**INSTRUCTIONS**

1. Write your name and student identification number on the answer sheet.

2. Please cover your answer sheet at all times.

3. This is a closed book exam. You may use the PH2200 formula sheet that is included with the exam.*

4. Equations may not be stored in calculators, nor may calculators be exchanged.

5. Record your answers in the form A, B, C, etc, on the answer sheet.

6. This exam consists of 20 concept questions worth two points each and nine problems having a total of 30 parts. The problem parts are equally weighted: each is worth two points. The total number of points on the exam is 100.

7. If you have any questions during the exam, please raise your hand and wait for assistance.


* The formula sheet is not included with this practice exam.

Concept Questions: Each question has a single correct answer and is worth two points.

1. Following the discovery of radioactivity in 1896, researchers working with radiation emitted from materials such as pitchblende observed that the emissions followed three different paths between electrically charged plates. From the sketch below, it appears that
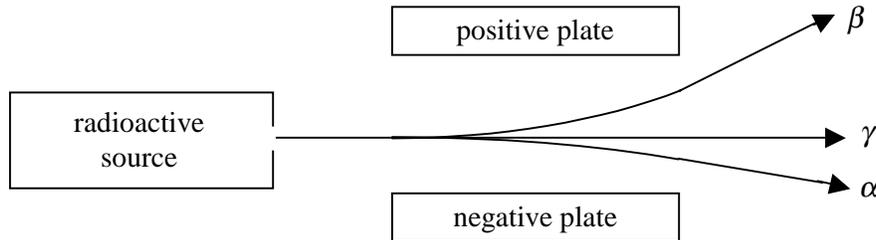

(A) β is positively charged, γ and α are negatively charged.
(B) β is negatively charged, γ and α are positively charged.
(C) β is positively charged, γ is neutral and α is negatively charged.
(D) β is negatively charged, γ is neutral and α is positively charged.
(E) none of the above.

2. Consider three identical small, conducting spheres on insulating stands. Sphere *A* has a net charge +*Q* and spheres *B* and *C* are neutral. *A* and *B* are touched together and then are separated. *B* and *C* are then touched together and separated. Finally, *C* and *A* are touched together and separated. What is now the net charge on each sphere?

(A) +*Q*/3
(B) +*Q*/2
(C) +*Q*/2 on *A*, +*Q*/4 on both *B* and *C*
(D) +*Q*/4 on *B*, +3*Q*/8 on both *A* and *C*
(E) none of the above.

3. The figure to the right shows an edge-on view of three extremely large, parallel insulating sheets positively charged with uniform and identical surface charge densities. In which of the regions shown is the electric field a maximum?
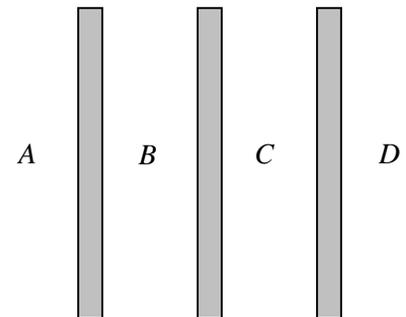
(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *B* and *C*
(F) *A* and *D*
(G) The electric field is the same in all four regions of space.

4. The total flux of the electric field through the six faces of a certain cube is $+\Phi_E$ where Φ_E is a positive constant. Which of the following statements is not necessarily true?

    (A) More electric field lines exit the cube than enter the cube.
    (B) The cube encloses a net positive charge.
    (C) The charge enclosed by the cube is $+\varepsilon_o \Phi_E$.
    (D) The flux of the electric field through one face of the cube is $+\frac{1}{6}\Phi_E$.

5. The location marked P in the figure to the right lies midway between the point charges $+q$ and $-q$. The gray lines labeled A, B, C, and D are edge-on views of four planes. Which of these planes is an equipotential surface?
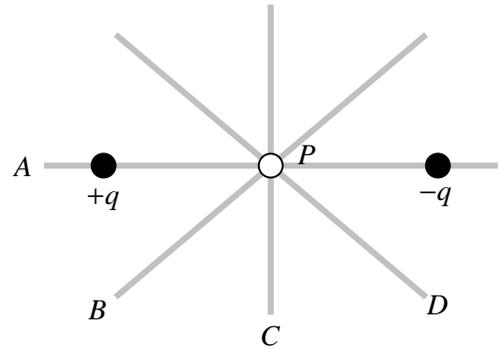
    (A) A
    (B) B
    (C) C
    (D) D
    (E) both B and D

6. A parallel plate capacitor is charged using a battery, and the battery is then removed. The plates of the capacitor are then brought closer together. Which of the following statements is false?

