Northern Virginia Community College

PHYSICS 232
Practice Problems

Tatiana Stantcheva

November 29, 2016

Partially funded by the VCCS Paul Lee Professional Development Foundation

Contents

Chapter 15

Waves

15.1 Section A

1. A wave is described by

$$y(x,t) = (0.1\text{ cm})\sin(3x + 10t)\ ,$$

where x is in m, y in cm, and t in seconds. (a) What is the angular wave number? (b) What is the angular frequency?

Ans. 3.0 rad/cm; 10 rad/s

2. Water waves in thesea are observed to have a wavelength of 300 m and a frequency of 0.07 Hz. What is the speed of these waves?

Ans. 21 m/s

3. What is the speed of a transverse wave in a rope of length 2.00 m and mass 60.0 g under tension of 500 N?

Ans. 129 m/s

4. When a certain string is clamped at both ends, four consecutive resonant frequencies are measured to be 100, 150, 200, and 250 Hz. One of the resonant frequencies (below 200 Hz) is missing. Which one?

Ans. 50 Hz

5. A string clamped at both ends vibrates in its fifth resonant frequency equal to 750 Hz. What is its sixth harmonic?

Ans. 900 Hz

6. A string fixed at both ends is 8.40 m long and has a mass of 0.120 kg. It is subjected to a tension of 96.0 N and set oscillating.

   (a) What is the speed of the waves on the string?

   (b) What is the longest possible wavelength of a wave to create a standing wave pattern?

   (c) Give the frequency of that wave.

Ans. 81.98 m/s; 16.8 m; 4.88 Hz

15.2 Section B

1. The displacement of a string carrying a traveling sinusoidal wave is given by

$$y(x,t) = y_m \sin\left(kx - \omega t + \phi\right) \ .$$

At time $t = 0$ the point $x = 0$ has a displacement of zero and is moving in the positive y direction. Determine the phase constant *phi*.

Ans. π rad

2. The tension in a string with a linear mass density of 0.0010 kg/m is 0.40 N. What is the frequency of a sinusoidal wave with a wavelength of 20 cm on this string?

Ans. 100 Hz

3. Use the wave equation to find the speed of a wave given by

$$y(x,t) = (3.0\text{ mm})\sin\left(\left(4.00\text{ m}^{-1}\right)x - \left(7.00\text{ s}^{-1}\right)t\right)$$

Ans. 1.75 m/s

4. What is the second lowest frequency for standing wave patterns on a wire that is 10.0 m long, has a mass of 100 g, and is stretched under a tension of 250 N.

Ans. 15.8 Hz

5. A rope, under tension of 200 N and fixed at both ends, oscillates in a second harmonic standing wave pattern. The displacement of the rope is given by:

$$y(x,t) = (0.10 \text{ m}) \left(\sin \frac{\pi x}{2}\right) \sin(12\pi t) \ ,$$

where $x = 0$ at one end of the rope, x is in meters, and t in seconds. What are:

(a) the length of the rope,

(b) the speed of the waves on the rope, and

(c) the mass of the rope?

(d) If the rope oscillates in a third harmonic standing wave pattern, what will be the period of oscillations?

Ans. 4 m; 24 m/s; 1.4 kg; 0.11 s

6. A string carries a sinusoidal wave with an amplitude of 2.0 cm and a frequency of 100 Hz. What is the maximum speed of any point on the string?

Ans. 12.57 m/s

7. A transverse sinusoidal wave traveling on a string has a frequency of 100 Hz, a wavelength of 0.040 m, and an amplitude of 2.0 mm. What is the maximum acceleration in $\frac{\text{m}}{\text{s}^2}$ of any point on the string?

Ans. 790 $\frac{\text{m}}{\text{s}^2}$

8. A transverse wave with amplitude of 2.5 cm is traveling along a string in the positive direction. The velocity of the wave is $v = 30$ m/s and the frequency is 50 Hz. The tension in the string is 25 N.

(a) What is the wavelength of the wave?

Ans. (a) 0.6 m

(b) If the displacement is at maximum at $x = 0$ and $t = 0$, write down the formula describing the wave.

Ans. (b) $(2.5\text{ cm})\sin\left((10.47\text{ m}^{-1})\,x - (314\text{ s}^{-1})\,t + \frac{\pi}{2}\right)$

(c) What is the mass density of the string?

(d) What is the maximum speed of particles on the string?

Ans. 0.03 kg/m; 7.85 m/s

9. Standing waves are produced by the interference of two traveling sinusoidal waves, each of frequency 100 Hz. The distance from the second noted, to the fifth node is 60 cm. Determine the wavelength of each of the two original waves.

Ans. 40 cm

10. Two sinusoidal waves, each of wavelength 5 m and amplitude 10 cm, travel in opposite directions on a 20-m long stretched string that is clamped at each end. Excluding the nodes at the ends of the string, how many nodes appear in the resulting standing wave?

Ans. 7

11. A string clamped at its ends, vibrates in three segments. The string is 100 cm long. Determine the wavelength.

Ans. 66.7 cm

15.3 Section C

1. Two identical traveling waves, moving in the same direction, are out of phase by $\frac{\pi}{2}$ rad. Waht is the amplitude of the resultant wave in terms of the common amplitude y_m of the two combining waves?

Ans. $\sqrt{2}y_m$

2. Suppose the maximum speed of a string carrying a sinusoidal wave is v_s. When the displacement of a point on the string is half its maximum, what is the speed of the point?

Ans. $\frac{\sqrt{3}v_s}{2}$

3. Two sinusoidal waves have the same angular frequency, the same amplitude y_m, and travel in the same direction in the same medium. If they differ in phase by 50 deg, determine the amplitude of the resultant wave.

Ans. $1.8y_m$

Chapter 16

Sound

16.1 Section A

1. A hiker determines the length of a lake by listening for the echo of his shout reflected by a cliff at the far end of the lake. He hears the echo 1.5 s after shouting. Estimate the length of the lake.

   Ans. 260 m

2. A column of soldiers, marching at 120 paces per minute, keep in step with the beat of a drummer at the head of the column. On a warm day (20°C), it is observed that the soldiers in the rear end of the column are striding forward with the left foot when the drummer is advancing with the right foot. What is the approximate length of the column?

   Ans. 86 m

3. What is the sound level of a sound whose intensity is $8.5 \times 10^{-8}\ \frac{\mathrm{W}}{\mathrm{m}^2}$?

   Ans. 49.3 dB

4. What is the intensity of a sound whose sound level is 25 dB?

   Ans. $3.16 \times 10^{-10}\ \frac{\mathrm{W}}{\mathrm{m}^2}$

5. A tuning fork of unknown frequency makes 6 beats every 2.0 seconds with a standard fork of frequency 384 Hz. What is the possible values of the frequency of this fork?

Ans. 387, 381 Hz

16.2 Section B

1. A certain sound source is increased in sound level by 30.0 dB. By what multiple is its intensity in $\frac{\mathrm{W}}{\mathrm{m}^2}$ increased?

Ans. 1000 times

2. A violin string 15.0 cm long and fixed at both ends oscillates in its $n = 1$ mode. The speed of waves on the string is 250 m/s, and the speed of sound in air is 348 m/s. What are (a) the frequency, and (b) the wavelength of the emitted sound?

Ans. 833 Hz; 0.42 m

3. If you were to build a pipe organ with open-tube pipes spanning the range of human hearing (20 Hz to 20 kHz) what would be the range of the lengths of pipes required?

Ans. 8.575×10^{-3} m to 8.575 m

4. An organ pipe is 78.0 cm long. Assuming $T = 20°$C, what are the fundamental and first three audible overtones at room temperature (20°C) if the pipe is (a) closed at one end, and (b) open at both ends?

Ans. $(110, 330, 550, 770)$ Hz; $(220, 440, 660, 880)$ Hz

5. The water level in a vertical glass tube 1.00 m long can be adjusted to any position in the tube. A tuning fork vibrating at 686 Hz is held just over the open top end of the tube, to set up a standing wave of sound in the air-filled top protion of the tube. Considering room temperature (20°C), at what positions of the water level will sound from the fork set up resonance in the tube's air-air filled portion?

Ans. 0.125 m; 0.375 m; 0.625 m; 0.875 m

6. A well with vertical sides and water at the bottom resonates at 7.00 Hz and at no lower frequency. The air in the well has a density of 1.10 $\frac{\text{kg}}{\text{m}^3}$ and a bulk modulus of 1.33×10^5 Pa. How far down in the well is the water surface?

Ans. 12.4 m

7. Two violin strings are tuned to the same frequency , 294 Hz. The tension in one string is then decreased by 2.0%. What will be the beat frequency heard when the two strings are played together?

Ans. 2.9 Hz

8. A state trooper chases a speeder along a straight stretch of road; both vehicles move at 160 km/h. The siren on the trooper's vehicle produces sound at a frequency of 500 Hz. What is the Doppler shift in the frequency heard by the speeder?

Ans. 500 Hz

9. An ambulance with a siren emitting a whine at 1600 Hz overtakes and passes a cyclist pedaling a bike at 2.44 m/s. After being passed, the cyclist hears a frequency of 1590 Hz. How fast is the ambulance moving? (Take the ambient temperature to be 20°C)

Ans. 4.6 m/s

10. Two automobiles are equipped with the same single frequency horn. When one is at rest and the other is moving toward an observer at 15 m/s, a beat frequency of 5.5 Hz is heard. What is the frequency the horns emit? Assume $T = 20°\text{C}$

Ans. 120 Hz

11. The predominant frequency of a certain police car's siren is 1550 Hz when at rest. Assuming T=20°C, what frequency do you detect if you move with a speed of 30 m/s (a) toward the car, and (b) away from the car.

Ans. 1686 Hz; 1414 Hz

16.3 Section C

1. A person sees a heavy stone strike the concrete pavement. A moment later two sounds are heard from the impact: one travels in the air and the other in the concrete, and they are 1.4 s apart. How far away did the impact occur?

