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Physics 104

Exam 3 April 24, 2003

Name DEL

ex3sp03

ID # \_\_\_\_\_

Section # \_\_\_\_\_ TA Name \_\_\_\_\_

Fill in your name, student ID # (not your social security #), and section # (under ABC of special codes) on the Scantron sheet. Fill in the letters given for the first 5 questions on the Scantron sheet. These letters determine which version of the test you took, and it is very important to get this right. Make sure your exam has questions 6-25.

- 1. B
- 2. C
- 3. E
- 4. D
- 5. B

6. Which of the following best describes the image of a convex mirror when the object's distance from the mirror is less than the absolute value of the focal point distance?

- a. virtual, upright and magnification greater than one
- b. real, inverted and magnification less than one
- c. real, inverted and magnification greater than one
- d. virtual, inverted, and magnification greater than one
- e. virtual, upright and magnification less than one

CONVEX MIRROR HAS  $f < 0$   
 $p > 0$  (REAL OBJECT) AND  
 $\frac{1}{p} = \frac{1}{f} - \frac{1}{q}$ , SINCE  $\frac{1}{p} > 0$

AND  $\frac{1}{f} < 0$ ,  $-\frac{1}{q}$  MUST BE  $> 0 \Rightarrow q < 0$ .

THEN IF  $\frac{1}{p} + \frac{1}{q} = \frac{1}{f} < 0$ ,  $\frac{1}{p} < |-\frac{1}{q}|$  SO  $|q| < p$ .

THAT MEANS  $|M| = |q|/p < 1$ ;  $q < 0 \Rightarrow$  VIRTUAL IMAGE.

7. You stand two feet away from a plane mirror. How far is it from you to your image?

- a. 2.0 ft
- b. 4.0 ft
- c. 3.0 ft
- d. 5.0 ft
- e. 1.0 ft

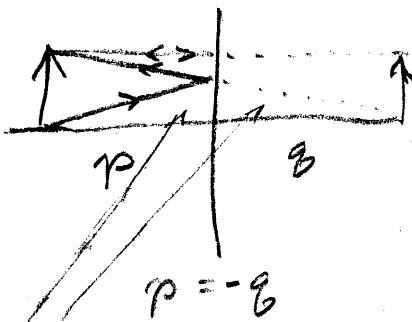


IMAGE IS AS FAR BEHIND MIRROR AS YOU ARE IN FRONT OF IT.

THESE TRIANGLES ARE THE SAME.

8. The real image of an object is located 45.0 cm away from a concave mirror, which has a focal length of 10.0 cm. How far is the object from the mirror?

- a. 12.9 cm  
 b. 40.0 cm  
 c. 35.0 cm  
 d. 22.5 cm  
 e. 4.5 cm

$$q = +45 \text{ (REAL)}$$

$$f = +10 \text{ (CONCAVE)}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow \frac{1}{p} + \frac{1}{45} = \frac{1}{10}$$

$$\frac{1}{p} = \frac{1}{10} - \frac{1}{45} = .0777... \quad p = 12.9$$

9. An object is placed at a distance of 50 cm from a thin lens along the axis. If a real image forms at a distance of 40 cm from the lens, on the opposite side from the object, what is the focal length of the lens?

- a. 45 cm  
 b. 22 cm  
 c. 90 cm  
 d. 200 cm  
 e. 150 cm

$$p = +50 \quad q = +40 \text{ (REAL)}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow \frac{1}{50} + \frac{1}{40} = \frac{1}{f} = .045$$

$$f = +22$$

10. A projector lens is needed to form an image on a screen 10 times the size of its corresponding object. The screen is located 8.0 m from the lens. What is the required focal length of the lens?