    (A) The electric field inside the capacitor remains the same.
    (B)   The capacitance of the capacitor increases.
    (C) The charge on the capacitor remains the same.
    (D) The potential difference between the plates of the capacitor decreases.
    (E) The energy stored in the capacitor increases.

7. Your are given different wires made of the same metal. Which of the following has the largest resistance?

    (A) long, thick and cool wire
    (B) long, thick and hot wire
    (C) long, thin and cool wire
    (D) long, thin and hot wire
    (E) short, thick and cool wire
    (F) short, thick and hot wire
    (G) short, thin and cool wire
    (H) short, thin and hot wire

8. A number of identical light bulbs are to be connected to a single electrical outlet. Will the bulbs provide more brightness if they are connected in series of parallel?

    (A) series
    (B) parallel
    (C) The brightness is the same for the series and parallel combinations.

9. The figure to the right shows a particle carrying a positive charge $+q$ at the origin of a Cartesian coordinate system.

    Also shown is a target located in the third quadrant. A uniform magnetic field is directed perpendicularly into the plane of the paper. The particle can be projected in the plane of the paper only, along the positive or negative *x*- or *y*-axis. Thus, there are four possible directions for the initial velocity of the particle. The particle moves with a constant speed and can be made to hit the target for only two of the four directions of the initial velocity. Which two are they?
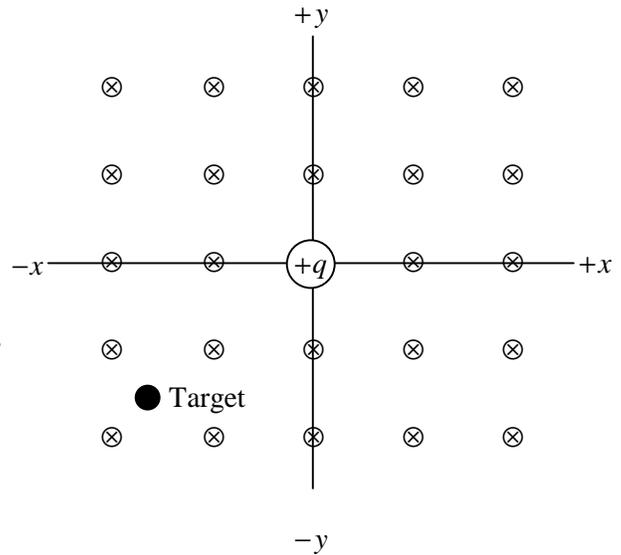
    (A) $+x$ and $+y$
    (B) $+x$ and -*y*
    (C) -*x* and $+y$
    (D) -*x* and -*y*

10. The figure to the right shows a conducting wire wound in a helical shape so as to form a spring. The bottom end of the wire just barely touches the mercury (a good electrical conductor). After the switch is closed, current in the circuit causes the light to glow. Does the bulb
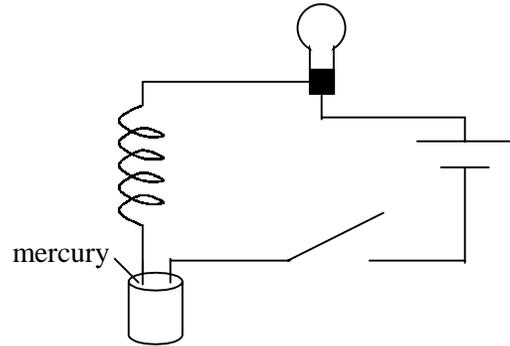
    (A) glow continually,
    (B) glow briefly and then go out, or
    (C) repeatedly turn on and off like a turn signal on a car?

