Physics for the Life Sciences

PHYS 109 فيز

‘Selected Problems’

PART II & III

Prepared by
NOUF ALKATHRAN

Preface

This manuscript is prepared by Nouf ALKATHRAN, it reports five selected problems with their solutions.

The first part (Part 1) concern the first seven chapters of the textbook, the Physical theme is Mechanics. I selected in each chapter of the textbook five problems. The solutions are done by the Female section Teaching staff, that I would like to think for their efforts to success this course PHYS 109.

The second part (Part 2) will concern all the other chapters included in the Syllabus of PHYS109. I selected the problems and the solutions are done by the Male section Teaching staff.

Please, for any remark or correction, send an email.

Nouf ALKATHRAN

nalkathran@ksu.edu.sa

March 2018

PROB. OF CHAP. 8: Gases

8.3. A container of volume $V = 400\ cm^3$ has a mass of 244.5500 g when evacuated. When the container is filled with air of pressure p = 1 atm at temperature T = 20°C, the mass of the system increases to 245.0307 g. Assuming air behaves like an ideal gas, calculate from these data the average molar mass of air.

8.4. 1.0 mol oxygen gas is initially at a pressure of 6.0 atm and a temperature 300K. (a) If the gas is heated at constant volume until the pressure has tripled, what will be the final temperature? (b) If the gas is heated such that both pressure and volume are doubled, what will be the final temperature?

8.6. An ideal gas is initially at temperature 300 K, volume $1.5\ m^3$, and pressure 2.0×10^4 Pa. What will be its final temperature if it is compressed to a volume of $0.7\ m^3$ and the final pressure is 8.0×10^4 Pa?

8.13. Nitrogen is commercially available as a compressed gas contained in metal cylinders. (a) If a cylinder of 120 L is filled with N_2 to a pressure of 1.45 × 104 kPa at 20°C, how many mol of nitrogen does the cylinder contain? (b) If we open the valve on the cylinder and allow N_2 to escape, how many litres of nitrogen at p = 1 atm and 20°C would leave the cylinder?

8.17. Calculate the pressure exerted by 25 g of nitrogen gas in a 1.0 L container at 298 K**.**

PROB. OF CHAP. 11: Static Fluids

11.4. What is the pressure increase in the fluid in a syringe when a force of 50.0 N is applied to its circular plunger, which has a radius of 1.25 cm?

11.7. Refer to the hydraulic lift shown in Fig. 11.9. The diameter of the larger piston is 0.30 m, and the diameter of the small piston is 0.030 m. Determine the force needed to apply to the small piston so that a car of mass 1200 kg can be raised by the large piston.

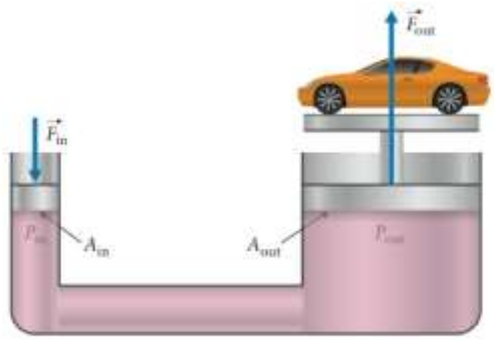


Figure 11.9 A hydraulic lift.

11.8. The U-shaped glass tube in Fig. 11.32 contains two liquids in mechanical equilibrium: water of density $\rho_w = 1.0$ kg/L and an unknown liquid of density ρ_l. The unknown liquid is in the left tube, floating on top of the water with a clearly visible interface. Use h_1 =150 mm and h_2 =15 mm with the heights as labelled in Fig. 11.32. What is the density ρ_l?

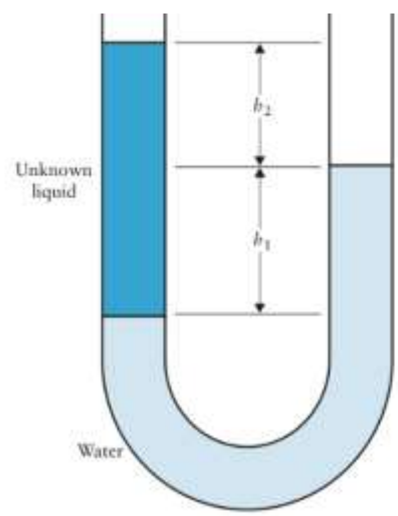
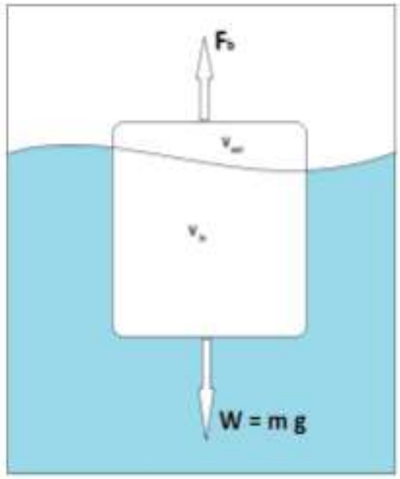


Figure 11.32

1.1.9. The density of ice is $\rho_{ice} = 920$ kg/m^3, and the average density of seawater is $\rho_w = 1.025$ g/cm^3. What fraction of the total volume of an iceberg is exposed?



11.11. (a) Fig. 11.28 (b) shows a wooden sphere with a diameter of d = 0.10 m (use density ρ = 0.90 g/cm3) held under water by a string. What is the tension in the string? (b) Fig. 11.28 (a) shows a sphere of radius r = 0.10 m and density of ρ = 2.0 g/cm3 suspended in water. What is the tension in the string? Note: Draw the free body diagram in each case.