   Ans. 540 m

2. A stone is dropped into a well. The splash is heard 3.00 s later. What is the depth of the well?

   Ans. 40.7 m

3. The pressure variation in a sound wave is given by

$$\Delta P = (0.0025 \text{ Pa}) \sin\left(\frac{\pi}{3}x - 1700\pi t\right) \ ,$$

   where x is in meters, and t in seconds. Assume the density of the medium to be $\rho = 2.7 \times 10^3 \, \frac{\text{kg}}{\text{m}^3}$ and its bulk modulus $B = 1.0 \times 10^5$ Pa, and determine (a) the wavelength, (b) the frequency, (c) the speed, and (d) the displacement amplitude of the wave.

   Ans. 6 m; 850 Hz; 5.1×10^3 m/s; 2.4×10^{-8} m

4. The pressure in a traveling sound waves is given by the equation:

$$\Delta P = (1.50 \text{ Pa}) \sin\left(\left(0.900\pi \frac{1}{\text{m}}\right) x - \left(315\pi \frac{1}{\text{s}}\right) t\right) \ .$$

   Find (a) the pressure amplitude, (b) the frequency, (c) the wavelength, and (d) the speed of the wave.

   Ans. 1.50 Pa; 50 Hz; 7.0 m; 350 m/s

5. If the amplitude of a sound wave is tripled, (a) by what factor will the intensity increase? (b) By how many dB will the sound level increase?

   Ans. 9; 9.54 dB

6. Two sound waves, from two different sources with the same frequency, 540 Hz, travel in the same direction at 330 m/s. The sources are in phase. What is the phase difference of the waves at a point that is 4.40 m from one source and 4.00 m from the other?

Ans. 4.1 rad

7. The frequency of a steam train whistle as it approaches you is 538 Hz. After it passes you, its frequency is measured as 486 Hz. How fast was the train moving? (assume constant velocity)

Ans. 17.4 m/s

8. A bat flies toward a wall at a speed of 5.0 m/s. As it flies, the bat emits an ultrasonic sound wave with frequency 30 kHz. What frequency does the bat hear in the reflected wave?

Ans. 30,888 kHz

Chapter 21

Electric Charge and Electric Force

21.1 Section A

1. What is the magnitude of the electric force of attraction between an iron nucleus ($q = +26e$) and its innermost electron if the distance between them is 1.5×10^{-12} m?

   Ans. 2.7×10^{-3} N

2. What must be the distance between point charge $q_1 = 26.0\mu$C and point charge $q_2 = -47.0\mu$C for the electrostatic force between them to have a magnitude of 5.7 N?

   Ans. 1.4 m

3. Two small plastic spheres are given positive electrical charges. When they are 15.0 cm apart, the repulsive force between them has magnitude 0.220 N. What is the charge on each sphere (a) if the two charges are equal? (b) if one sphere has four times the charge of the other?

   Ans. 0.74 μC; (0.37 μC, 1.5μC)

21.2 Section B

1. Two charged balls are 15.0 cm apart. They are moved, and the force on each of them is found to have been tripled. How far apart ar they now?

   Ans. 8.66 cm

2. In the Bohr theory of the hydrogen atom, an electron moves in a circular orbit about a proton, where the radius of the orbit is 5.29×10^{-11} m.

   (a) Find the magnitude of the electric force exerted on each particle.

   Ans. 8.24×10^{-8}

   (b) If this force causes the centripetal acceleration of the electron, what is the speed of the electron?

   Ans. 2.19×10^{6} m/s

3. Three small negatively charged metal spheres in vacuum are fixed on a horizontal straight line along the x axis. One ($q_1 = -12.5\mu$C) is at the origin, another ($q_2 = -5.0\mu$C) is at location with coordinates $(2.0, 0)$ m, and the third ($q_3 = -10\mu$C) is at location $(3.0, 0)$ m. Compute the net electric force on the last sphere due to the other two.

   Ans. 0.575 N

4. Four equal oint charges, $+3\mu$C each, are placed at the four corners of a square that is 0.40 m on a side. Find the force on any one of the charges?

   Ans. 0.97 N

5. Two small spheres with mass $m = 25.0$ g are hung by silk threads of length $L = 2.0$ m as shown in Fig. 21.1. When the spheres are given equal quantities of negative charge, so that $q_1 = q_2 = q$, each thread hangs at $\theta = 10°$ from the vertical. Determine the magnitude of q.

   Ans. 1.52μC

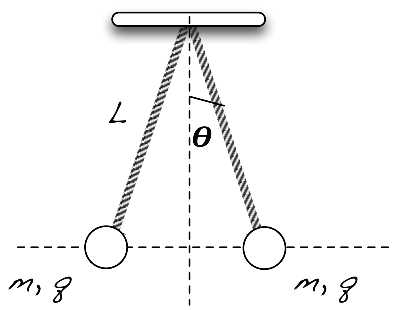

Figure 21.1: Hanging Charges (Problem 5)

21.3 Section C

1. Two point charge q_1 and q_2 are 3.0 m apart, and their combined charge is 20 μc. If they repel each other with a force of 0.075 N, what are the two charges?

   Ans. 5 μC, 15 μC

2. Two small non-conducting spheres have a total charge of 90.0 μC. When placed 1.16 m apart, the force each exerts on the other is 12.0 N and is repulsive. What is the charge on each. What if the force was attractive?

   Ans. 30μC, 60μC

Chapter 22

Electric Field

22.1 Section A

1. What is the magnitude of the acceleration experienced by an electron in an electric field of 600 N/C? How does the direction of the acceleration depend on the direction of the field at that point?

   Ans. 1.1×10^{14}m/s^2, opposite to E

2. A small object carrying a charge of -55.0μ C experiences a downward force of 6.20×10^{-9} N when placed at a certain point in an electric field.

   (a) What would be the magnitude and direction of the electric field?

   (b) What would be the magnitude and direction of the force acting on a copper nucleus (atomic number = 29; atomic mass = 63 g/mol) placed at this same point in the electric field?

   Ans. 1.13×10^{-4} N/C upward; 5.23×10^{-22} N upward

22.2 Section B

3. An electron is released from rest in a uniform electric field and accelerates to the north at a rate of 145 m/s^2. What is the magnitude and direction of the electric field?

Ans. 8.3×10^{-10} N/C

4. A water droplet of radius 0.020 cm remains stationary in the air. If the electric field of the Earth is 150 N/C downward, how many excess electron charges must the water droplet have?

Ans. 1.4×10^{10}

5. The electric field midway between two equal but opposite point charges is 845 N/C and the distance between the charges is 16.0 cm. What is the magnitude of the charge on each?

Ans. 3.0×10^{-10} C

6. The earth has a net electric charge that causes a field at point near its surface equal to 150 N/C and directed in toward the center of the earth. What magnitude and sign of charge would a 60-kg human have to acquire to overcome his or her weight by the force exerted by the earth's electric field.

Ans. -3.92 C

7. An electron ($q = -e$; $m = 9.1 \times 10^{-31}$ kg) is projected out along the $+x$ axis with an initial speed of 3.0×10^6 m/s. It goes 45 cm and stops due to a uniform electric field in the region. Find the magnitude and direction of the field.

Ans. 57 N/C

8. An α particle ($q = +2e$; $m = 4u$) is traveling to the right at 1.50 km/s. What uniform electric field is needed to cause it to travel to the left at the same speed after 2.65 μs?

Ans. 23.5 N/C

9. An electron with speed $v_o = 2.15 \times 10^6$ im/s is traveling parallel to an electric field of magnitude $E = 11.4 \times 10^3$ N/C. (a) How far will it travel before it stops, (b) and how much time will elapse before it returns to its starting point?

1.15×10^{-3} m; 2.15 ns

10. Electron is at rest in a space with electric field with magnitude 700 N/C.

    (a) How long will it take for the electron to reach speed $v = 1.2 \times 10^5$

    (b) What is the distance between the initial position of the electron when it is at rest, and the position when it has reached a speed $v = 1.2 \times 10^5$ m/s?

Ans. 0.975 ns; 58.5μs

11. Electron is moving in an electric field with magnitude 700 N/C pointing in the same direction as the velocity of the electron. The speed of the electron is 5.0×10^5 m/s.

    (a) How long before the electron stops?

    (b) How far will the electron be from its initial position when it stops?

Ans. 4.07×10^{-9} s; 1.02×10^{-3} m

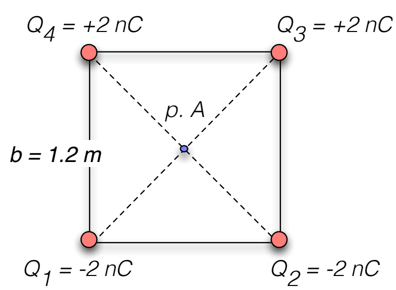

Figure 22.1: Four charges forming a square (Problem 12)

12. Four charged particles form a square with a side $b = 1.2$ m. The charges of the particles are $Q_1 = -2.0$ nC, $Q_2 = -2.0$ nC, $Q_3 = +2.0$ nC, $Q_4 = +2.0$ nC, as shown in Fig. 22.1. What is the magnitude and the direction of the electric field at point A, the intersection of the diagonals?

Ans. 70.72 N/C

13. Positive point charges of $+20\mu$C are fixed at two of the vertices of an equilateral triangle with sides of 2.0m, located in vacuum. Determine the magnitude of the E-field at the third vertex.

Ans. 0.214 N/C

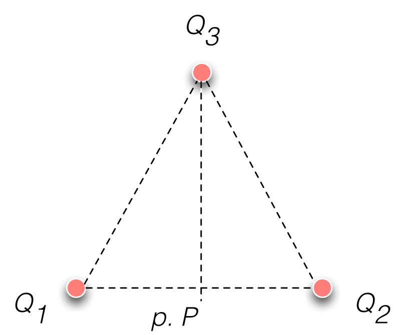

Figure 22.2: Equilateral Triangle (Problem 14)

14. Three charged particles form an equilateral triangle as shown in Fig. 22.2. The distance between them is $l = 25$ cm.The charges of the particles are $Q_1 = -1.2\mu$C, $Q_2 = +2.4\mu$C, $Q_3 = -1.8\mu$C. what is the magnitude and the direction of the electric field at point A located in the middle between the particles Q_1 and Q_2?

Ans. 2.1×10^6 N/C at 170.54°

15. Four point charges with charges $+4\mu$C, $+4\mu$C, -4μC, -4μC, in this order, are placed at the four corners of a square that is 20 cm on a side. Find the electric field at the center of the square.