11. Four long wires at the corners of a square carry current *I* or *2I* as shown in the figure. What is the direction of the magnetic force on the wire at the top right?
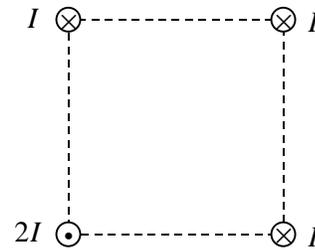
    (A) to the right
    (B) to the left
    (C) up
    (D) down
    (E) The force is zero.

12. A long, straight cylindrical shell carries a current uniformly distributed over its cross section. The magnitude of the magnetic field is greatest
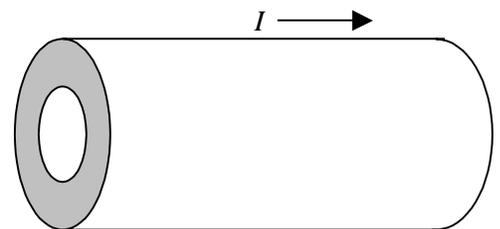
    (A) at the center of the hollow region.
    (B) in the hollow region near the inner surface of the shell.
    (C) on the inner surface of the shell.
    (D) on the outer surface of the shell.

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13. A long straight wire is in the plane of a rectangular conducting loop. The straight wire carries a constant current in the direction shown in the figure. While the wire is being moved toward the rectangle, the current in the rectangle is
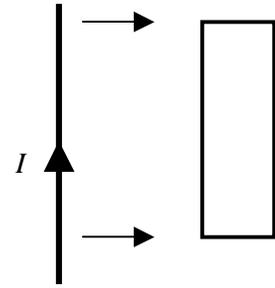
   (A) zero.
   (B) clockwise.
   (C) counterclockwise.
   (D) clockwise in the left side and counterclockwise in the right side.
   (E) counterclockwise in the left side and clockwise in the right side.

14. In a demonstration conducted during lecture, a magnet was dropped through a non-magnetic metallic tube held vertically. Why did the magnet fall through the tube much slower than the non-magnetic material?

   (A) Induced currents were set up flowing around the cylindrical circumference of the tube.
   (B) Induced currents were set up flowing along the length of the tube.
   (C) The Earth's magnetic field was drawn into the top of the tube and attracted the falling magnet.
   (D) The Earth's magnetic field was drawn into the bottom of the tube and repelled the falling magnet.
   (E) This demonstration was never performed.

15. The switch in the circuit to the right is initially open. It is closed at time $t = 0$. Which of the following statements is false?
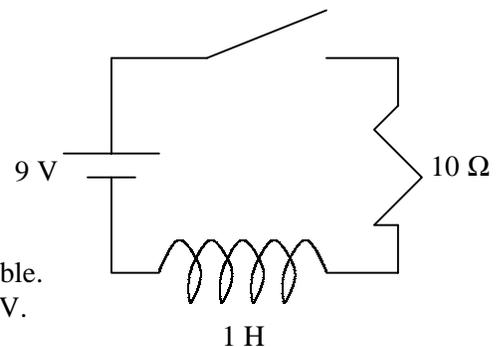
   (A) At $t = 0.0001$ s the current in the circuit is negligible.
   (B) At $t = 0.0001$ s the potential difference across the inductor is about 9 V.
   (C) At $t = 100$ s, the energy dissipated by the resistor is negligible.
   (D) At $t = 100$ s, the potential difference across the inductor is negligible.
   (E) At $t = 100$ s, the potential difference across the resistor is about 9 V.

16. A light bulb and a parallel plate capacitor (including a dielectric material between the plates) are connected in series to the 60-Hz ac voltage at a wall outlet. When the dielectric material is removed from the space between the plates, does the brightness of the bulb,

   (A) increase,
   (B) decrease, or
   (C) remain the same?

17. According to Maxwell's equations, magnetic field lines

   (A) start at south poles and end at north poles.
   (B) start at north poles and end at south poles.
   (C) start at both north and south poles and extend to infinity.
   (D) form closed loops.
   (E) sometimes cross, unlike electric field lines which never cross.