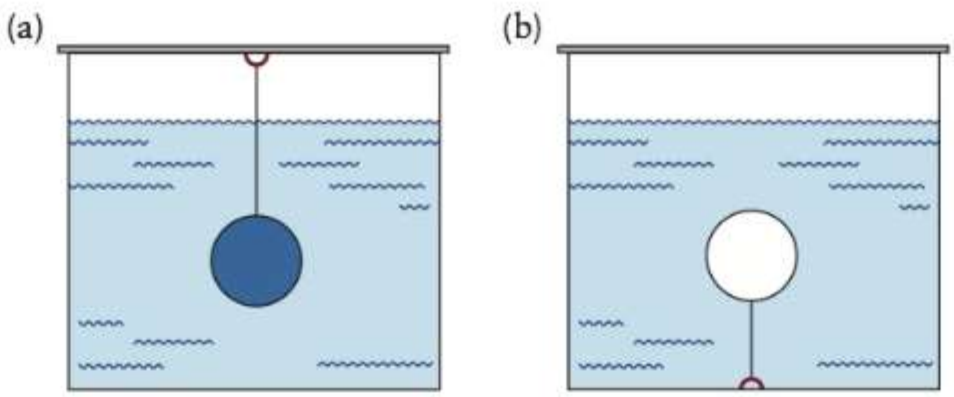


Figure 11.28 (a) A sphere of radius r = 10 cm and density ρ_a = 1.8 g/cm^3 is suspended in water. (b) A wooden sphere of diameter d = 10 cm and density ρ_b = 0.95 g/cm^3 is held under water by a string.

PROB. OF CHAP. 12: Fluid Flow

12.1. What is the net upward force on an airplane wing of area A=20.0 m^2 if air streams at 3.03×10^2 m/s across its top and at 2.8 3 $\times10^2$ m/s past the bottom? Note that this airplane moves at subsonic speed, which is less than the speed of sound (called Mach 1, about 3.3 3$\times$ 10^2 m/s).

12.3. A large water-containing tank is open to air. It has a small hole 16 m below the water surface through which water leaks at a rate of 2.5 L/min. Determine (a) the speed of the water that is ejected from the hole, and (b) the diameter of the hole.

12.4. An ideal dynamic fluid flows through a tapering tube. Upstream, the tube has a cross-sectional area of 10.0 cm^2; the fluid pressure is 120 kPa, its density is ρ= 1.65 g/cm^3, and the flow speed is 2.75 m/s. In the downstream section, the cross-sectional area is 2.5 cm^2. Calculate in the downstream section (a) the fluid density, (b) the fluid flow speed, and (c) the fluid pressure.

12.12. Water is pumped into a storage tank from a well delivering 140 L/min through a pipe of 6.0 cm^2 cross- sectional area. What is the average velocity of the water in the pipe as it is pumped from the well?

12.15. The hypodermic syringe in Fig. 12.34 contains water. The barrel of the syringe has a cross-sectional area A_1 = 30 mm^2. The pressure is 1.0 atm everywhere while no force is exerted on the plunger. When a force of FS magnitude 2.0 N is exerted on the plunger, the water squirts from the needle. Determine the water's flow speed through the needle, v_2. Assume that the pressure in the needle remains at a value of p_2 = 1.0 atm, and that the syringe is held horizontal. The final speed of the water in the barrel is negligible.

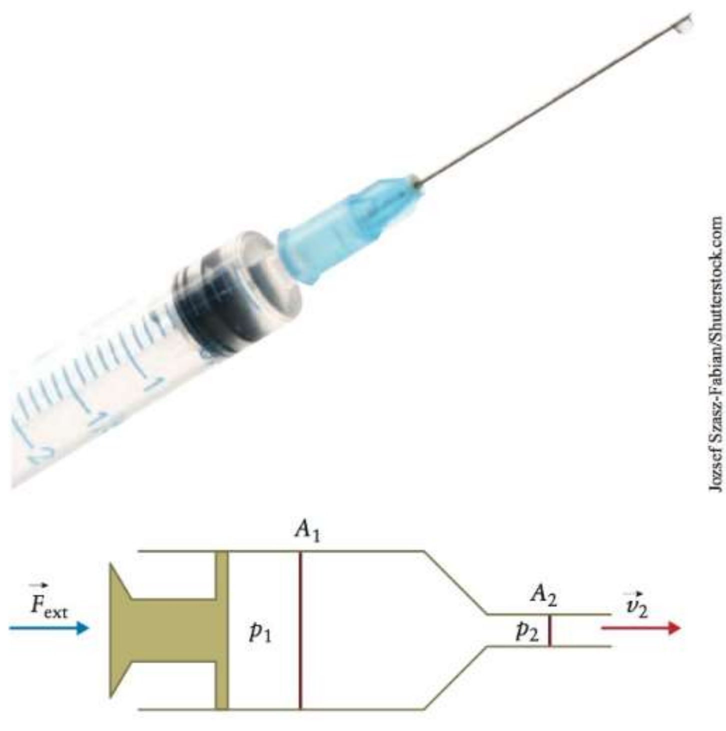


Figure 12.34

PROB. OF CHAP. 16: Electric Force and Field

16.1. We study three point charges at the corners of a tri- angle, as shown in Fig. 16.21. Their charges are $q_1 = +5.0 \times 10^{-9}$ C, $q_2 = -4.0\times10^{-9}$ C, and $q_3 = +2.5\times10^{-9}$ C. Two distances of separation are also given, $l_{12} = 4$ m and $l_{13} = 6$ m. Find the net electric force on q_3.

