -1.5$

$f = -0.67$ (CONVEX MIRROR SO f IS −)

$R = 2|f| = 1.33$

An object is placed 20 cm from a converging lens with focal length 15 cm. A concave mirror with focal length 10 cm is located 75 cm to the right of the lens as shown in the figure.

Note: *The figure is not drawn to scale.*



4. Determine the location of the final image.

__ A. 48 cm to the right of the lens
__ B. 96 cm to the right of the lens
X C. 30 cm to the left of the mirror
__ D. 0.225 cm to the left of the mirror
__ E. 0.225 cm to the right of the mirror

$\frac{1}{p_1} + \frac{1}{q_1} = \frac{1}{f_1}$ $f_1 = +15$ (CONVERGING)

$\frac{1}{20} + \frac{1}{q_1} = \frac{1}{15}$ $\frac{1}{q_1} = .0167$

$q_1 = 60$ $p_2 = 75 - 60 = 15$

$f_2 = +10$ (CONCAVE)

$\frac{1}{p_2} + \frac{1}{q_2} = \frac{1}{f_2}$ $\frac{1}{15} + \frac{1}{q_2} = \frac{1}{10}$

$q_2 = +30$

5. If the height of the object is 1.0 cm, what is the height of the image?

__ A. 1.2 cm
__ B. 2.4 cm
X C. 6.0 cm
__ D. 12 cm
__ E. 24 cm

$M = M_1 \times M_2 = \left(-\frac{q_1}{p_1}\right)\left(-\frac{q_2}{p_2}\right) =$

$= \left(-\frac{60}{20}\right)\left(-\frac{30}{15}\right) = 6$

$6 \times 1.0 \text{ cm} = 6.0 \text{ cm}$

M_1 AND M_2 BOTH −
BUT INVERTED TWICE = UPRIGHT

6. The leg of a spider is 0.2 cm long. When viewed through a microscope, a person with a near point of 25 cm sees an image 2 m long located 10 m away. What is the angular magnification?

X A. 25
__ B. 50
__ C. 100
__ D. 250
__ E. 1000

Φ' = FINAL ANGLE = $\frac{2\,M}{10\,M} = 0.2$ RAD

Φ = INITIAL ANGLE = $\frac{0.2\,cm}{25\,cm} = .008$ RAD

$M = \frac{\Phi'}{\Phi} = \frac{0.2}{.008} = 25$

7. A compound microscope is made from two converging lenses. Which one of the following statements is true concerning the operation of this microscope?

__ A. Both lenses form real images.
__ B. Both lenses form virtual images.
__ C. Only the lens closest to the eye forms an image.
X D. The lens closest to the object forms a real image; the other lens forms a virtual image.
__ E. The lens closest to the object forms a virtual image; the other lens forms a real image.

SEE DIAGRAMS IN TEXTBOOK AND LAB MANUAL

8. Mrs. York has been prescribed eyeglasses with lenses that have a refractive power of +3.2 diopters. The glasses are worn 2.0 cm from her eyes. With the lenses, she can read a magazine held 25 cm from her eyes. Which one of the following statements is necessarily true? Note: The near points and far points given in the following answers are measured relative to her eye.

__ A. She has a far point of 3.2 m.
__ B. She has a far point of 0.25 m.
__ C. She has a near point of 3.2 m
__ D. She has a near point of 6.4 m.
X E. She has a near point of 0.87 m.

GLASSES BRING THE MAGAZINE AT 25 cm (p + 2 cm), TO HER NEAR POINT (q) FOR COMFORTABLE READING, DIOPTERS = $\frac{1}{f}$ IN METERS!

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ SO $\frac{1}{f} = 3.2 = \frac{1}{0.23\,m} + \frac{1}{q}$

$q = -0.87$ m (VIRTUAL IMAGE, $q < 0$)

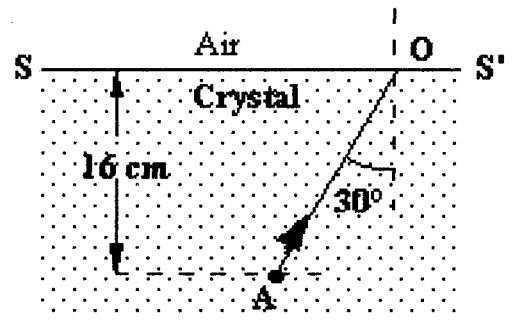
9. Rachel has a far point of 5 m. Which statement below concerning Rachel's vision is true?

__ A. She has normal vision.
X B. She is myopic and requires diverging lenses to correct her vision.
__ C. She is myopic and requires converging lenses to correct her vision.
__ D. She is hyperopic and requires diverging lenses to correct her vision.
__ E. She is hyperopic and requires converging lenses to correct her vision.