- a. 0.32 m  
 b. 0.54 m  
 c. 1.25 m  
 d. 0.73 m  
 e. 0.80 m

$$q = +800 \text{ (8 m, REAL BECAUSE IT APPEARS ON A SCREEN)}$$

$$M = -10 \text{ (REAL IMAGES ARE INVERTED)}$$

$$M = -q/p = -800/p = -10 \Rightarrow p = 80$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{1}{80} + \frac{1}{800} = .01375 \quad f = 72.7 \text{ cm}$$

11. If a wave from one slit of a Young's double-slit set-up arrives at a point on the screen one wavelength behind the wave from the other slit, what is observed at that point?

- a. dark fringe  
 b. multi-colored fringe  
 c. bright fringe  
 d. gray, not dark nor bright

ONE WAVELENGTH PATH DIFFERENCE IS CONSTRUCTIVE INTERFERENCE

12. A Young's double slit has a slit separation of  $2.50 \times 10^{-5}$  m on which light of a single wavelength is directed. The resultant bright fringes on a screen 1.00 m from the double slit are separated by  $2.30 \times 10^{-2}$  m. What is the wavelength of this beam? (1 nm =  $10^{-9}$  m)

- a. 373 nm
- b. 454 nm
- c. 575 nm
- d. 667 nm
- e. 725 nm

$d = 2.50 \times 10^{-5}$        $\theta \approx \frac{\Delta y}{L} = \frac{2.30 \times 10^{-2}}{1} = .023$  SMALL  
 $L = 1.00$   
 $\Delta y_{\text{BRIGHT}} \approx L \frac{m\lambda}{d}$        $m=1$  FOR SEPARATION OF 1 FRINGE  
 $\lambda = \frac{\Delta y_{\text{BR}} \cdot d}{L} = \frac{2.30 \times 10^{-2} \times 2.50 \times 10^{-5}}{1} = 575 \text{ nm}$   
 [ SINCE  $\theta$  IS SMALL, WE USED  $\sin \theta = \frac{m\lambda}{d} \approx \tan \theta = \frac{\Delta y}{L}$  ]

13. A beam of polarized light of intensity  $I_0$  passes through a sheet of ideal polarizing material. The polarization axis of the beam and the transmission axis of the sheet differ by  $30^\circ$ . What is the intensity of the emerging light?

- a.  $0.87 I_0$
- b.  $0.75 I_0$
- c.  $0.50 I_0$
- d.  $0.25 I_0$
- e.  $0.33 I_0$

$I_0 \cos^2 30^\circ = 0.75 I_0$   
 MALUS' LAW

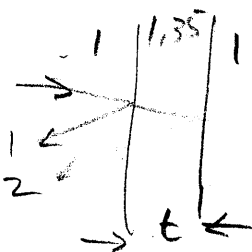
14. Waves from a radio station with a wavelength of 600 m arrive at a home receiver a distance 50 km away from the transmitter by two paths. One is a direct-line path and the second by reflection from a mountain directly behind the receiver. What is the minimum distance between the mountain and receiver such that destructive interference occurs at the location of the listener? Assume no phase change on reflection.

- a. 300 m
- b. 450 m
- c. 150 m
- d. 600 m
- e. 75 m

SMALLEST PATH DIFF. FOR DESTRUCTIVE INTERFERENCE IS  $\lambda/2$  (WITH NO PHASE CHANGE).  
 $\frac{\lambda}{2} = 2d$   
 $d = \lambda/4 = 600/4$   
 $d = 150 \text{ m}$

15. A soap bubble ( $n = 1.35$ ) is floating in air. If the thickness of the bubble wall is 300 nm, which of the following wavelengths of visible light is strongly reflected?