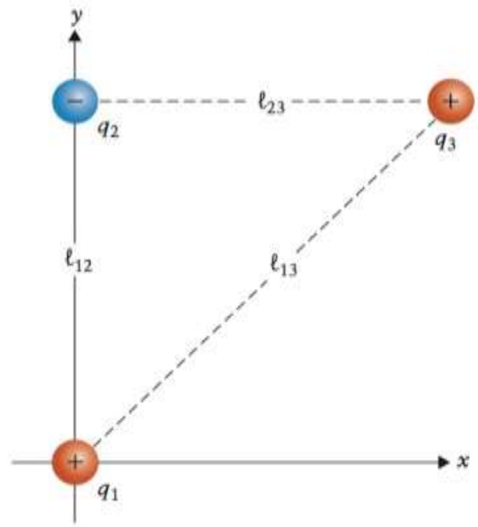


Figure 16.21

16.11. Calculate the electric field halfway between two point charges, one carrying $+10.0\times10^{-9}$ C and the other (a) $+5.0\times10^{-9}$ C at a distance of 20 cm, and (b) -5.0×10^{-9} C at a distance of 20 cm.

16.13. An electron is released into a uniform electric field of magnitude 1.5×10^{3} N/C. Calculate the acceleration of the electron, neglecting gravity.

16.17. In a hydrogen atom, what are the magnitude and the direction of the electric field due to the proton at the location of the electron, which we assume is 5.0×10^{-11} m away from the proton?

16.24. Point charges $q_1 = +5$ µC and $q_2 = -20$ µC are fixed in place and separated by a distance $L = 1.5$ m. At what point or points along the line that passes through both point charges will the electric field be zero?

PROB. OF CHAP. 17: Electric Energy and Potential

17.1. A large number of energetic cosmic-ray particles reach Earth's atmosphere continuously and knock electrons out of the molecules in the air. Once an electron is released, it responds to an electrostatic force that is due to an electric field $\vec{E}$ produced in the atmosphere by other point charges. Near the surface of Earth, this electric field has a magnitude of $|\vec{E}|$ = 150 N/C and is directed downward, as shown in Fig. 17.30. Calculate the change in electric potential energy of a released electron when it moves vertically upward through a distance d = 650 m.

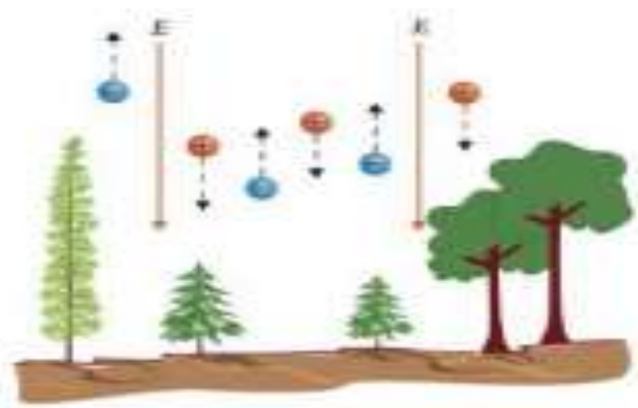


Figure 17.30

17. 6. Fig. 17.33 shows three positive point charges at the corners of a rectangle. Find the electric potential at the upper right corner if q_1 = +8 μC, q_2 = +2 μC, and q_3 = +4μC. The distances are d_1 = 6.0 cm and d_2 = 3.0 cm. The potential is defined such that it is 0 V at infinite distance from the point charge arrangement shown.

Figure 17.33

17.5. An ion is accelerated through a potential difference of 60 V, causing a decrease in its electric potential energy of 1.92×10^{-17} J. Calculate the charge the ion carries.

17.15. An air-filled parallel plate capacitor has a plate area of 5.0 cm^2 and plate separation of 1.0 mm. It stores a charge of 0.4 nC. (a) What is the potential difference across its plates? (b) What is the magnitude of the electric field between its plates?

17.16. An air-filled parallel plate capacitor has a plate area of 2.0 cm^2 and plate separation of 5.0 mm. If a 12.0 V battery is connected to its plates, how much energy does the device store?

PROB. OF CHAP. 18: The Flow of Charges

18.1. All commercial electric devices have identifying plates that specify their electrical characteristics. For example, a typical household device may be specified for a current of 6.0 A when connected to a 120 V source. What is the resistance of this device?

18.3. A total charge of 8.0 mC flows through the cross-section of a metallic wire in 4 s. What is the current in the wire?

18.5. When used at 120 V, a resistor carries a current of 0.6 A. What current is carried if the potential difference is lowered to 70 V?

18.7. A potential difference of 12 V causes a current of 0.4 A in a 3.2-m-long metallic wire with uniform radius 4.0 mm. What are (a) the resistance of the wire, and (b) the resistivity of the wire?

18.13. You often see birds resting on power lines that carry currents of 50 A. The copper wire on which the bird stands has a radius of 1.1 cm. Assuming that the bird's feet are 4.0 cm apart, calculate the potential difference across its body.

PROB. OF CHAP. 19: The Atom

19.2. A hydrogen atom is in its first excited state (n = 2). Using Bohr's atomic model, calculate (a) the radius of the electron's orbit, (b) the potential energy of the electron, and (c) the total energy of the electron.

19.3. The size of Rutherford's atom is about 0.1 nm. (a) Calculate the attractive electrostatic force between an electron and a proton at that distance. (b) Calculate the electrostatic potential energy of that atom. Express the result in unit eV. (c) The size of Rutherford's atomic nucleus is about 1 fm. Calculate the repulsive electrostatic force between two protons at that distance. (d) Calculate the electrostatic potential energy of a pair of protons in such a nucleus. Express the result in unit MeV.

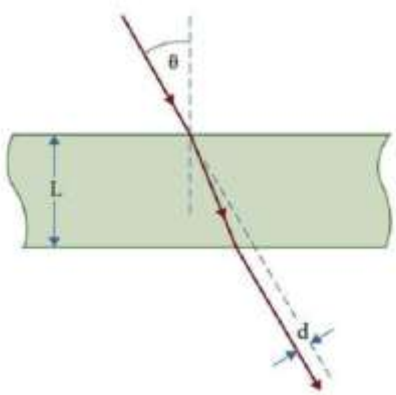
19.4. Calculate the electric force on the electron in the ground state of the hydrogen atom.