18. A ray of red light passes through a series of media with different refractive indices n_1, n_2 and n_3. It then enters a medium with an index of refraction n_1 as shown. In which medium does the light travel fastest?
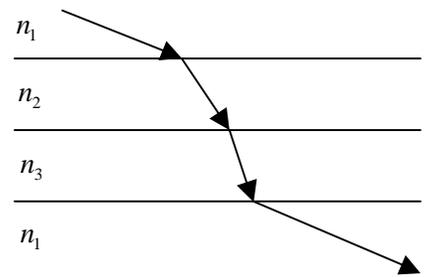
    (A) medium with index n_1.
    (B) medium with index n_2.
    (C) medium with index n_3.

19. A clock is held facing a plane mirror. From the point of view of a person looking into the mirror, does the image of the second hand rotate

    (A) clockwise, or
    (B) counterclockwise?

20. The concave side of a satellite dish antenna reflects electromagnetic waves in a manner similar to the reflection of visible light by a spherical mirror. If the electromagnetic waves come from a distant source (a satellite in a geosynchronous orbit about the Earth) and the radius of curvature of the dish is R, how far in front of the dish should the actual receiver be placed?
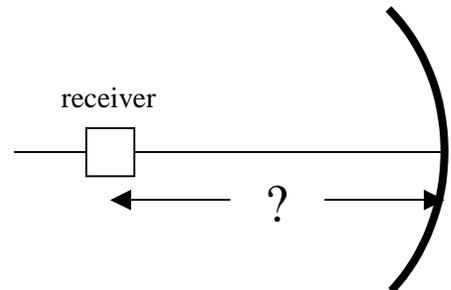
    (A) $\frac{1}{4}R$
    (B) $\frac{1}{2}R$
    (C) R
    (D) $2R$
    (E) $4R$

Problems: Each part of each problem is worth two points.

1. The charging of individual raindrops is ultimately responsible for the electrical activity of a thunderstorm. A raindrop having a charge of $+10.0 \times 10^{-6}$ C experiences an electric force having a magnitude of 28.8 N.

   (a) How many electrons have been removed from the raindrop to produce its charge of $+10.0 \times 10^{-6}$ C ?

      (A) 1.60×10^{13}
      (B) 2.22×10^{13}
      (C) 3.17×10^{13}
      (D) 6.24×10^{13}
      (E) 9.97×10^{13}

   (b) What is the magnitude of the electric field experienced by the raindrop?

      (A) 3.71×10^{5} N/C
      (B) 6.53×10^{5} N/C
      (C) 8.86×10^{5} N/C
      (D) 1.04×10^{6} N/C
      (E) 2.88×10^{6} N/C

   (c) If the electric force experienced by the given raindrop is due solely to a second charged raindrop at distance of 0.250 m away, what is the magnitude of the charge of the second raindrop?

      (A) 1.25×10^{-6} C
      (B) 5.00×10^{-6} C
      (C) 10.0×10^{-6} C
      (D) 15.0×10^{-6} C
      (E) 20.0×10^{-6} C

2. The visible portion of a lightning strike is preceded by an invisible stage in which a column of electrons extends downward from a cloud to the ground. Assume the linear charge density along the column is -1.00×10^{-3} C/m. Treat the column of charge as if it were straight and infinitely long.

$\lambda = -1.00\times10^{-3}$ C/m

1.00 m

Gaussian surface
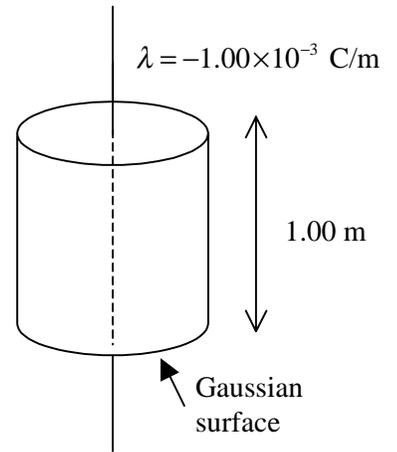
(a) What is the flux of the electric field through a closed Gaussian cylinder 1.00 m in length that is coaxial with the column of electrons?