- a. 620 nm (red)  
 b. 580 nm (yellow)  
 c. 500 nm (blue)  
 d. 850 nm (infrared)  
 (e) 540 nm (green)



RAY #1 IS PHASE SHIFTED  
 RAY #2 IS NOT

STRONG REFLECTION =  
 CONSTRUCTIVE INTERFERENCE

FOR CONSTRUCTIVE WITH PHASE SHIFT  $2t = (m + \frac{1}{2}) \frac{\lambda}{n}$

$$\lambda = \frac{2nt}{m + \frac{1}{2}} = \frac{2 \cdot 1.35 \cdot 300 \text{ nm}}{m + \frac{1}{2}} = 1620 \text{ nm} \quad (m=0)$$

NANOMETERS

$$\lambda = \frac{2 \cdot 1.35 \cdot 300 \text{ nm}}{1 + \frac{1}{2}} = 540 \text{ nm} \quad (m=1)$$

16. A simple magnifier makes an image appear at the near point distance from the eye of the viewer (25 cm). What is the magnifying power of the magnifier if it is constructed of a lens of focal length of 4.0 cm?

- (a) 7.3  
 b. 1.2  
 c. 5.0  
 d. 50  
 e. 6.2

FOR IMAGE AT NEAR POINT

$$M_{\text{max}} = 1 + \frac{25}{f} = 1 + 6.25 = 7.3$$

( $m = \frac{25}{f}$  IS FOR IMAGE AT  $\infty$ )

17. You are designing eyeglasses for someone whose near point is 60 cm. What focal length lens should you prescribe so that an object can be clearly seen when placed at 25 cm in front of the eye?

- a. -15 cm  
 (b) 43 cm  
 c. 18 cm  
 d. 60 cm  
 e. 25 cm

FOR OBJECT AT 25  $p = 25 \text{ cm}$

IMAGE MUST BE UPRIGHT AND AT 60 cm

$q = -60$ , VIRTUAL IMAGE

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow \frac{1}{25} + \frac{1}{-60} = 0.0233 \dots = \frac{1}{f}$$

$$f = 43 \text{ cm}$$

18. If different transmission filters are used with an astronomical telescope, which of the following would give the best angular resolution?

- a. blue
- b. red
- c. green
- d. All yield the same resolution.
- e. infrared

SMALLEST RESOLUTION IS BEST  
 RESOLUTION  $\theta_{MIN} \sim 1.22 \frac{\lambda}{D}$   
 SMALLEST  $\lambda$  IS BEST  
BLUE HAS SMALLEST  $\lambda$

19. A 1.5 m tall woman stands 5.0 m in front of a camera with a 4.0 cm focal length lens. What is the size of the image formed on film?

- a. 1.2 cm
- b. 2.4 cm
- c. 1.9 cm
- d. 0.60 cm
- e. 1.0 cm

FOR A REAL IMAGE ON THE FILM BEHIND THE LENS  $q_b > 0$  SO WITH  $p = 500 \text{ cm} > 0$ ,

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} > 0 \Rightarrow f = +4 \text{ cm}$$

THEN  $\frac{1}{500} + \frac{1}{q} = \frac{1}{4} \Rightarrow \frac{1}{q} = \frac{1}{4} - \frac{1}{500} \Rightarrow q = 4.03 \text{ cm}$

$M = \frac{-q}{p} = -\frac{4.03}{500} = -8.06 \times 10^{-3}$   $h' = Mh = -150 \times 8.06 \times 10^{-3}$   
 $h' = -1.21 \text{ cm}$

20. You are building a compound microscope with an objective lens of focal length 0.70 cm and an eyepiece lens of focal length 5.0 cm. You mount the lenses 18 cm apart. What is the maximum magnification of your microscope?

- a. 3.1
- b. 7.3
- c. 67
- d. 175
- e. 130

$f_o = 0.70$   $f_e = 5.0$   $L = 18$   
 MAX EYEPIECE  $m = 1 + \frac{25}{f_e} = 6.00$   $q = -25$   
 A VIRTUAL IMAGE AT 25 cm. THEN FOR THE EYEPIECE  
 $\frac{1}{p_e} + \frac{1}{-25} = \frac{1}{5}$ ;  $p_e = 4.167$ ;  $q_o = L - p_e = 18 - 4.167 = +13.83$

$$\frac{1}{p_o} + \frac{1}{q_o} = \frac{1}{f_o} \Rightarrow \frac{1}{p_o} + \frac{1}{13.83} = \frac{1}{0.70}; p_o = 0.737 \quad M_o = \frac{-q_o}{p_o} = \frac{-13.83}{0.737}$$