19.5. What is the wavelength of light that can cause a transition of an electron in the hydrogen atom from the orbit with n = 3 to n = 5?

19.7. Calculate the wavelength of an electron in a hydrogen atom that is in the orbit with n = 3.

PROB. OF CHAP. 21: Geometric Optics

21.5. A light ray strikes a flat, L=2.0-cm-thick block of glass (n=1.5) in Fig. at an angle of $\theta = 30°$ with the normal. (a) find angles of incidence and refraction at each surface. (b) Calculate the lateral shift of the light ray d?



21.7. A light ray travels through air and then strikes the surface of mineral oil at an angle of 23.1° with the normal to the surface. What is the angle of refraction if the light ray travels at 2.17×10^8 m/s through the oil?

21.11. A light ray is incident from air onto a glass surface with index of refraction n = 1.56. Find the angle of incidence for which the corresponding angle of refraction is one- half the angle of incidence. Both angles are defined with the normal to the surface.

21.13. A converging lens has a focal length f = 20.0 cm. Locate the images for the object distances given below. For each case state whether the image is real or virtual and upright or inverted, and finds the magnification. (a) 40 cm; (b) 20 cm; (c) 10 cm.

21.17. A contact lens is made of plastic with an index of refraction of n = 1.58. The lens has a focal length of f = +25.0 cm and its inner surface has a radius of curvature of +22.0 mm. What is the radius of curvature of the outer surface?

PROB. OF CHAP. 22: The Atomic Nucleus

22.2. The nucleus of the deuterium atom consists of one proton and one neutron. What is the binding energy of this nucleus if the mass of the deuterium nucleus is given as 2.014102 u? Note that the atomic unit u has a value u = 1.6605677 × 10^{-27} kg.

22.3. Nuclear waste from power plants may contain ^{239}Pu, a plutonium isotope with a half-life of 24000 years. How long does it take for the stored waste to decay to 10% of its current activity level?

22.7. Calculate the mass of the neutron produced during the reaction $^{11}_{5}B + ^{4}_{2}He \rightarrow ^{14}_{7}N + ^{1}_{1}n^{0}$. In order to find the mass of the neutrons, you are given the masses of boron, nitrogen, and alpha particle, which are 11.01280 amu, 14.00752 amu, and 4.00387 amu, respectively. Moreover, you are also given the kinetic energy of the incident α-particle, 5.250 MeV. The energies of the resultant neutron and nitrogen atom are to be 3.260 MeV and 2.139 MeV.

22.12. The activity of a radioisotope is found to decrease by 40% of its original value in 20 days. (a) Calculate the decay constant. (b) What is the half-life?

Physics for the Life Sciences

PHYS 109 فيز

‘Solutions for the Selected Problems’

PART II & III

SOL. PROB. OF CHAP. 8: Gases

8.3. A container of volume V = 400 cm^3 has a mass of 244.5500 g when evacuated. When the container is filled with air of pressure p = 1 atm at temperature T = 20°C, the mass of the system increases to 245.0307 g. Assuming air behaves like an ideal gas, calculate from these data the average molar mass of air.

Solution:

The mass of the air in the container is:

(245.0307 - 244.5500) g = 0.4807 g

From the ideal gas equation we have:

$$PV = \frac{m}{M}RT \Rightarrow M = \frac{mRT}{PV}$$

$$M = \frac{0.4807 \times 8.314 \times 293}{1.013 \times 10^5 \times 400 \times 10^{-6}} = 28.9 \text{ g/mole}$$

8.4. 1.0 mol oxygen gas is initially at a pressure of 6.0 atm and a temperature 300K. (a) If the gas is heated at constant volume until the pressure has tripled, what will be the final temperature? (b) If the gas is heated such that both pressure and volume are doubled, what will be the final temperature?

Solution:

The gas starts from a state 1 and terminates in a state 2.

a) $P_1V = nRT_1$ and $P_2V = nRT_2$

$$\frac{P_1V}{P_2V} = \frac{nRT_1}{nRT_2} \Rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow \frac{P_1}{3P_1} = \frac{T_1}{T_2} \Rightarrow$$

$$\frac{1}{3} = \frac{T_1}{T_2} \Rightarrow T_2 = 3T_1 \Rightarrow T_2 = 900 \text{ K}$$

b)

$$\frac{P_1V_1}{P_2V_2} = \frac{nRT_1}{nRT_2} \Rightarrow \frac{P_1V_1}{2P_1 2V_1} = \frac{T_1}{T_2} \Rightarrow$$

$$\frac{1}{4} = \frac{T_1}{T_2} \Rightarrow T_2 = 4T_1 \Rightarrow T_2 = 1200 \text{ K}$$

8.6. An ideal gas is initially at temperature 300 K, volume 1.5 m^3, and pressure 2.0×10^4 Pa. What will be its final temperature if it is compressed to a volume of 0.7 m^3 and the final pressure is 8.0×10^4 Pa?

Solution:

$$P_1V_1 = nRT_1 \text{ and } P_2V_2 = nRT_2$$

$$\frac{P_1V_1}{P_2V_2} = \frac{nRT_1}{nRT_2} \Rightarrow \frac{P_1V_1}{P_2V_2} = \frac{T_1}{T_2} \Rightarrow$$

$$T_2 = \frac{P_2V_2}{P_1V_1}T_1 \Rightarrow$$

$$T_2 = \frac{8 \times 10^4 \times 0.7}{2 \times 10^4 \times 1.5} \times 300 = 560 \text{ K}$$

8.13. Nitrogen is commercially available as a compressed gas contained in metal cylinders. (a) If a cylinder of 120 L is filled with N_2 to a pressure of 1.45 × 104 kPa at 20°C, how many mol of nitrogen does the cylinder contain? (b) If we open the valve on the cylinder and allow N_2 to escape, how many litres of nitrogen at p = 1 atm and 20°C would leave the cylinder?