Ans. 5.1×10^6 N/C

16. In a rectangular coordinate system a positive point charge $q = 6.0 \times 10^{-9}$ C is placed at the point $x = +0.150$ m, $y = 0$ m, and an identical point charge is plaed at $x = -0.150$ m, $y = 0$ m. Find the $x-$ and the $y-$components of the electric field at

(a) origin

(b) $x = +3.00$ m, $y = 0$ m

(c) $x = +0.150$ m, $y = -0.400$ m

(d) $x = +0.0$ m, $y = 0.2$ m

Ans. (a) $(0, 0)$ N/C, (b) $(2.67 \times 10^3, 0)$ N/C, (c) $(1.30 \times 10^2, -5.10 \times 10^2)$ N/C, (d) $(0, 1.38 \times 10^3)$ N/C

22.3 Section C

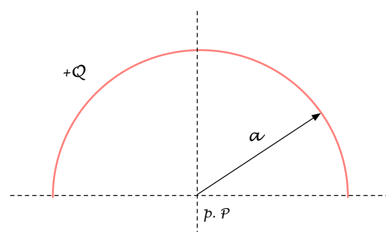

Figure 22.3: Semi-circle (Problem 17)

17. Positive charge Q is uniformly distributed around a semicircle of radius a., as shown in Fig. 22.3. Find the electric field (magnitude and directioN) at the center?

Ans. $\frac{2kQ}{\pi a^2}$

18. Negative charge $-Q$ is distributed uniformly around a quarter-circle of radius a that lies in the first quadrant, with the center of curvature at the origin. Find the $x-$ and the $y-$ components of the net electric field at the origin.

Ans. $\frac{kQ}{\pi a^2}$

19. A small sphere with mass $m = 1$ g is hanging on a string with length $l = 36$ cm. What will be the period of the oscillations of this pendulum if the sphere has a charge $q = -20 \times 10^{-9}$ C and is located n region with $E = 100,000$ N/C pointing downwards (towards the center of the Earth)?

Ans. 1.35 s

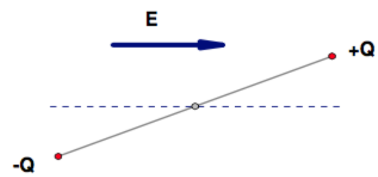

Figure 22.4: Dipole Oscillations (Problem 20)

20. An electric dipole. of dipole moment p and moment of inertia I, is placed in a uniform electric field E. if displaced by an angle θ as shown in Fig. 22.4 and released, under what conditions will it oscillate in simple harmonic motion? What will be its period of oscillations?

Ans. $2\pi\sqrt{\frac{I}{pE}}$

Chapter 23

Gauss' Law

23.1 Section A

1. When a piece of paper is held with one face perpendicular to a uniform electric field, the flux through it is 25.0 N.m^2/C. What is the flux through the paper when it is turned 25° with respect to the field?

   Ans. 23 N.m^2/C

2. A charge of 25μC is placed in the center of a cube. Determine the net electric flux in N.m^2/C through the walls of the cube.

   Ans. 2.8×10^6 N.m^2/C

3. A point particle with charge $q = 5.0$ nC is placed inside a cube at its center. Determine the electric flux through one face of the cube.

   Ans. 94 N.m^2/C

23.2 Section B

1. A point particle with charge $q = 5.0\mu$C is placed at th corner o a cube. What is the total electric lux in N.m^2/C through all sides of the cube.

   Ans. 7.1×10^4 N.m^2/C

2. Charge Q is distributed uniformly throughout an insulating sphere of radius R. Determine what fraction of the charge is located at a distance equal or less than $r = \frac{R}{2}$.

   Ans. 0.125

3. Charge Q is distributed uniformly throughout an insulating disk of radius R and negligible thickness. Determine what fraction of the charge is located within a distance of $r = \frac{R}{3}$ from the center.

   Ans. 0.11

4. Determine the flux of the electric field $(24\ \mathrm{N/C})\hat{\imath} + (30\ \mathrm{N/C})\hat{\jmath} + (16\ \mathrm{N/C})\hat{k}$ through a 2.0 m^2 portion of the yz plane.

   Ans. 48 $\mathrm{N.m^2/C}$

5. A conducting sphere of radius 0.01 m has a charge of 1.0×10^{-9} C deposited on it. Determine the magnitude of the electric field just outside the surface of the sphere.

   Ans. 900 $\mathrm{N.m^2/C}$

6. Charge Q is distributed uniformly throughout an insulating sphere of radius R. What is the magnitude of the electric field at a point $\frac{R}{2}$ from the center?

   Ans. $\frac{Q}{8\pi\epsilon_o R^2}$

7. A solid conducting sphere with radius R, that carries positive charge Q, is concentric with a very thin insulating shell of radius $2R$ that also carries charge Q. The charge Q is distributed uniformly over the insulating shell. Find the electric field in each of the regions

   (a) $0 < r < R$

   (b) $R < r < 2R$

   (c) $r > 2R$

   Ans. (a) $\frac{kQr}{R^3}$, (b) $\frac{kQ}{r^2}$, (c) $\frac{2kQ}{r^2}$.

23.3 Section C

1. A solid non-conducting very long cylinder has a linear charge densit of λ. Determine the electric field of the cylinder at a distance r not very fram from its surface.

Ans. $\frac{\lambda}{2\pi\epsilon_o r}$

Chapter 24

Electric Potential

24.1 Section A

1. When a piece of paper is held with one face perpendicular to a uniform electric field, the flux through it is 25.0 N.m^2/C. What is the flux through the paper when it is turned 25° with respect to the field?

   Ans. 23 N.m^2/C

2. How much work is needed to move a -7.0 μC charge from ground to a point of electric potential $+6.00$ V?

   Ans. -4.2×10^{-5} J

3. The electric field between two parallel plates connected to a 45 V battery is 1,500 V/m. How far apart are the plates?

   Ans. 0.03 m

4. An electric field of 640 V/m is desired between two parallel plates 11.0 mm apart. How large a voltage should be applied?

   Ans. 7.04 V

5. Assuming the electric potential $V = 0$ at the distance $r \rightarrow$, (a) what is the electric potential 0.50×10^{-10} m from a proton? (b) What is the potential energy of an electron at this point?

Ans. 28.8 V; −28.8 eV

6. If the electric potential is given by $V = xy - 3z^2$, what is the function for the $y-$component of the electric field?

Ans. $-x$

7. If an electron has a kinetic energy of 100 eV, what is the speed of the electron?

5.9×10^6 m/s

8. A point charge $q = +4.6\ \mu$C is held fixed at the origin. A second point charge $Q = +1.20\ \mu$C with mass of 2.80×10^{-4} kg is placed on the $x-$axis, 0.250 m from the origin.
   (a) What is the electric potential energy U of the pair of charges.
   (b) Charge Q is released from rest. What is its speed when its distance from the origin is 0.5 m?

Ans. 0.1987 J; 26.6 m/s

24.2 Section B

9. An electron is to be accelerated from 3.00×10^6 m/s to 8.00×10^6 m/s. Through what potential difference must the eectron pass to accomplish this?

Ans. 156.4 V

10. An electron starts from rest 72.5 cm from a fixed point charge with $Q = -0.125\ \mu$C. How fast will the electron be moving when it is very far away?

Ans. 2.3×10^7 m/s

11. Two protons and an α-particle are held at rest at the corners of an equilateral triangle whose side length is 8.00×10^{-10} m. The particles are released and move apart. What is their total energy when they are infinitely far away from each other?

Ans. 9.00 eV

12. A charge of 1.5 μC is located at $(0, 0)$ and a charge of 2.1 μC is located at $(4 \text{ m}, 0)$. What is the electric potential at $(4 \text{ m}, 3 \text{ m})$?

Ans. 9,000 V

13. Two charged particles with charges $Q_1 = 3.5$ μC and $Q_2 = -2.5$ μC, are initially separated by a distance 2.3 m. What is the work required to separate the charges to a distance 6.9 m?

Ans. 0.0228 J

14. Two protons are aimed directly toward each other by a cyclotron accelerator. Each is moving at a speed of 1,000 km/s, measured relative to the earth. Find the minimum distance between the protons.

Ans. 1.4×10^{-13} m

15. Two very small metal spheres carrying charges of $+10$ μC and -25 μC are located at coordinates $(0, 0)$ and $(3.0 \text{ m}, 0)$, respectively. How much work would have to be done to bring a third sphere with a charged of -10 μC from very far away to the point $(0, 4.0 \text{ m})$?

Ans. 0.225 J

16. How much work must be done to bring three electrons from a great distance apart to within 1.0×10^{-10} m from one another?

Ans. 14.4 eV

17. An α-particle with kinetic energy 11.0 MeV makes a head-on collisions with a lead nucleus that is at rest. What is the distance of closest approach of the two particles? (Assume the lead nucleus remains stationary and that it may be treated as a point charge. Atomic number of lead is 82. The α-particle is a helium nucleus with atomic number 2.)

Ans. 2.15×10^{-14} m

18. In a certain region of space, the electric potential is given by $V(x, y, z) = Axy - Bx^2 + Cy$, where A, B, and C are positive constants. What the $x-$, $y-$ and $z-$ components of the electric field?

Ans. $(-Ay + 2Bx, -Ax - C, 0)$

19. The electric potential in a certain area is given as: $V = 5x^2 + 4xy - z^2$. What is the electric field in that area?

Ans. $(-10x - 4y, -4x, 2z)$

20. The electric potential in a region of space is given by the function $V = 3x^2 + 2xy + \ln z$. Determine the electric field in that region.

Ans. $(-6x - 2y)\,\hat{\imath} - 2x\hat{\jmath} - \frac{1}{z}\hat{k}$

21. The electric potential in a certain area is given as: $V = 3x^2 + 5yz$. What would be the electric force on a proton at location $(4, 0, 0)$ (given in meters).