   (A) -5.90×10^{7} V·m
   (B) -7.77×10^{7} V·m
   (C) -9.97×10^{7} V·m
   (D) -1.13×10^{8} V·m
   (E) -2.26×10^{8} V·m

(b) What is the flux of the magnetic field through the cylinder described in part (a)?

   (A) 0
   (B) -1.30 T·m^{2}
   (C) $+1.30$ T·m^{2}
   (D) -2.60 T·m^{2}
   (E) $+2.60$ T·m^{2}

(c) At what distance from the column of electrons does the electric field have a magnitude of 3.00×10^{6} V/m, the dielectric strength for air?   This is an estimate of the radius of a visible lightning bolt.

   (A) 0.658 m
   (B) 5.99 m
   (C) 7.43 m
   (D) 11.5 m
   (E) 23.2 m

3. Regard a flat portion of the surface of the Earth and a cloud layer 775 m above the Earth as the plates of parallel plate capacitor having a capacitance of 1.14×10^{-8} F. Assume the dielectric constant of the air between the plates is 1.00.

    cloud layer

    • A

    • B   775 m
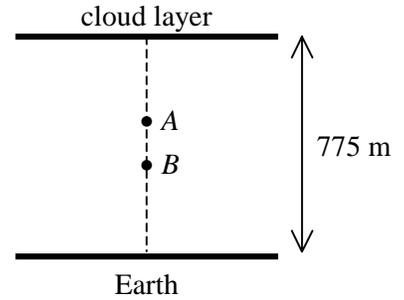
    Earth

(a) What is the area of the plates?

    (A) 5.50×10^{5} m^2
    (B) 7.99×10^{5} m^2
    (C) 9.98×10^{5} m^2
    (D) 2.26×10^{6} m^2
    (E) 4.97×10^{6} m^2

Assume that charge builds up on the cloud layer and the Earth until a uniform electric field with a magnitude of 3.00×10^{6} V/m exists in the space between them.

(b) If points *A* and *B* in the figure are 255 m apart, what is the magnitude of the electric potential difference between the two points?

    (A) 5.65×10^{8} V
    (B) 7.65×10^{8} V
    (C) 9.85×10^{8} V
    (D) 1.89×10^{9} V
    (E) 3.01×10^{9} V

(c) What is the magnitude of the charge on the cloud layer?

    (A) 15.3 C
    (B) 26.5 C
    (C) 29.0 C
    (D) 34.8 C
    (E) 49.0 C

(d) What is the electric energy density in the region between the cloud layer and Earth?

    (A) 19.0 J/m^3
    (B) 27.4 J/m^3
    (C) 32.8 J/m^3
    (D) 39.8 J/m^3
    (E) 43.6 J/m^3

4. The rear window defogger of a car consists of thirteen identical thin wires, each having a resistance of $20.5\ \Omega$, a length of 1.30 m, and a resistivity of $88.0\times10^{-8}\ \Omega\cdot m$. The wires are connected in parallel to the 12.0 V car battery.

(a) What is the cross-sectional area of each wire?

   (A) $1.18\times10^{-8}\ m^2$
   (B) $2.28\times10^{-8}\ m^2$
   (C) $3.38\times10^{-8}\ m^2$
   (D) $4.48\times10^{-8}\ m^2$
   (E) $5.58\times10^{-8}\ m^2$

(b) What is the current through each wire?

   (A) 0.115 A
   (B) 0.250 A
   (C) 0.585 A
   (D) 0.676 A
   (E) 0.863 A

(c) What power does the battery deliver to the rear window defogger?

   (A) 75.9 W
   (B) 91.3 W
   (C) 105 W
   (D) 125 W
   (E) 147 W

5. In a heart pacemaker, a capacitor of 3.43×10^{-7} F discharges through a 1.80×10^6 Ω resistor. One pulse is delivered to the heart each time the charge on the capacitor is 1/4 of its initial value
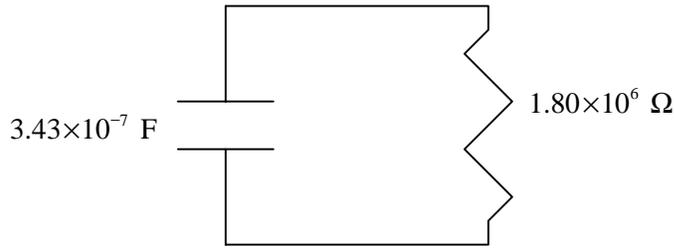
(a) What is the time constant for this circuit?