Solution:

(a) $P_1V = n_1RT \Rightarrow n_1 = \frac{P_1V}{RT} \Rightarrow n_1 = \frac{1.45 \times 10^7 \times 120 \times 10^{-3}}{8.314 \times 293} \Rightarrow n_1 = 714\, mol$

(b) If we open the valve the remaining gas will have a pressure equal to the atmospheric one. Thus in the cylinder they will remain:

$$P_2V = n_2RT \Rightarrow n_2 = \frac{P_2V}{RT} \Rightarrow n_2 = \frac{101.3 \times 10^3 \times 120 \times 10^{-3}}{8.314 \times 293}$$

$$\Rightarrow n_2 = 5 \text{ mol}$$

Thus they will have escape $n_1 - n_2 = 714 - 5 = 709$ mol

This corresponds to a volume:

$$V = \frac{nRT}{P} = \frac{709 \times 8.314 \times 293}{101.3 \times 10^3} = 17.1 \text{ m}^3 = 1.71 \times 10^4 \text{L}$$

8.17. Calculate the pressure exerted by 25 g of nitrogen gas in a 1.0 L container at 298 K**.**

Solution:

$$n = \frac{m}{M} = \frac{25}{28} = 0.89$$

$$P = \frac{nRT}{V} = \frac{0.89 \times 8.314 \times 298}{1.0 \times 10^{-3}} = 2205 \times 10^3 = 2.2 \times 10^6 \text{ Pa}$$

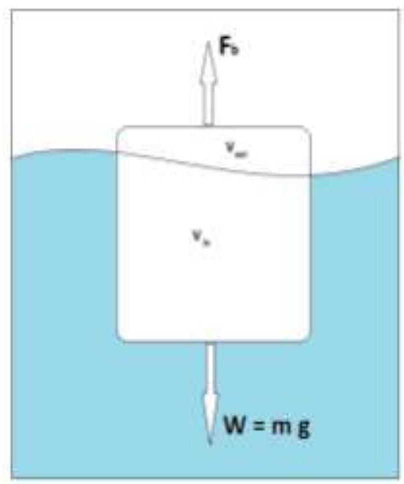
SOL. PROB. OF CHAP. 11: Static Fluids

11.4. What is the pressure increase in the fluid in a syringe when a force of 50.0 N is applied to its circular plunger, which has a radius of 1.25 cm?

Solution:

$$p = \frac{F}{A} = \frac{F}{\pi r^2} = \frac{50.0\text{ N}}{(3.14)(1.25\times10^{-2})m^2} = 101910\text{ Pa}$$

11.9. The density of ice is ρ_{ice} = 920 kg/m^3, and the average density of seawater is ρ_w = 1.025 g/cm^3. What fraction of the total volume of an iceberg is exposed?



Solution:

At equilibrium $\sum F = 0$

$$F_b = mg$$

$$\rho_w V_{in} g = \rho_{ice} V_T g$$

$$\frac{V_{in}}{V_T} = \frac{\rho_{ice}}{\rho_w} = \frac{920\,\frac{kg}{m^3}}{1025\,\frac{kg}{m^3}} = 0.898$$

$$\frac{V_{out}}{V_T} = 1 - 0.898 = 0.102$$

fraction of the total volume of an iceberg is exposed = 10.2 %

11.7. Refer to the hydraulic lift shown in Fig. 11.9. The diameter of the larger piston is 0.30 m, and the diameter of the small piston is 0.030 m. Determine the force needed to apply to the small piston so that a car of mass 1200 kg can be raised by the large piston.

Solution:

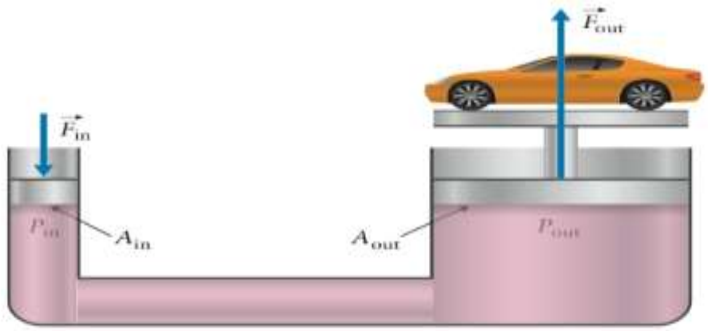


Figure 11.9 A hydraulic lift.

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_1 = \frac{F_2 \times A_1}{A_2} = \frac{mg \times \pi r_1^2}{\pi r_2^2} = \frac{1200kg \times 9.81m/s^2 \times \left(\frac{0.030}{2}m\right)^2}{\left(\frac{0.30}{2}m\right)^2}$$

F_1 = 117.72 N

11.8. The U-shaped glass tube in Fig. 11.32 contains two liquids in mechanical equilibrium: water of density $\rho_w = 1.0$ kg/L and an unknown liquid of density ρ_l. The unknown liquid is in the left tube, floating on top of the water with a clearly visible interface. Use h_1 =150 mm and h_2 =15 mm with the heights as labelled in Fig. 11.32. What is the density ρ_l?