Ans. $-3.84 \times 10^{-18}\hat{\imath}$ N

22. A uniform electric field $\vec{E} = -300$ V/m$\hat{\imath}$ points in the negative x direction as shown in Fig. 24.1. The x and y coordinates are given in meters. Determine the electric potential difference

    (a) $V_B - V_A 4$

    (b) $V_C - V_B$

    (c) $V_C - V_B$

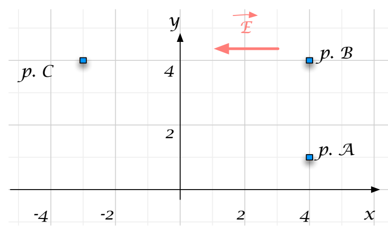

Figure 24.1: E-V calculation (Problem 22)

Ans. 0; -2100 V; -2100 B

23. Derive the electric field due to a single point charge using the relation between the electric field and the electric potential and that the elecric potential of due to a single point charge is $V = \frac{1}{4\pi\epsilon_o}\frac{Q}{r}$.

24. The electric field produced by a long uniformly charged rod is given by the formula: $E = \frac{\gamma}{2\pi r}$, where γ is the linear charge density defined as charge per unit length, and r is the distance to the rod. What is the electric potential as a function of r produced by the rod. (Assume the electric potential is zero at inifity.)

Ans. $-\frac{\gamma}{2\pi}\ln r +$ const.

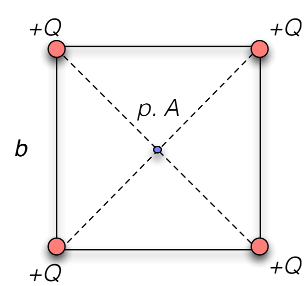

Figure 24.2: Four charges on a square (Problem 25)

25. Four equal point charges Q are fixed at the corners of a square of side b as shown in Fig. 24.2.

    (a) What is their total electrostatic potential energy?

(b) How much potential energy will a fifth charge, Q, have at the center of the square (assume $V = 0$ at $r \to \infty$).

Ans. $\left(4 + \sqrt{2}\right) \frac{kQ^2}{b}$, $4\sqrt{2}\frac{kQ^2}{b}$

26. For the charges in Fig. 24.2, determine the electric potential at p.A. Assume $b = 1.2$ m, $Q_1 = Q_2 = -2.0$ nC, and $Q_3 = Q_4 = +2.0$ nC.

Ans. 0 V

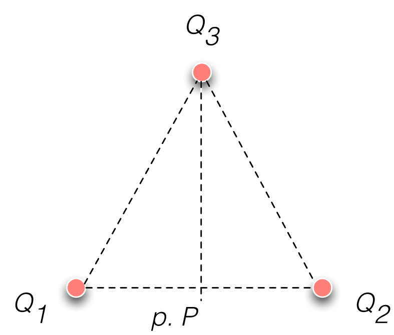

Figure 24.3: Three charges on a triangle (Problem 27)

27. Three charged particles form an equilateral triangle as shown in Fig. 24.3. The distance between them is $l = 25$ cm. The charges of the particles are $Q_1 = -1.2\mu$C, $Q_2 = +2.4\mu$C, $Q_3 = -1.8\mu$C.

    (a) What is the electric potetial at point A?

    (b) What is the potential energy of the particles?

    (c) How much work is required to separate the charges to infinity?

1.16×10^4 V, -0.18 J, +0.18 J

28. A half-ring (semicircle) of uniformly distributed charge Q has a radius of a as shown in Fig. 24.4. Derive the expression for the el. potential at its center?

Ans. $\frac{Q}{4\pi\epsilon_o a}$

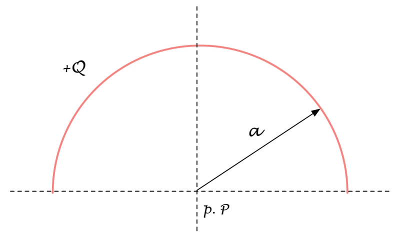

Figure 24.4: Half a ring (Problem 28)

29. A small sphere with a mass of 1.50 g hangs by a thread between two parallel vertical plates 5.00 cm apart, as shown in Fig. 24.5. The charge on the sphere is $q = 8.90 \times 10^{-6}$ C. What potential difference between the pates will cause the thread to assume an angle of 30° with the vertical?

Ans. 47.7 V

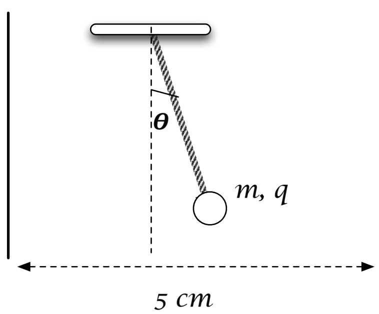

Figure 24.5: Half a ring (Problem 29)

24.3 Section C

30. An insulated spherical conductor of radius r_1 carries a charge Q. A second conducting sphere of radius r_2 and initially uncharged is then connected to the first by a long conducing wire.

    (a) After the connection, what can you say about the electric potential of each sphere?

(b) How much charge is transferred to the second sphere? Assume the connected spheres are far apart compared to their raddi. (Why make this assumption?)

Ans. Equal; $Q_1 = \frac{Qr_1}{r_1+r_2}$ and $Q_2 = \frac{Qr_2}{r_1+r_2}$

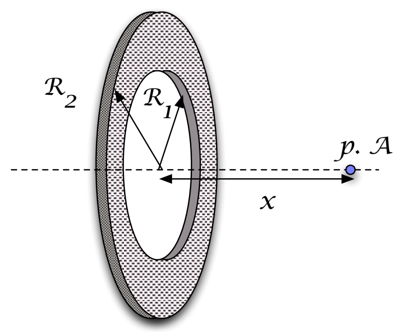

Figure 24.6: Half a ring (Problem **??**)

31. A flat ring of inner radius R_1 and outer radius of R_2 carries a uniform surface charge density σ. Determine the electric potential at a distance x along the perpendicular line through its center.

Ans. $\frac{\sigma}{2\epsilon_o}\left(\sqrt{x^2+R_2^2}-\sqrt{x^2+R_1^2}\right)$

Chapter 25

Capacitors

25.1 Section A

1. The two plates of a capacitor hold $+2,500$ μC and $-2,500$ μC of charge, respectively, when the potential difference is 950 V. What is its capacitance?

   Ans. 2.63 μC

2. A $0.40-\mu$F capacitor is desired. What are must the plates have if they are to be separated by a 4.0-mm air grap?

   Ans. 180.8 m^2

3. You have six 1.8-μF capacitors. What is their equivalent capacitance if they are connected (a) in parallel, and (b) in series?

   Ans. 1.08×10^{-5} F, 3.0×10^{-7} F

4. Three 4-mF capacitors are connected in series across a 12-V battery. What is the total energy stored by this combination of capacitors?

   Ans. 96 mJ

5. A 1-mF, a 2-mF, and a 3-mF capacitor are connected in series, the combintaion being connected across a 9.0-V battery. Which capacitor has the greatest charge on it?

   Ans.

25.2 Section B

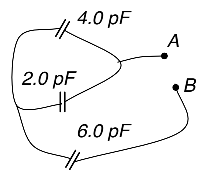

Figure 25.1: Capacitors (Problem 6)

6. What is the equivalent capacitance of the circuit on Fig. 25.1

Ans. 3 pF

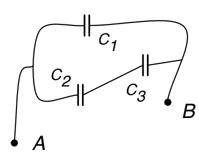

Figure 25.2: Capacitors (Problem 7)

7. For the circuit given in Fig. 25.2, determine (a) the equivalent capacitance of the circuit, and (b) how much charge is stored on each capacitor if $C_1 = C_2 = 2C_3 = 14.0\mu$F and $V_{AB} = 15.0$ V.

Ans. $C_1 + \frac{C_2C_3}{C_2+C_3}$; $Q_1 = 210\ \mu$C; $Q_2 = Q_3 = 70\ \mu$C

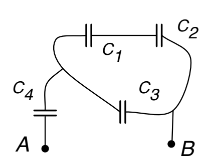

Figure 25.3: Capacitors (Problem 8)

8. For the circuit given in Fig. 25.3 the electric potential difference between points A and B is given to be V, and each capacitor has capacitance equal to C. Determine

(a) the equivalent capacitance between points A and B,

(b) the charge on each capacitor,

(c) and the potential difference across each capacitor.

Ans. $\frac{3}{5}C$;

$Q_1 = Q_2 = \frac{1}{5}CV,\ Q_3 = \frac{2}{5}CV,\ Q_4 = \frac{3}{5}CV$;

$V_1 = V_2 = \frac{1}{5}V,\ V_3 = \frac{2}{5}V,\ V_4 = \frac{3}{5}V$

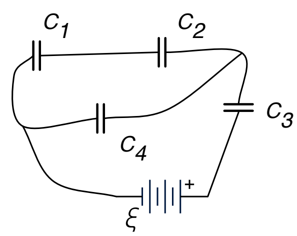

Figure 25.4: Capacitors (Problem 9)

9. Four capacitors are connected as shown in Fig. 25.4. If the capacitance is given as $C_1 = 2.3$ nF, $C_2 = 3.7$ nF, $C_3 = 3.0$ nF, and $C_4 = 5.0$ nF, and battery has an electromotive force $\varepsilon = 2.5$ V,

   (a) What is the total capacitanc of the circuit?

   (b) What is the charge stored on the plates of the capacitor C_4?

   (c) What is the charge stored on the plates of the capacitor C_3?

Ans. 2.34 nF; 5.86 nC; 3.98 nC

10. A 1-pF capacitor is connected in parallel with a 2-pF capacitor, the parallel combination is then being connected in series with a 3-pF capacitor. The resulting combination is then connected across a 10-V battery as shown in Fig. 25.5. Determine (a) the voltage across the 2-pF capacitor, and (b) the charge on the 2-pF capacitor.

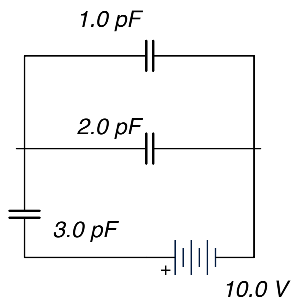

Figure 25.5: Capacitors (Problem 10)

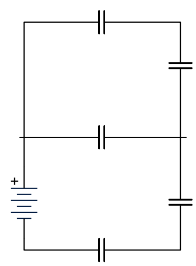

Figure 25.6: Capacitors (Problem 11)

Ans. 5V; 10pC

11. Five 12-mF capacitors are connected across a 12-V battery as shown in Fig. 25.6. Determine the total capacitance of the circuit, and the charge on the bottom capacitor.