FAR POINT IS NORMALLY ∞, 5m IS TOO NEAR SO SHE IS NEARSIGHTED (MYOPIC), AND DIVERGING LENS BRINGS OBJECTS AT ∞ TO 5m FOR COMFORTABLE VIEWING. $p = \infty$, $q = -5$ (UPRIGHT, VIRTUAL IMAGE) SO

$\frac{1}{p} + \frac{1}{q} = \frac{1}{\infty} + \frac{1}{-5} = \frac{1}{f}$ $f = -5$ (DIVERGING)

The figure shows a point source of unpolarized light at A inside a uniform transparent crystal. The ray AO in the crystal strikes the plane surface SS' making an angle of 30° with the normal. This angle is the critical angle for transmission into air.



n_1 IS FOR THE MATERIAL THE INCIDENT LIGHT COMES FROM

10. What angle of incidence (instead of 30°) would you use if you wanted the reflected rays of light to be completely polarized?

__A. 15°
X B. 27°
__C. 30°
__D. 60°
__E. 63°

YOU NEED THE BREWSTER ANGLE
$\tan\theta_p = \frac{n_2}{n_1}$. SINCE 30° = CRITICAL ANGLE,
$n_1 \sin 30° = 1$ SO $n_1 = 2$, n_2 (AIR) = 1
SO $\tan\theta_p = \frac{1}{2}$ $\theta_p = 26.6°$

11. Two slits are separated by 2.00×10^{-5} m. They are illuminated by light of wavelength
5.60×10^{-7} m. If the distance from the slits to the screen is 6.00 m, what is the separation between the central bright fringe and the third dark fringe?

X A. 0.420 m
__B. 0.224 m
__C. 0.168 m
__D. 0.084 m
__E. 0.070 m

THE 3RD DARK FRINGE IS AFTER THE 2ND BRIGHT FRINGE SO THE PATH DIFFERENCE $d\sin\theta = 2\frac{1}{2}\lambda$
$\sin\theta = \frac{2.5 \times 5.60 \times 10^{-7}}{2.00 \times 10^{-5}} = .070$; SMALL θ SO
$\tan\theta \approx \sin\theta = .07 = \Delta y / L$ $\Delta y = .07 \times 6$ M $= 0.420$ m

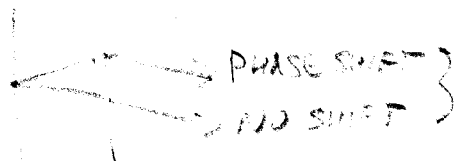
12. Light of wavelength 530 nm is incident on two slits that are spaced 1.0 mm apart. How far from the slits should the screen be placed so that the distance between the m = 0 and m = 1 bright fringes is 1.0 cm?

__A. 7.9 m
__B. 9.5 m
__C. 16 m
X D. 19 m
__E. 36 m

PATH DIFFERENCE FOR m = 1 BRIGHT FRINGE IS $m\lambda = \lambda = d\sin\theta$ SO
$\sin\theta = \frac{530 \times 10^{-9}\ m}{1.0 \times 10^{-3}\ m} = 5.30 \times 10^{-4}$
SMALL θ SO $\tan\theta \approx \sin\theta$ AND
$\tan\theta = \frac{\Delta y}{L} = \frac{1\ cm}{L} = 5.30 \times 10^{-4}$
$L = 1\ cm / 5.30 \times 10^{-4} = 1887$ cm

13. A portion of a soap bubble appears green (λ = 500 nm in vacuum) when viewed at normal incidence in white light. Determine the two smallest, non-zero thicknesses for the soap film if its index of refraction is 1.40.

__ A. 89 nm and 179 nm
X B. 89 nm and 268 nm
__ C. 125 nm and 250 nm
__ D. 125 nm and 375 nm
__ E. 170 nm and 536 nm



$2t = \frac{1}{2}\lambda_n$ OR $\frac{3}{2}\lambda_n$

$\lambda_n = \lambda/n = 500/1.40 = 357\text{ nm}$ $t = \frac{1}{4}(357)$ OR $\frac{3}{4}(357)$ $(m=1)$

14. Light of wavelength 625 nm shines through a single slit of width 0.32 mm and forms a diffraction pattern on a flat screen located 8.0 m away. Determine the distance between the middle of the central bright fringe and the first dark fringe.