Solution:

The pressure at contact level between the water and liquid is

$$P = P_0 + \rho_w g h_1 = P_0 + \rho_l g (h_1 + h_2)$$

$$\rho_l = \frac{\rho_w h_1}{(h_1 + h_2)} = \frac{1.0\ \mathrm{kg/L} \times 150\ \mathrm{mm}}{(150\ \mathrm{mm} + 15\ \mathrm{mm})} = 0.909\frac{\mathrm{kg}}{\mathrm{L}} = 909\ \mathrm{kg/m^3}$$

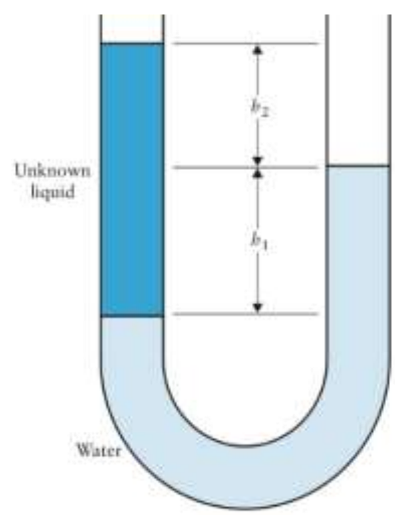


Figure 11.32

11.11. (a) Fig. 11.28 (b) shows a wooden sphere with a diameter of d = 0.10 m (use density ρ = 0.90 g/cm3) held under water by a string. What is the tension in the string? (b) Fig. 11.28 (a) shows a sphere of radius r = 0.10 m and density of ρ = 2.0 g/cm3 suspended in water. What is the tension in the string? Note: Draw the free body diagram in each case.

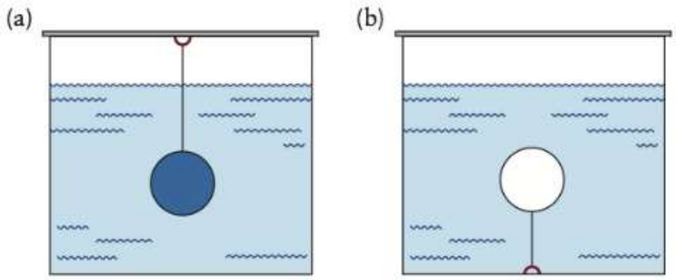
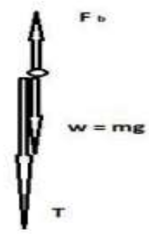


Figure 11.28 (a) A sphere of radius r = 10 cm and density ρ_a = 1.8 g/cm^3 is suspended in water. (b) A wooden sphere of diameter d = 10 cm and density ρ_b = 0.95 g/cm^3 is held under water by a string.



Solution:

(a) At equilibrium ∑F = 0

$$T = mg - F_b$$

$$T = \rho_a Vg - \rho_w Vg = (\rho_a - \rho_w)Vg = (\rho_a - \rho_w)\left(\frac{4}{3}\pi r^3\right)g$$

$$T = (1.8 \times 10^3 kg/m^3 - 1 \times 10^3 kg/m^3)\left(\frac{4}{3}\pi(0.1m)^3\right)(9.81m/s^2)$$
$$= 32.85\ N$$

(b) At equilibrium $\sum F = 0$

$$T = F_b - mg$$

$$T = \rho_w Vg - \rho_b Vg = (\rho_w - \rho_b)Vg = (\rho_w - \rho_b)\left(\frac{4}{3}\pi r^3\right)g$$

$$T = (1 \times 10^3 \text{kg/m}^3 - 0.95 \times 10^3 \text{kg/m}^3)\left(\frac{4}{3}\pi(0.05\text{m})^3\right)(9.81\text{m/s}^2)$$
$$= 0.25\ \text{N}$$

SOL. PROB. OF CHAP. 12: Fluid Flow

12.1. What is the net upward force on an airplane wing of area A=20.0 m^2 if air streams at 3.03×10^2 m/s across its top and at 2.83×10^2 m/s past the bottom? Note that this airplane moves at subsonic speed, which is less than the speed of sound (called Mach 1, about 3.33×10^2 m/s).

Solution:

We will assume that the width of the airplane wing is negligible and ignore any terms of the Bernoulli equation related to gravitational potential energy. We use the subscript 1 for the quantities of the air flowing above the wing and 2 for those below the wing. Then we have,

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

or

$$\frac{1}{2}\rho v_1^2 - \frac{1}{2}\rho v_2^2 = p_2 - p_1$$

Assuming that the density of air is 1.225 kg/m^3 we obtain,

$$\left(\frac{1.225}{2}\right)[(3.03\times10^2)^2 - (2.83\times10^2)^2] = 7178.5\ \text{Pa} = p_2 - p_1$$

Therefore, there is a net upward pressure applied on the wing. The pressure is distributed over the area A of the wing resulting in a net upward force,

$$F_{net} = P_{net}\,A = 7187.5\times20.0 = 143.6\ \text{kN}$$

12.3. A large water-containing tank is open to air. It has a small hole 16 m below the water surface through which water leaks at a rate of 2.5 L/min. Determine (a) the speed of the water that is ejected from the hole, and (b) the diameter of the hole.

Solution:

(a) The pressure is the atmospheric one at both the top of the tank and at the hole. Moreover, the fluid is assumed to be at rest at the top of the tank. Therefore, Bernoulli's equation is simplified to,

$$\rho g z = \frac{1}{2}\rho v^2$$

The water speed at the hole is obtained from the expression,

$$v = \sqrt{2gz} = \sqrt{2 \times 9.8 \times 16}\ \frac{m}{s} = 17.71\frac{m}{s} \approx 18\ \mathrm{m/s}$$

(b) The diameter of the hole, *d*, can be calculated from the given volume flow rate, using the ejection speed we calculated in (a),

$$d^2 = \frac{4\left(\frac{\Delta V}{\Delta t}\right)}{\pi v} = \frac{4 \times 2.5 \times \left(\frac{10^{-3}}{60}\right)}{3.14 \times 18} = 3 \times 10^{-6}\ \mathrm{m}^2$$

Finally,

$$d = 1.7\ \mathrm{mm}$$

Note that in the numerical substitution we have converted the volume flow rate from (L/min) to (m^3/s).