    (A) 0.617 s
    (B) 0.967 s
    (C) 1.05 s
    (D) 1.39 s
    (E) 1.62 s

(b) What fraction of its initial energy is stored in the discharging capacitor at the instant the charge on the capacitor is 1/4 of its initial value?

    (A) 1/16
    (B) 1/8
    (C) 1/4
    (D) 1/2
    (E) No energy is lost by the discharging capacitor.

(c) How many pulses does the pacemaker deliver to the heart each minute? (Assume that after a pulse is delivered to the heart, the time needed to recharge the capacitor is negligible compared with the discharge time, that is, assume that the capacitor is instantly recharged after delivering a pulse.)

    (A) 60.0
    (B) 65.3
    (C) 70.1
    (D) 75.0
    (E) 80.4

6. Microwaves in a microwave oven are produced by electrons executing circular motion in a uniform magnetic field. Suppose the magnitude of the field in a particular oven is 8.58×10^{-2} T .

(a) What is the angular speed or cyclotron frequency of an electron in the given magnetic field?

(A) 1.51×10^{10} rad/s
(B) 2.31×10^{10} rad/s
(C) 4.45×10^{10} rad/s
(D) 6.96×10^{10} rad/s
(E) 9.02×10^{10} rad/s

Suppose a particular electron has a velocity of 1.51×10^{7} m/s directed perpendicular to the magnetic field.

(b) What is the magnitude of the magnetic force on the electron?

(A) 1.04×10^{-13} N
(B) 2.08×10^{-13} N
(C) 3.24×10^{-13} N
(D) 4.16×10^{-13} N
(E) 5.32×10^{-13} N

(c) What is the radius of the circular orbit of the electron?

(A) 1.25×10^{-4} m
(B) 2.50×10^{-4} m
(C) 5.00×10^{-4} m
(D) 7.50×10^{-4} m
(E) 1.00×10^{-3} m

(d) The electron's motion takes place inside a special tube called a magnetron. If the magnetron can accommodate electron orbits with a maximum radius of 1.25×10^{-3} m , what is the maximum kinetic energy of an orbiting electron inside a magnetron with a field of 8.58×10^{-2} T ?

(A) 1.26×10^{-16} J
(B) 1.44×10^{-16} J
(C) 1.62×10^{-16} J
(D) 1.78×10^{-16} J
(E) 1.94×10^{-16} J

7. In the figure to the right, the uniform magnetic field with a magnitude of 4.00×10^{-2} T is surrounded by a field-free space. A rectangular loop having a resistance of 4.00×10^{-3} Ω moves horizontally through this region with a constant speed. At the instant shown in the figure, the loop straddles the uniform field and the field-free region. An induced current of 0.500 A flows clockwise through the loop. Answer all questions at the instant shown in the figure.

0.100 m

0.500 A
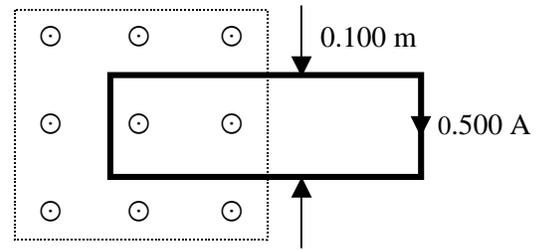
(a) Is the loop moving to the right or to the left?

   (A) to the right
   (B) to the left

(b) What is the magnitude of the applied force required to move the loop at constant speed?

   (A) 5.00×10^{-4} N
   (B) 1.00×10^{-3} N
   (C) 2.00×10^{-3} N
   (D) 4.00×10^{-3} N
   (E) 8.00×10^{-3} N

(c) What is the power delivered by the applied force?

   (A) 5.00×10^{-4} W
   (B) 1.00×10^{-3} W
   (C) 2.00×10^{-3} W
   (D) 4.00×10^{-3} W
   (E) 8.00×10^{-3} W

(d) What is the speed of the loop?