Ans. 4.5 mF; 54 mC

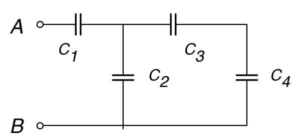

Figure 25.7: Capacitors (Problem 12)

12. For the circuit shown in Fig. 25.7 determine (a) what is the total capacitance between points a and b. (b) If the voltage between a and b is $V_{ab} = 6.0$ V, what is the voltage across the capacitor C_2?

Ans. 3.6 μF; 2.4V

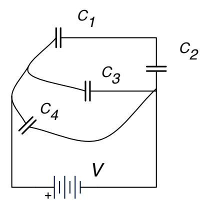

Figure 25.8: Capacitors (Problem 13)

13. For the circuit given in Fig. 25.8, $C_1 = 1.0$ μF, $C_2 = 3$ μF, $C_3 = 0.25; \mu$F, and $C_4 = 1.0$ μF (a) Determine the equivalent capacitance of the circuit. (b) If the battery emf is 10.0 V, how much is the stored charge on C_2?

Ans. 2.0Ω; 7.5μC

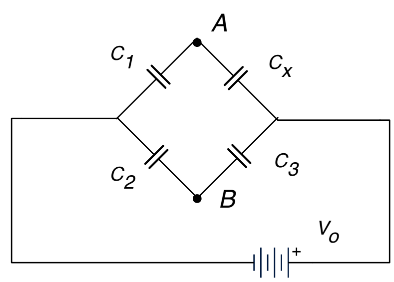

Figure 25.9: Capacitors (Problem 14)

14. In the capacitance bridge shown in Fig. 25.9, a voltage V_o is applied and the variable capacitor is C_1 is adjusted until there is zero voltage between points a and b as measured on the voltmeter. Determine the unknown capacitance C_x if $C_1 = 8.9$ μF and the fixed capacitors have $C_2 = 18.0$ μF and $C_3 = 6.0$ μF.

Ans. 3.0 μF

15. How much energy is stored by the electric field between two square plates, 8.0 cm on a side, separated by a 1.5 mm air gap? The charge split on the plates is equal to 420 μC.

Ans. 2.34×10^3 J

16. A parallel plate capacitor has a capacitance of 10 mF and is charged with a 20-V power supply. The power supply is then removed and a dielectric with dielectric constant 4 is used to fill the space between the plates. What is the voltage now across the capacitor?

Ans. 5.0 V

17. A 3500-pF air-gap capacitoris connected to a 22-V battery. If a piece of mica ($K = 7$) is placed between the plates, how much charge will flow from the battery?

Ans. 0.46 μC

18. A spherical oil droplet is located between the plates of a parallel plate capacitor. The plates of the capacitor are horizontal, the charge of the oil drop is $+1.0e$ and the oil drop is in equilibrium. If the voltage across the capacitor is 500 V and the distance between the plates is 0.5 cm, what is the radius of the droplet? (Oil density is $0.9 \times 10^3 \, \frac{\mathrm{kg}}{\mathrm{m}^3}$)

Ans. 76 μm

19. Two identical parallel plate capacitors are connected in parallel and charged completely by a 6.0-V battery. Find the difference in the electric potential between their plates if after disconnecting the battery, the distance between the plates of one of the capacitors is decreased by 2.

Ans. 4.0 V

25.3 Section C

20. Determine the capacitance of the Earth, assuming it to be a spherical conductor.

Ans. 7.11×10^{-4} F

21. It takes 25 J of energy to move a 0.20-mC charge from one plate of a 16-μF capacitor to the other. How much charge is on each plate?

Ans. 2.0 C

22. Show that each plate of a parallel-plate capacitor exerts a force on the other equal to

$$F = \frac{1}{2}\frac{Q^2}{\epsilon_o A} \ ,$$

by calculating the rate at which the work changes by increasing the separation, $\frac{dW}{dx}$. Why does using $F = QE$, with E being the electric field between the plates, give the wrong answer?

Chapter 26

Electric Current

26.1 Section A

1. How many electrons per second pass through a section of wire carrying a current of 0.70 A?

   Ans. 4.4×10^{18}

2. An electric current of 1.50 A flows in a wire. How many electrons are flowing past any point in the wire per second?

   Ans. 9.375×10^{18}

3. What is the resistance of a toaster oven if 110 V produces an electric current of 4.2 A?

   Ans. $26.2\ \Omega$

4. Determine the potential difference between the ends of a wire of resistance $5.0\ \Omega$ if a charge of 720 C passes through it per minute.

   Ans. 60 V

5. What is the maximum power consumption of a 9.0 V portable cassette player that draws a maximum of 350 mA of electric current?

Ans. 3.15 W

6. (a) What is the resistance and current through a 60-W lightbulb if it is connected to its proper source voltage of 120 V? (b) Repeat for a 150-W bulb

Ans. 240 Ω; 96 Ω

7. A steel trolley-car rail has a cross-sectional area of 56.0 cm^2. What is the resistance of 10.0 km of rail? The resistivity of steel is 3.00×10^{-7} Ω.m

Ans. 0.54 Ω

26.2 Section B

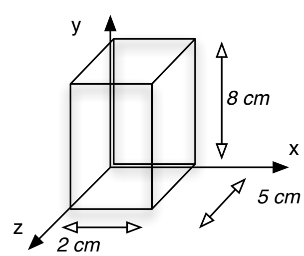

Figure 26.1: Copper Slab (Problem 8)

8. A slab made of copper has a rectangular shape and dimensions as shown in Fig. 26.1. What is the resistance of the it along the z axis?

Ans. 5.25×10^{-7} Ω

9. A bird stands on a dc electric transmission line carrying 2500 A. The line has 2.5×10^{-5} Ω resistance per meter and the bird's feet are 4.0 cm apart. What potential difference does the bird feel?

Ans. 2.5×10^{-3} V

10. A certain copper wire has a resistance of 10.0 Ω. (a) At what point along the length must the wire be cut so that the resistance of one piece is 5 times the resistance of the other? (b) What is the resistance of each piece?

Ans. $\frac{1}{6}\times$length; 1.67 Ω and 8.33 Ω

11. A length of wire is cut in half and the two lengths are wrapped together side by side to make a thicker wire. How does the resistance of thisnew combination copare to the resistance of the original wire?

Ans. $\frac{1}{4}\times$

12. At \$0.110 per KWh, what does it cost to leave a 60-W porch light on day an dnight for a year?

Ans. \$57.82

13. An iron wire at 20°C is heated until its resistance doubles. At what temperature will that occur? Assume the temperature coefficient is constant over that temperature range.

Ans. 173.6 °C

14. If we raise the temperature from 20 °C to 50 °C, by what percentage will the resistivity of the wire change? ($\alpha = 0.0068\ \mathrm{K}^{-}1$)

Ans. 20%

15. When put across the terminals of two 1.5-V cells in series, a small flashlight bulb draws 330 mA. How much power does it consume? How much energy does it tak fom the cells in 1.0 minute of operation?

Ans. 59.4 J

16. A person with body resistance between his hands of 10 kΩ accidentally grasps the terminals of a 14-kV power supply.

(a) If the internal resistance of the power supply is 2,000 Ω, what is the current through the person's body?

(b) What is the power dissipated in the body?

(c) If the power supply is to be made safe by increasing its internal resistance, what should the internal resistance be for the maximum current in the above situation to be 1.00 mA or less?

Ans. 1.167 A; 1.634×10^4 W; 14 MΩ

26.3 Section C

17. Calculate the peak voltage across, and peak current through an 1800-W arc welder conected to a 450-V AC line.

Ans. 636 V; 5.66 A

18. The current-density magnitude in a certain circular wire is

$$J = \left(2.75 \times 10^{10}\ \frac{\mathrm{A}}{\mathrm{m}^4}\right) r^2\ ,$$

where r is the radial distance out to the wire's radius of 3.00 mm. The potential applied to the wire (end to end) is 60.0 V. How much energy is converted to thermal energy in 1.00 h?

Ans. 7.55×10^5 J

19. When a wire carries a current of 1.20 A, the drift velocity (the average velocity with which the electrons float along the wire) is 1.20×10^{-4} m/s. What is the drift velocity when the current is 6.00 A?

Ans. 5.0×10^{-4} m/s

Chapter 27

DC Circuits

27.1 Section A

1. Compute the internal resistance of an electric generator which has an emf of 120 V and a terminal voltage of 110 V when supplying 20 A.

Ans. 0.50 Ω

2. An electrical cable consists of 125 strands of fine wire, each having $2.66\mu\Omega$ resistance. The same potential difference is applied between the ends of all the strands and results in a total current of 0.750 A. Determine (a) The current in each strand, (b) the potential difference between the ends, and (c) the resistance of the cable.

Ans. 6.00 mA, 1.59×10^{-8} V, 21.2 nΩ

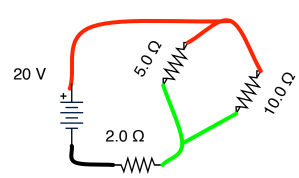

Figure 27.1: Electric Circuit (Problems 3 and 4)

3. For the circuit given in Fig. 27.1, determine the current through and the voltage across the 2.0-Ω resistor.

Ans. 3.75 A, 7.5 V

4. For the circuit given in Fig. 27.1, determine the voltage across the 10-Ω resistor.

Ans. 12.5 V

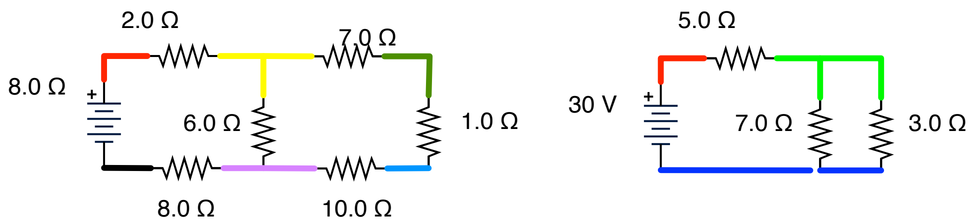

Figure 27.2: Electric Circuit (Problem 5)

5. Fig. 27.2 shows two circuits made of resistors and batteries. Determine the electric current through the battery in each circuit.

Ans.