12.4. An ideal dynamic fluid flows through a tapering tube. Upstream, the tube has a cross-sectional area of 10.0 cm^2; the fluid pressure is 120 kPa, its density is ρ= 1.65 g/cm^3, and the flow speed is 2.75 m/s. In the downstream section, the cross-sectional area is 2.5 cm^2. Calculate in the downstream section (a) the fluid density, (b) the fluid flow speed, and (c) the fluid pressure.

Solution:

(a) The fluid density is the same both upstream and downstream

(b) We will calculate the flow speed downstream using the equation of continuity,

$$A_{up}\, v_{up} = A_d\, v_d$$

or

$$v_d = \frac{A_{up}}{A_d} v_{up} = \left(\frac{10.0}{2.5}\right) 2.75 = 11.0 \text{ m/s}$$

(c) To determine the pressure in the downstream area we use Bernoulli's equation,

$$p_{up} + \frac{1}{2}\rho v_{up}^2 = p_d + \frac{1}{2}\rho v_d^2$$

or

$$p_d = p_{up} + \frac{1}{2}\rho v_{up}^2 - \frac{1}{2}\rho v_d^2 = 120 \times 10^3 + \left(\frac{1.65 \times 10^3}{2}\right)[(2.75)^2 - (11)^2]$$
$$= 26.4 \text{ kPa}$$

12.12. Water is pumped into a storage tank from a well delivering 140 L/min through a pipe of 6.0 cm^2 cross-sectional area. What is the average velocity of the water in the pipe as it is pumped from the well?

Solution:

The volume flow rate is given as,

$$\frac{\Delta V}{\Delta t} = Av$$

Therefore,

$$v = \frac{1}{A}\left(\frac{\Delta V}{\Delta t}\right) = \left(\frac{1}{6.0 \times 10^{-4}}\right)\left(140 \times \frac{10^{-3}}{60}\right) = 3.9 \text{ m/s}$$

12.15. The hypodermic syringe in Fig. 12.34 contains water. The barrel of the syringe has a cross-sectional area A_1 = 30 mm^2. The pressure is 1.0 atm everywhere while no force is exerted on the plunger. When a force $\mathbf{F}_{ext}$ of magnitude 2.0 N is exerted on the plunger, the water squirts from the needle. Determine the water's flow speed through the needle, v_2. Assume that the pressure in the needle remains at a value of p_2 = 1.0 atm, and that the syringe is held horizontal. The final speed of the water in the barrel is negligible.

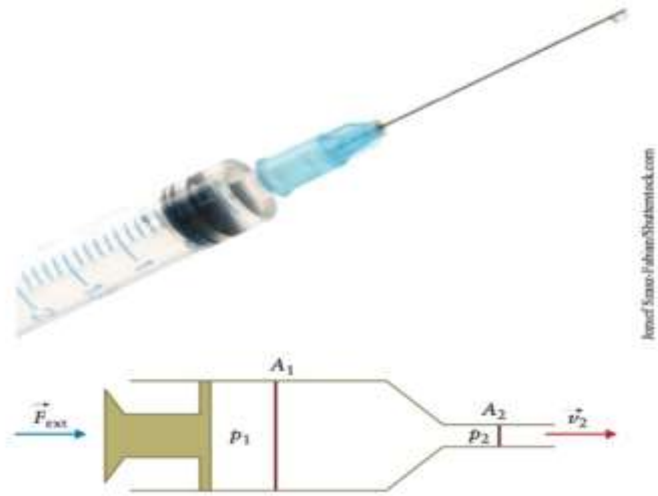


Figure 12.34

Solution:

The external force results in a pressure on the barrel,

$$p_{ext} = \frac{2}{30 \times 10^{-6}} = 6.67 \times 10^4 \text{ Pa}$$

Therefore, taking into account that the flow speed in the barrel is negligible, Bernoulli's equation becomes,

$$p_{ext} + p_1 = p_2 + \frac{1}{2}\rho v_2^2$$

But $p_1 = p_2 = 1\ atm$, so finally we have,

$$v_2 = \sqrt{\frac{2\, p_{ext}}{\rho}} = \sqrt{\frac{2 \times 6.67 \times 10^4}{1000}} = 11.55\frac{m}{s} \approx 12 \text{ m/s}$$

where we have used for the density of the water $\rho = 1000 \text{ kg/m}^3$.

SOL. PROB. OF CHAP. 16: Electric Force and Field exercise solution

16.1. We study three point charges at the corners of a tri- angle, as shown in Fig. 16.21. Their charges are $q_1 = +5.0 \times 10^{-9}$ C, $q_2 = -4.0\times 10^{-9}$ C, and $q_3 = +2.5\times 10^{-9}$ C. Two distances of separation are also given, l_{12} = 4 m and l_{13} = 6 m. Find the net electric force on q_3.