   (A) 0.100 m/s
   (B) 0.200 m/s
   (C) 0.300 m/s
   (D) 0.400 m/s
   (E) 0.500 m/s

8. The light from a laser pointer used by many people giving presentations has a wavelength of 632×10^{-9} m and an average intensity of 955 W/m^2

   (a) What is the frequency of this electromagnetic wave?

      (A) 1.13×10^{14} Hz
      (B) 2.05×10^{14} Hz
      (C) 3.95×10^{14} Hz
      (D) 4.74×10^{14} Hz
   (E) 5.62×10^{14} Hz

   (b) What is the maximum electric field in this electromagnetic wave?

      (A) 848 V/m
      (B) 915 V/m
      (C) 1130 V/m
      (D) 1240 V/m
      (E) 1370 V/m

   (c) What is the radiation pressure exerted by the beam of the laser pointer on a perfect absorber?

      (A) 1.71×10^{-6} N/m^2
      (B) 2.00×10^{-6} N/m^2
      (C) 2.24×10^{-6} N/m^2
      (D) 2.97×10^{-6} N/m^2
      (E) 3.19×10^{-6} N/m^2

9. An optical fiber used for long-distance communication consists of a small diameter (8.00×10^{-6} m) glass core surrounded by a larger diameter (1.25×10^{-4} m) glass sheath whose index of refraction is lower than that of the core. Assume the index of refraction of the core is 1.75 and that of the sheath is 1.52. Suppose that light is incident on the surface of the core at a 75.0° angle as shown in the figure below.
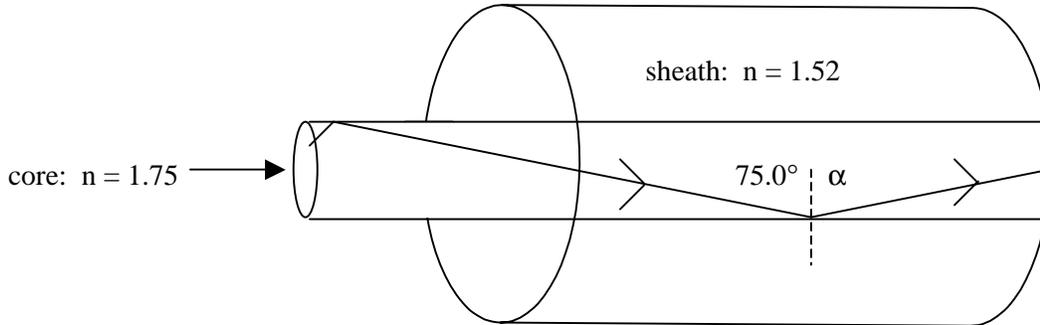
(a) Find the critical angle for this fiber-optic system.

    (A) 39.0°
    (B) 46.6°
    (C) 51.2°
    (D) 57.8°
    (E) 60.3°

(b) Determine the angle of reflection α.

    (A) 45.0°
    (B) 55.3°
    (C) 60.0°
    (D) 73.1°
    (E) 75.0°

(c) What is the speed of light in the glass core?

    (A) 1.71×10^{8} m/s
    (B) 2.05×10^{8} m/s
    (C) 2.41×10^{8} m/s
    (D) 2.89×10^{8} m/s
    (E) 3.00×10^{8} m/s

KEY

Name: _____   ID#   _____

Concept Questions   *Problems*

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

Problems:

D — 1. (a) _____   E — 4. (a) _____   B — 7. (a) _____
E — (b) _____   C — (b) _____   C — (b) _____
E — (c) _____   B — (c) _____   B — (c) _____
D — 2. (a) _____   A — 5. (a) _____   E — (d) _____
A — (b) _____   A — (b) _____   D — 8. (a) _____
B — (c) _____   C — (c) _____   A — (b) _____
C — 3. (a) _____   A — 6. (a) _____   E — (c) _____
B — (b) _____   B — (b) _____   E — 9. (a) _____
B — (c) _____   E — (c) _____   E — (b) _____
D — (d) _____   C — (d) _____   A — (c) _____
10 _____   10 _____   10 _____

Column Subtotals

50

Exam Score _____