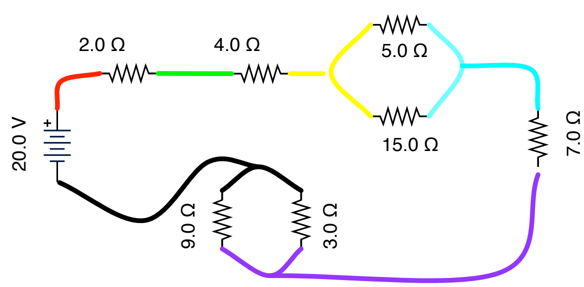

Figure 27.3: Electric Circuit (Problem 6)

6. For the circuit shown in Fig. 27.3, determine (a) the total resistance, (b) the current through the 4.0-Ω resistor, and (c) the voltage across the 4.0-Ω resistor?

Ans.

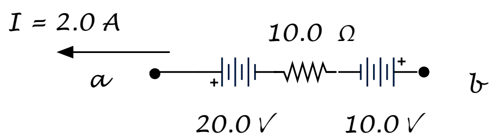

Figure 27.4: Electric Circuit (Problem 7)

7. Fig. 27.4 shows one branch of a larger elecric circuit. Find the electric potential difference between points a and b, $V_a - V_b$.

Ans. +10.0 V

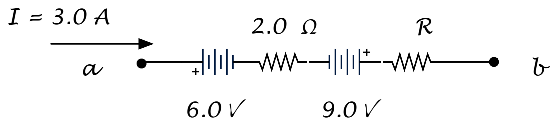

Figure 27.5: Electric Circuit (Problem 8)

8. For the circuit branch shown in Fig. 27.5, find the electric potential difference between points a and b, $V_b - V_a$.

Ans. −5.1 V

9. In an RC circuit with given R and C values, how long do you have to wait before the capacitor is discharged to one half of its maximum value?

Ans. $0.693RC$

10. In an RC circuit with given R and C values, how long do you have to wait before the capacitor is discharged to one eight of its maximum value?

Ans. $2.08RC$

11. In an RC circuit with a time constant $\tau = 2.5$ ms, how long do you have to wait before the voltage across the capacitor drops to one quarter of its maximum value?

Ans. 5.2 ms

27.2 Section B

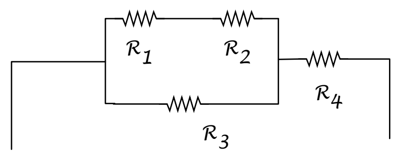

Figure 27.6: Electric Circuit (Problem 12)

12. Four resistors are shown in Fig. 27.6. If $R_1 = 2\ \Omega, R_2 = 8\ \Omega; R_3 = 2.5\ \Omega$, and $R_4 = 3\ \Omega$, and the circuit is connected to a 6-V battery.
    (a) Calculate the total resistance of the circuit.
    (b) How much is the voltage resistor R_4?
    (c) What is the voltage across the resistor R_3?

Ans. 5 Ω; 3.6 V; 2.4 V

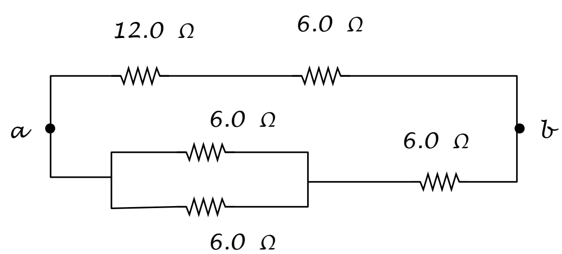

Figure 27.7: Electric Circuit (Problem 13)

13. Determine the equivalent resistance of the circuit in Fig. 27.7

Ans. 6.0 Ω

14. In the circuit given in Fig. 27.8, the electric potential at p.a is given $V_a = 10.0$ V and the current and the resistances are as indicated. Determine (a) the electric potential at b, V_b, (b) the electric potential at c, V_c, (c) the current through the $6.0 - \Omega$ resistor, and (d) the current through the $3.0 - \Omega$ resistor.

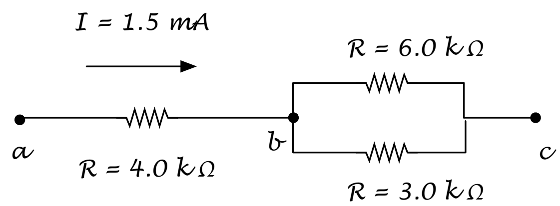

Figure 27.8: Electric Circuit (Problem 14)

Ans. 4.0 V; 1.0 V; 0.5 mA; 1.0 mA

15. Fig. 27.9 shows a part of a circuit with seven resistors. A 5.0-A current flows into the circuit at point a and out of the circuit at point b.

    (a) Find the equivalent resistance between a and b.

    (b) What is the potential difference between a and b?

    (c) How much current flows through the 12.0-Ω resistor?

Ans. 11.6 Ω; 58 V; 1.1 A

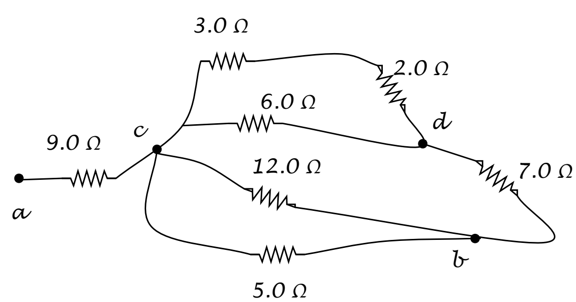

Figure 27.9: Electric Circuit (Problems 15 and 25)

16. If in the circuit shown in Fig. 27.9, the 5.0-A current does not flow from a to b, but instead you measure that there is a potential difference between c and d equal to 15.0 V, determine

    (a) the resistance of the circuit between c and d,

    (b) the current through the 6.0-Ω resistor, and

(c) the voltage across the 3.0-Ω resistor.

Ans. 2.17 Ω; 2.5 A; 9.0 V

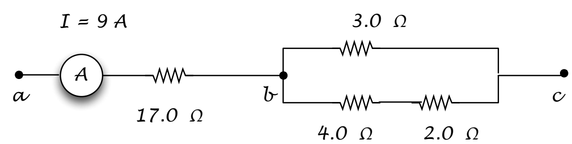

Figure 27.10: Electric Circuit (Problem 17)

17. The diagram shown in Fig. 27.10 shows a branch of a larger circuit consisting of resistors. An ammeter reads 9.0 A for the current that flow through the 17.0-Ω resistor. Determine what current passes through each resistor shown?

Ans. 9.0 A; 6.0 A; 3.0 A; 3.0 A

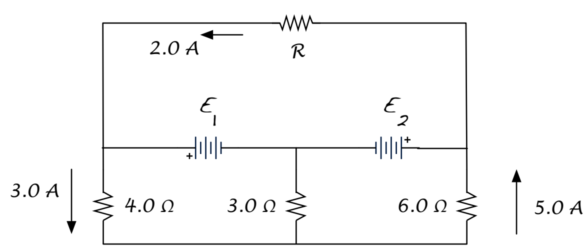

Figure 27.11: Electric Circuit (Problem 18)

18. Fig. 27.11 shows a circuit consisting of resistors and batteries. If the currents and the resistances are as shown on the diagram, determine (a) the current in the 3.0-Ω resistor, (b) the electromotive force of the two batteries, E_1 and E_2, and (c) the unknown resistance, R.

Ans. 8.0 A; 36 V and 54 V; 9.0 V

19. Fig. 27.12 shows a circuit consisting of resistors and batteries. Determine the current through the 600-Ω and the 100-Ω resistors.

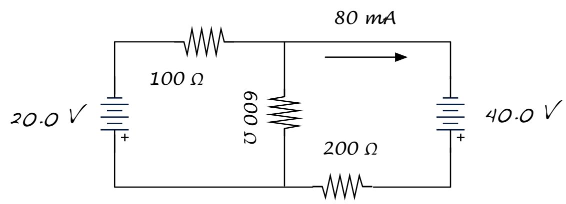

Figure 27.12: Electric Circuit (Problem 19)

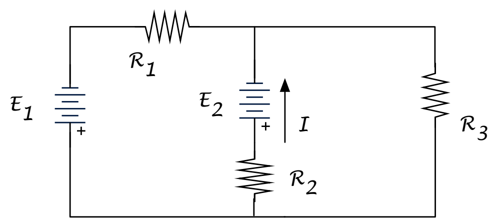

Figure 27.13: Electric Circuit (Problem 20)

Ans. 0.04 A (up); 0.04 A (right)

20. If $E_1 = 12.0$ V, $E_2 = 9.0$ V, $R_1 = 10.0$ kΩ, $R_2 = 5.0$ kΩ, $R_3 = 3.0$ kΩ, and the current through the R_2 resistor has a value of 0.85 mA and direction as shown, determine the current through R_3 and its direction.

Ans. 15.8×10^{-3} A

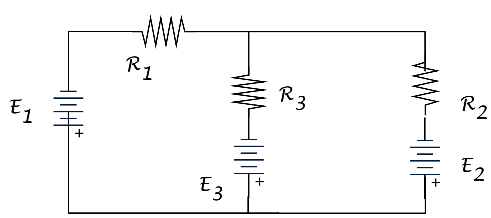

Figure 27.14: Electric Circuit (Problem 21)

21. For what value of E_3 the current through R_3 on the diagram in Fig. 27.14 will be zero?

Ans. $\frac{E_1 R_2 + E_2 R_1}{R_1 + R_2}$

22. In an RC circuit, the capacitor is initially charged with $Q_o = 2.5$ pC and has a capacitance of $C = 12.0$ pF. If the resistance is $R = 5.6$ MΩ, how much time do you need to wait for the voltage across the capacitor to drop by a factor of 8?

Ans. 0.14 ms

23. In an RC circuit, $R = 10$ kΩ and $C = 2.0$ μF. If the capacitor is initially charged with $Q_{\text{max}} = 25$ nC, determine

    (a) The voltage across the capacitor at the instant when the circuit is just connected.

    (b) The time for the voltage across the capacitor to be 1/64 of the its maximum value.

Ans. 0.0125 V; 0.083 s

24. A capacitor with capacitance $C = 455$ pF is charged with charge of magnitude 65.5 nC on each plate. The capacitor is then connected to a voltmeter that has internal resistance 1.28 MΩ.

    (a) What is the current through the voltmeter just after the connection is made?