$M_o = 18.76$   $M = M_o \times m = 110 \rightarrow$  EXACT

APPROXIMATE FORMULA  $M = \frac{L \gamma}{f_o f_e} = \frac{18 \times 25}{0.7 \times 5} = 129$

21. Einstein's theory of relativity is based in part on which one of the following postulates?

- a. the existence of an absolute frame of reference
- b. space and time are absolutes
- c. energy is conserved only in elastic collisions
- d. speed of light in a vacuum is same for all observers regardless of source velocity
- e. conservation of momentum

22. An astronaut at rest has a heart rate of 65 beats/min. What will her heart rate be as measured by an earth observer when the astronaut's spaceship goes by the earth at a speed of  $0.60c$ ?

- a. 39 beats/min  
b. 108 beats/min  
c. 81 beats/min  
d. 103 beats/min  
e. 52 beats/min

$$\text{At } 0.60c \quad \gamma = \frac{1}{\sqrt{1-0.6^2}} = 1.25$$

HER CLOCK IS SLOWER SO THERE WILL BE FEWER BEATS / MIN ON EARTH (EARTH CLOCK IS FASTER, MINUTES DON'T LAST AS LONG AS HERS)

$$65/\gamma = 65/1.25 = 52$$

23. The observed relativistic length of a super rocket moving by the observer at  $0.70c$  will be what factor times that of the measured rocket length if it were at rest?

- a. 0.45  
b. 0.82  
c. 1.4  
d. 0.71  
e. 0.55

OBSERVED LENGTH IS CONTRACTED BY  $\gamma$

$$\gamma = \frac{1}{\sqrt{1-0.7^2}} = \frac{1}{\sqrt{.51}} = 1.40$$

SO OBSERVED LENGTH IS  $\frac{1}{\gamma} = 0.71$  TIMES THE LENGTH AT REST.

24. How fast would a rocket have to move past a ground observer if the latter were to observe a 4.0% length shrinkage in the rocket length? ( $c = 3.00 \times 10^8$  m/s) (see #23 ↑)

- a.  $0.12 \times 10^8$  m/s  
b.  $0.28 \times 10^8$  m/s  
c.  $0.84 \times 10^8$  m/s  
d.  $1.2 \times 10^8$  m/s  
e.  $1.4 \times 10^8$  m/s

4% SHRINKAGE MEANS  $\frac{1}{\gamma} = 96\% = 0.96$

$$\frac{1}{\gamma} = \sqrt{1 - \left(\frac{v}{c}\right)^2} = 0.96 \quad \left(\frac{v}{c}\right)^2 = 1 - 0.96^2$$

$$\frac{v}{c} = \sqrt{1 - 0.96^2} = 0.28$$

$$v = 0.28 \times 3 \times 10^8 = 0.84 \times 10^8 \text{ m/s}$$

25. An unknown particle in an accelerator moving at a speed of  $2.00 \times 10^8$  m/s has a measured total energy of  $1.80 \times 10^{-9}$  J. What is its mass? ( $c = 3.00 \times 10^8$  m/s)

- a.  $1.49 \times 10^{-26}$  kg  
b.  $0.650 \times 10^{-26}$  kg  
c.  $0.810 \times 10^{-26}$  kg  
d.  $1.01 \times 10^{-26}$  kg  
e.  $2.00 \times 10^{-26}$  kg

$$\frac{v}{c} = \frac{2 \times 10^8}{3 \times 10^8} = \frac{2}{3} \quad \gamma = \frac{1}{\sqrt{1 - \left(\frac{2}{3}\right)^2}} = 1.342$$

$$E = \gamma mc^2 \quad \text{SO} \quad m = \frac{E}{\gamma c^2}$$

$$m = \frac{1.8 \times 10^{-9}}{1.342 \times (3 \times 10^8)^2} = 1.49 \times 10^{-26}$$