__ A. 0.156 cm
__ B. 0.516 cm
X C. 1.56 cm
__ D. 5.16 cm
__ E. 6.51 cm

$a\sin\theta = m\lambda$; $\sin\theta = \frac{625\times10^{-9}\text{ m}}{0.32\times10^{-3}}$

$\sin\theta = 1.95\times10^{-3}$, SMALL $\therefore \tan\theta = \Delta y/L$

$\Delta y = L\tan\theta = 8.0\times1.95\times10^{-3} = 1.56\times10^{-2}\text{ m}$

15. White light is passed through a diffraction grating that has 2.50×10^5 lines/m. On each side of the white central maximum, a spectrum of colors is observed. What is the wavelength of the light observed at an angle of 7.00° in the first-order bright fringes?

X A. 487 nm
__ B. 589 nm
__ C. 632 nm
__ D. 668 nm
__ E. 731 nm

$\therefore m\lambda = d\sin\theta$ $d = \frac{1\text{ m}}{2.5\times10^5} = 4\times10^{-6}\text{ m}$

FIRST FRINGE $m = 1$ SO

$\lambda = 4\times10^{-6}\sin 7^\circ = 4.87\times10^{-7}\text{ m}$

16. In a science fiction novel, a starship takes 3 days to travel between two distant space stations according to its own clocks. Instruments on one of the space stations indicate that the trip took 4 days. How fast did the starship travel, relative to the space station?

X A. 1.98×10^8 m/s
__ B. 2.24×10^8 m/s
__ C. 2.51×10^8 m/s
__ D. 2.83×10^8 m/s
__ E. 2.99×10^8 m/s

TIME DILATION

$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{4}{3}$; $\frac{1}{1 - \frac{v^2}{c^2}} = \frac{16}{9}$

$9 = 16 - 16\frac{v^2}{c^2}$

$16\frac{v^2}{c^2} = 7$ $\frac{v^2}{c^2} = \frac{7}{16}$

$\frac{v}{c} = \frac{\sqrt{7}}{4}$ $v = \frac{\sqrt{7}}{4}c = 1.98\times10^8\text{ m/s}$

17. The momentum of an electron is 1.60 times larger than the value computed non-relativistically. What is the speed of the electron?

__ A. 2.94×10^8 m/s
__ B. 2.76×10^8 m/s
__ C. 2.61×10^8 m/s
X D. 2.34×10^8 m/s
__ E. 1.83×10^8 m/s

$p = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}} = 1.60\, mv$

$\frac{1}{1 - v^2/c^2} = 1.60^2 = 2.56 \quad 1 = 2.56 - 2.56\frac{v^2}{c^2}$

$v^2/c^2 = 1.56/2.56 \quad v = 0.78c$

18. The rest energies of three subatomic particles are:
Particle X: 107 MeV; Particle Y: 140 MeV; Particle Z: 0.51 MeV.
Which one of the following statements is necessarily true concerning these three particles?

__ A. Particle Z, at rest, could decay into particle X and give off electromagnetic radiation.
__ B. Particle X, at rest, could decay into particle Y and give off electromagnetic radiation.
__ C. Particle X, at rest, could decay into particles Y and Z and give off electromagnetic radiation.
X D. Particle Y, at rest, could decay into particles X and Z and give off electromagnetic radiation.
__ E. Particle Z, at rest, could decay into particles X and Y and give off electromagnetic radiation.

INITIAL PARTICLE MUST HAVE AT LEAST AS MUCH AS SUM OF DECAY PRODUCTS, EXCESS FOR RADIATION

19. Rocket ship A travels at 0.400c relative to an earth observer. According to the same observer, rocket ship A overtakes a slower moving rocket ship B that moves in the same direction. The captain of B sees A pass her ship at 0.114c. Determine the speed of B relative to the earth observer.

__ A. 0.100c
__ B. 0.214c
X C. 0.300c
__ D. 0.625c
__ E. 0.700c

RELATIVISTIC ADDITION OF VELOCITIES

$\frac{(v_B + 0.114c)}{\left[1 + \frac{0.114c\, v_B}{c^2}\right]} = 0.400c \quad (v_B + 0.114c) = 0.400c\left[1 + \frac{0.114 v_B}{c}\right]$

$v_B - 0.400(.114)v_B = 0.400c - .114c \quad ; \quad v_B = 0.300c$

20. A muon has rest energy 105 MeV. What is its kinetic energy when its speed is 0.95c ?

__ A. 37 MeV
__ B. 47 MeV
X C. 231 MeV
__ D. 441 MeV
__ E. 741 MeV

TOTAL $E = \frac{mc^2}{\sqrt{1 - v^2/c^2}} = \frac{105\ MeV}{\sqrt{1 - .95^2}} = 336\ MeV$

$K.E. = E - mc^2 = 336 - 105 = 231\ MeV$

Answer Key

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1. B
2. B
3. B
4. C
5. C
6. A
7. D
8. E
9. B
10. B
11. A
12. D
13. B
14. C
15. A
16. A
17. D
18. D
19. C
20. C