    (b) What is the time constant of this RC circuit?

    (c) How long before the current drops to half of its max. value?

Ans. 0.112 mA; 5.8×10^{-4} s; 0.4 ms

27.3 Section C

25. Three resistors are connected as shown in Fig. 27.15. You take a multimeter and measure the resistance of the circuit between a and b to be 20 Ω. Similarly, the resistance between a and c is 15 Ω. If $R_1 = 2R_2$ determine the resistance of all resistors.

Ans. 40 Ω, 20 Ω, 20 Ω

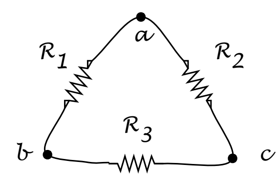

Figure 27.15: Electric Circuit (Problem 25)

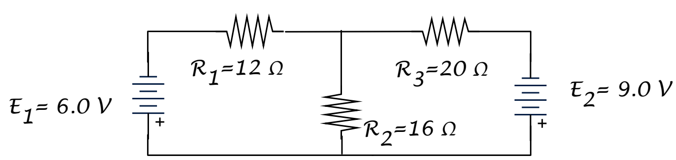

Figure 27.16: Electric Circuit (Problem 26)

26. Calculate the current through each resistor on the circuit in Fig. 27.16. Assume ideal batteries.

Ans. 0.096 A (←); 0.303 A (↑); 0.207 A (→)

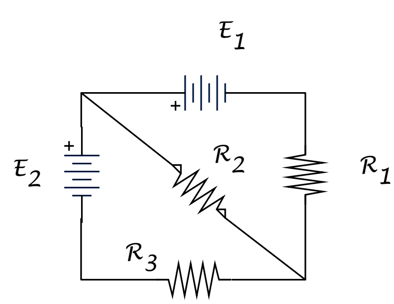

Figure 27.17: Electric Circuit (Problem 27)

27. Fig. 27.17 shows a circuit made of resistors and ideal batteries. If $R_1 = 3$ kΩ, $R_2 = 5$ kΩ, $R_3 = 10$ kΩ, and the batteries have the same EMF $E_1 = E_2 = 9.0$ V, determine the current through each of the resistors.

Ans. 0.95 mA (↑); 1.23 mA (↘); 0.28 mA (←)

Chapter 28

Magnetic Force and Magnetic Field

28.1 Section A

1. An electron ($e = 1.6 \times 10^{-19}$ C) is moving at 3.0×10^5 m/s in the positive x direction. A magnetic field of 0.8 T is in the positive z direction. What is the magnetic force on the electron.

Ans. 4.0×10^{-14} N

28.2 Section B

2. A straight 2.0-mm diameter copper wire can just "float" horizontally in air because of the Earth's magnetic field B, which is horizontal, perpenducular to the wire, and of magnitude 5.0×10^{-5} T. What current does the wire carry?

Ans. 5.5×10^3 A

3. A long wire stretches along the x axis and carries a 3.0-A current to the right ($+x$). The wire passes through a uniform magnetic field

$$\vec{B} = \left(0.2\hat{\imath} - 0.3\hat{\jmath} + 0.25\hat{k}\right) \text{ T}.$$

Determine the components of the magnetic force on one centimeter of the wire.

Ans. $(-7.5\hat{\jmath} - 9.0\hat{k}) \times 10^{-3}$ N/cm)

4. A point particle has a charge equal to -3.64 nC and a velocity equal to 2.75×10^3 m/s$\hat{\imath}$. Find the force on the charge if the magnetic field is $\vec{B} = 0.75\hat{\imath} + 0.75\hat{\jmath}$ T.

   Ans. $-7.5\hat{k}$ μN

5. A proton moves through a region onf space where there is a magnetic field and the electric field are given as:

$$\vec{B} = \left(0.45\hat{\imath} + 0.20\hat{\jmath}\right) \text{ T} \quad \text{and} \quad \vec{E} = \left(3.0\hat{\imath} - 4.2\hat{\jmath}\right) \times 10^3 \text{ V/m}.$$

   At a given instant, the proton's velocity is

$$\vec{v} = \left(6.0\hat{\imath} + 3.0\hat{\jmath} - 5.0\hat{k}\right) \times 10^3 \text{ m/s}.$$

   Determine the components of the total force on the proton.

   Ans. $\left(6.4\hat{\imath} - 10.3\hat{\jmath} - 0.2\hat{k}\right) \times 10^{-16}$ N

6. A velocity selector has a magnetic field that has a magnitude equal to 0.28 T and is perpendicular to an electric field that has a magnitude equal to 0.46 MV/m. What must be the speed of a particle for that particle to pass through the selector undeflected?

   Ans. 1.6×10^6 m/s

7. What is the q/m for a particle that moves in a circle of radius 8.0 mm in a 0.46-T magnetic field if the magnetic force can be cancelled by applying an electric field with magnitude of 200 V/m?

   Ans. 1.2×10^5 C/kg

8. A particle with charge $q = 5.0$ nC and mass $m = 3.0$ mug moves in a region where the magnetic field has components $B_x = 2.0$ mT, $B_y = 3.0$ mT, and $B_z = -4.0$ mT. At an instant when the speed of the particle is 5.0! km/s and the direction of its velocity is 120° relative to the magnetic field, what is the magnitude of the acceleration of the particle?

Ans. 38.86 m/s^2

9. What is the magnitude of the magnetic force on a charged particle ($Q = 5.0$ μC) moving with a speed of 80 km/s in the positive x direction at a point where $B_x = 3B$, $B_y = -2B$, and $B_z = B$? (B is a constant)

Ans. $0.89B$

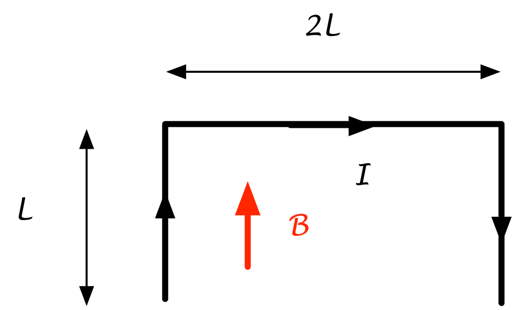

Figure 28.1: Force on a Wire (Problem 10)

10. A straight wire is bent into the shape shown in Fig. 28.1. Determine the net magnetic force on the wire.

Ans. $2ILB$

11. What will be the radius of curvature of the path of a 3.0 KeV proton in a perpendicular magnetic field of magnitude 0.8 T?

Ans. 9.89×10^{-3} m

12. An ion with a charge of $+3.2 \times 10^{-19}$ C is in a region where a uniform electric field of 5.0×10^4 V/m is perpendicular to a uniform magnetic field of 0.8 T. If its acceleration is zero, then what is its speed?

Ans. 6.3×10^4 m/s

13. Electrons with mass m and charge e are accelerated from rest through a potential difference V and are then deflected by a magnetic field $\vec{B}$ that is perpendicular to their velocity. (a) Determine the radius of their trajectory, and (b) the frequency as they go around their circular orbit.

Ans. $\frac{qB}{2\pi m}$

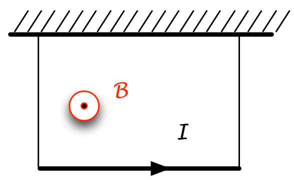

Figure 28.2: Force on a Wire (Problem **??**)

14. A wire with length $L = 2.0$ m hands on two ropes from the ceiling (as shown in Fig. 28.2). If the current along the wire is $I = 0.6$ A, the mass of the wire is $m = 20$ g, and it is in the presence of magnetic field $B = 0.2$ T, what is the tension in the ropes?

Ans. 0.22 N

28.3 Section C

15. Calculate the peak voltage across, and peak current through an 1800-W arc welder conected to a 450-V AC line.

Ans. 636 V; 5.66 A

Chapter 34

Ray Optics: Reflection, Refraction, Mirrors, Lenses

34.1 Section A

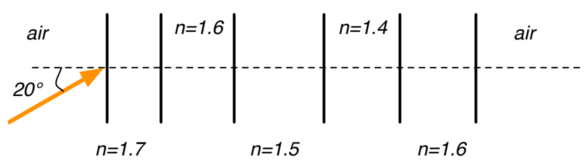

Figure 34.1: Five Transparent Layers (Problem 34.1.1)

1. A light ray passes from air through five transparent parallel layers of plastic with indices of refraction as given in Fig. 34.1. At what angle does the light emerge back into air?

2. A concave spherical mirror has a focal length of 12 cm. If an object is placed 6 cm in front of it, where is the image located?

   Ans. 12 cm behind the mirror

3. A convex spherical mirror has a focal length of 12 cm. If an object is placed 6 cm in front of it, where is the image located?

   Ans. 4 cm behind the mirror

4. The critical angle of a certain piece of plastic in air is $\theta_C = 37.3°$. What is the critical angle of the same plastic if it is immersed in water ($n = 1.33$)?

Ans. 53.7°

34.2 Section B

1. Incoming light falls onto a flat surface of an unknown medium. When the angle of incidence is equal to 67.548°, the reflected light is totally polarized. What is the angle between the refracted light and the perpendicular to the surface?

Ans. 22.45°

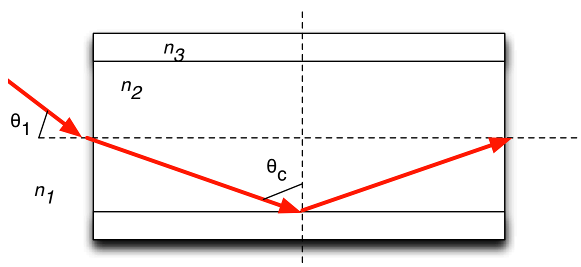

Figure 34.2: Optical Fiber (Problem 34.2.2)

2. Find the maximum angle of incidence θ_1 in air ($n_1 = 1.003$) of a ray that would propagate through an optical fiber that has a core index of refraction of $n_2 = 1.492$, a core radius of 50.00 μm, and a cladding index of $n_3 = 1.489$. A section of the fiber is sketched in Fig. 34.2.

Ans. 5°

3. A dentist wants a small mirror that will produce an upright image that has magnification of 5.5 when the mirror is located 2.1 cm from a tooth. (a) Should the mirror be concave or convex? (b) What should the radius of curvature of the mirror be?

Ans. Concave; 5.1 cm

4. A concave shaving mirror has a radius of curvature of 35.0 cm. It is positioned so that the magnification is $m = +2.5$. How far is the mirror from the face?

Ans. 10.5 cm

5. A shaving/cosmetic mirror is designed to magnify your face by a factor of 1.3 when your face is placed 20.0 cm in front of it. (a) What type of mirror is it? (b) Draw a diagram and show the image produced by the mirror. (c) Calculate the required radius of curvature for the mirror.

Ans. 173.3 cm

6. A glass ($n = 1.5$) double-convex thin lens has radii of curvature having magnitudes of 2.0 m and 5.0 m. Determine its focal length in air.

Ans. 35 cm

7. The near-point of a person's eye is 100 cm away rather than a more desirable 25.4 cm. A contact lens of what power should be prescribed?

Ans. +3 Dpt

8. A movie camera with a single lens of focal length 75 mm takes a picture of a 180 cm high person standing 27 m away. What is the height of the image of the person on the film?

Ans. 5.0 mm

9. In a cinema, a picture 2.5 cm wide on the film is projected to an image 3.0 m wide on a screen that is 18 m away. What is the focal length of the lens?

Ans. 15 cm

10. A converging lens with a focal length of 12.0 cm forms a virtual image 8.00 mm tall, at a distance 17.0 cm. (a) Determine the position and size of the object (b) Is the image upright or inverted? (c) Draw a ray diagram

Ans. 7.0 cm, 3.31 mm

11. A diverging lens has a focal length of 50 cm. A source of light is placed 100 cm in front of the lens. Where will the image be formed?

Ans. 33 cm in front of the lens

12. When a grasshopper sits 10 cm to the left of a converging lens, its image produced by the lens is located 30 cm to the right of the lens. If the grasshopper jumps 7.5 cm toward the lens, (a) find where the new image is located. (b) Draw a ray diagram of the situation after the jump. (c) What type of an image is it?

Ans. (a) 3.75 "in front"; (b) ; (c) virtual

13. An object that is 3.00 cm high is placed 20.0 cm in front of a thin lens that has a power equal to 10.0 D. Draw a ray diagram to find the position and the size of the image and check your results using the thin-lens equation.

Ans. 0.2 m "behind"; 3 cm

14. An object that is 3.00 cm high is placed 20.0 cm in front of a thin lens that has a power equal to -10.0 D. Draw a ray diagram to find the position and the size of the image and check your results using the thin-lens equation.

Ans. 6.67 "in front"; 1 cm

34.3 Section C

1. A fish is 10 cm from the front surface of a spherical fish bowl of radius 20 cm. How far behind the surface of the bowl does the fish appear to someone viewing the fish from in front of the bowl?

   Ans. -8.6 cm

2. Two thin lenses with focal lengths 10 cm and 25 cm are in contact. What is their equivalent focal length?

   Ans. 7.1 cm

3. When red light in vacuum is incident at the Brewster angle on a certain glass slab, the angle of refraction is 32.0°. What are (a) the index of refraction of the glass, and (b) the Brewster angle?

   Ans. 1.6; 58°

Chapter 35

Wave Optics: Interference

35.1 Section A

1. Two sound sources send identical waves of 20 cm wavelength out along the $+x$ axis. At what minimum (non-zero) separation of the sources will a listener on the axis beyond them hear (a) the loudest sound, and (b) the weakest sound?

   Ans. 20 cm; 10 cm

2. A double-slit experiment is performed with 480-nm light and narrow slits that are 0.050 cm apart. At what angle will one observe (a) the third-order bright spot and (b) the second minimum from the central maximum?

   Ans. $0.17°$; $0.083°$

35.2 Section B

1. Two 1.0-MHz radio antennae emitting in-phase are separated by 600 m along a north-south line. A radio placed 20 km east is equidistant from both transmitting antennae and picks up a fairly strong signal. How far north should that receiver be moved if it is again to detect a signal nearly as strong?

   Ans. 11.55 km

2. Young's double-slit experiment is performed with 589-nm light and a distance of 2.00 m between the slits and the screen. The tenth-order interference minimum is observed 7.26 mm from the central maximum. Determine (a) the spacing between the slits. (b) What if the same double-slit setting is immersed in water (n=1.33). Where on the screen would the tenth-order minimum be?

Ans. 1.70 mm; 5.46 mm

3. In a double-slit experiment , the wavelength of the light is 546 nm, the distance between the slits is 0.10 mm, and the distance from the slits to the screen is 20 cm. On the screen, what is the distance between the fifth-order maximum and the seventh-order minimum from the central maximum?

Ans. 2.7 mm

4. Sunlight incident on a screen containing two long, narrow slits 0.20 mm apart casts a pattern on a white sheet of paper 2.0 m beyond.

   (a) What is the distance on the screen separating the violet (λ = 400 nm) in the first-order maximum from the red (λ = 600 nm) in the second order?

   (b) How many red spots can be seen on the screen?

Ans. 8.0 mm; 667

35.3 Section C

1. A soap film of index 1.35 appears yellow (580 nm) when viewed from directly above. Compute two possible values of its thickness.

Ans. 107 nm, 322 nm

2. A mixture of yellow light of wavelength 580 nm and blue light of wavelength 450 nm is incident normally on an air film 290 nm thick. What is the color of the reflected light?

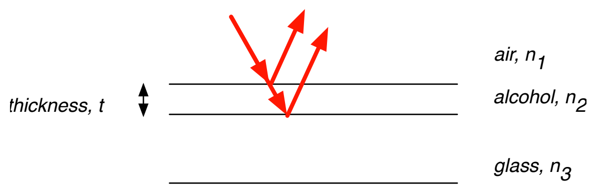

Figure 35.1: A Thin Film of Alcohol (Problem 35.3.3)

Ans. blue

3. A thin film of alcohol (n=1.36) with thickness $t = 1.3 \times 10^{-6}$ m, lies on a flat glass plate (n=1.51), as shown in Fig. 35.1. For what wavelength in the visible range of the spectrum the reflected light will be maximum?

Ans. 650 nm, 520 nm, 433 nm

Chapter 36

Wave Optics: Diffraction

36.1 Section A

1. A single slit of width 0.140 mm is illuminated by monochromatic light, and diffraction bands are observed on a screen 2.00 m away. If the second dark band is 16.0 mm from the central birght band, what is the wavelength of the light?

   Ans. 560 nm

2. Green light of wavelength 500 nm is incident normally on a grating, and the second-order image is diffracted 32.0° from the normal. How many lines/cm are marked on the grating?

   Ans. 5.3×10^3 lines/cm

3. Sound of frequency 1250 Hz leaves a room through a 1.00 m wide doorway. At what minimum angle relative to the centerline perpendciular to the doorway will someone outside the room hear no sound? ($T_{\text{air}} = 20°\text{C}$).

   Ans. 16°C

36.2 Section B

1. Monochromatic electromagnetic radiation from a distant source passes through a single slit. The diffraction pattern is observed on a screen 2.50 m from the slit. If the width of the central maximum is 6.00 mm, what is the slit width for a green light (500 nm)?

   Ans. 4.2×10^{-4} m

2. A narrow single slit (in air) is illuminated by IR from a He-Ne laser at 1152.2 nm and it is found that the center of the tenth dark spot lies at an angle of 6.2° off the central axis.

   (a) Determine the width of the slit.

   (b) If a screen is 2.0 m away, where on the screen is located the tenth bright spot above the central maximum?

   (c) At what angle would the tenth minimum appear if the entire arrangement were immersed in water ($n = 1.33$) instead of air ($n = 1.00029$)?

   Ans. (a) $1.07 \times 10^{-}4$; (b) 0.228 m; (c) 4.65°

3. A slit 1.00 mm wide is illuminated by light of wavelength 589 nm. We see a diffraction pattern on a screen 3.00 m away.

   (a) Determine the distance between the first two diffraction nimima on the same side of the central diffraction maximum?

   (b) Approximately, what is the distance between the first and the second maximum above the central maximum?

   Ans. (a) 1.77×10^{-3} m; (b) —

4. A diffraction grating has 300 lines per mm. If light of wavelength 620 nm is sent through this grating, what is the highest order maximum that will appear?

   Ans. 5

5. Light from a sodium lamp has two strong yellow components at 589.592 nm and 588.995 nm. How far apart in the first-order spectrum will these two be on a screen 1.00 m from a grating having 10 000 lines/cm?

Ans. 1.22 mm

6. A grating has 315 rulings/mm. For what wavelengths in the visible spectrum can fifth-order diffraction be observed when this grating is used in a diffraction experiment?

Ans. $\lambda \leq 635$ nm

7. Determine the ratio of the wavelengths of two spectral lines if the second-order image of one line coincides with the third-order image of the other line. The same grating is used for both lines.

Ans. 3:2

8. The angular resolution of the eye is about 5×10^{-4} rad. The moon is about 400,000 km from the earth and has a diameter of about 3500 km. What is the smallest distance between two points on the moon that can be resolved by unaided eye?

Ans. 200 km

9. The star Mizar in Ursa Major is a binary system of stars that have nearly equal magnitudes. The angular separation between the two stars is 14 seconds of arc. What is the minimum diameter of the pupil that allows resolution of the two stars using light that has a wavelength equal to 550 nm.

Ans. 0.14 mm

10. The Hale Telescope is a 200 inch reflecting telescope at the Palomar Observatory in California. It operates in the visible spectrum. (a) Determine its angular resolution for $\lambda = 550$ nm. (b) How far must two objects be on the surface of the moon if they are to be resolvable by the Hale telescope? The Earth-Moon distance is 3.844×10^8 m

Ans. (a) 1.08×10^{-7} rad; (b) 41.6 m

36.3 Section C

1. **Is the Great Wall of China visible to the naked eye from the International Space Station?** The ISS orbits at approximately 400 km above the surface of the Earth. Consider the length of the Great Wall to be approximately 9000 km and its width 6 m.

   Ans. —

2. Potassium iodide (KI) has the same crystalline structure as NaCl, with atomic planes separated by 0.353 nm. A monochromatic x-ray beam shows a first-order diffraction maximum when the glancing angle is $7.60°$. Calculate the x-ray wavelength.

   Ans. 0.0934 nm