Solution:

$$\boldsymbol{F_{23}} = \frac{(9\times 10^9)(4\times 10^{-9})(2.5\times 10^{-9})}{20}$$

$$\boldsymbol{F_{23}} = 4.5 \times 10^{-9}\text{N}$$

$$\boldsymbol{F_{13}} = \frac{(9 \times 10^9)(5 \times 10^{-9})(2.5 \times 10^{-9})}{36}$$

$$\boldsymbol{F_{13}} = 3.125 \times 10^{-9}\text{N}$$

To find θ, $\sin\theta = \frac{4}{6} \rightarrow sin\theta = 2/3$

$$\theta = \sin^{-1}\frac{2}{3} = 41.8°$$

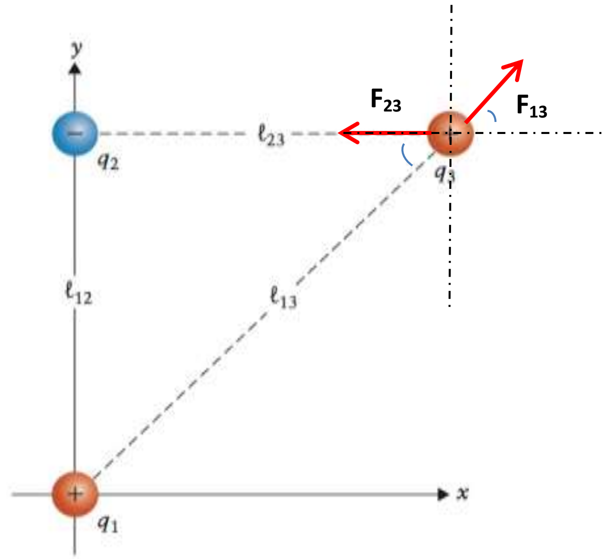


Figure 16.21

Resolve $\mathbf{F_{13}}$ into two x and y components

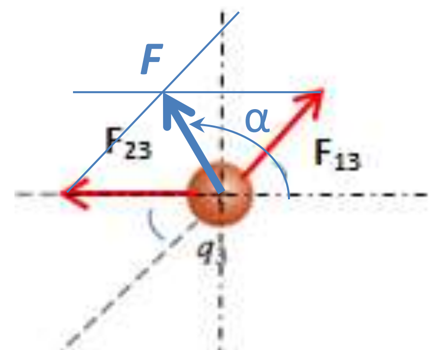
$\mathbf{F}_{13,x} = 3.125 \times 10^{-9}\cos 41.8° = 2.33 \times 10^{-9}\text{N}$

$\mathbf{F}_{13,y} = 3.125 \times 10^{-9}\sin 41.8° = 2.07 \times 10^{-9}\text{N}$

$\boldsymbol{F_x} = (2.33 \times 10^{-9}\text{N}) - (4.5 \times 10^{-9}\text{N}) = -2.19 \times 10^{-9}\text{N}$

$\boldsymbol{F_y} = (2.07 \times 10^{-9}\text{N})$

$\boldsymbol{F} = (-2.19 \times 10^{-9}, 2.07 \times 10^{-9})\text{N}$



The net force $\boldsymbol{F} = \sqrt{(-2.19 \times 10^{-9})^2 + (2.07 \times 10^{-9}\text{N})^2} = 3.01 \times 10^{-9}\text{N}$

At an angle with positive x-axis $\alpha = \tan^{-1}\frac{2.07\times 10^{-9}}{-2.19\times 10^{-9}}$, $\alpha = 136.6°$

16.11. Calculate the electric field halfway between two point charges, one carrying $+10.0\times10^{-9}$ C and the other (a) $+5.0\times10^{-9}$ C at a distance of 20 cm, and (b) -5.0×10^{-9} C at a distance of 20 cm.

Solution:

(a) $E_{net} = E_1 - E_2$

$$E_{net} = k\frac{q_1}{{r_1}^2} - k\frac{q_2}{{r_2}^2} = \frac{k}{r^2}(q_1 - q_2)$$

$$= \frac{9\times10^9}{(10\times10^{-2})^2}(10.0\times10^{-9} - 5.0\times10^{-9}) = 4.5\times10^3\,\text{N/C}$$

(b) $E_{net} = E_1 + E_2$

$$E_{net} = k\frac{q_1}{{r_1}^2} + k\frac{q_2}{{r_2}^2} = \frac{k}{r^2}(q_1 + q_2)$$

$$= \frac{9\times10^9}{(10\times10^{-2})^2}(10.0\times10^{-9} + 5.0\times10^{-9}) = 1.35\times10^4\,\text{N/C}$$

16.13. An electron is released into a uniform electric field of magnitude 1.5×10^3 N/C. Calculate the acceleration of the electron, neglecting gravity.

Solution:

$$F = ma \rightarrow a = \frac{F}{m}$$

$$F_{el} = Ee = (1.5\times10^3\ \text{N/C})(1.6\times10^{-19}) = 2.4\times10^{-16}\,\text{N}$$

$$a = \frac{2.4\times10^{-16}\,\text{N}}{9.11\times10^{-31}\ \text{kg}} = 2.6\times10^{14}\ \text{m/s}^2$$

16.17. In a hydrogen atom, what are the magnitude and the direction of the electric field due to the proton at the location of the electron, which we assume is 5.0×10^{-11} m away from the proton?

Solution:

$$E = k\frac{q}{r^2} = \frac{9\times10^9\times1.6\times10^{-19}}{(5\times10^{-11})^2} = 5.76\times10^{11}\ \mathrm{N/C}$$

16.24. Point charges q_1 = +5 μC and q_2 = −20 μC are fixed in place and separated by a distance L = 1.5 m. At what point or points along the line that passes through both point charges will the electric field be zero?

Solution:

Means that $E_1 = E_2$

The point should be either to the left of the negative charge or to the right of negative charge**.**

When the point distance x left to the positive charge

$\frac{k\times5\times10^{-6}}{x^2} = \frac{\mathrm{k}\times20\times10^{-6}}{(1.5+x)^2}$,by cancelling equal terms from both sides

$5(1.5+x)^2 = 20\,x^2$,dividing both sides by 5

$(1.5+x)^2 = 4\,x^2$,taking the square root of both sides

$1.5 + x = 2x \rightarrow \quad x = 1.5$ m

Therefore this point maybe the left of positive charge or right to the negative charge or vice versa according to the arrangement of the charges

SOL. PROB. OF CHAP. 17: Electric Energy and Potential

17.1. A large number of energetic cosmic-ray particles reach Earth's atmosphere continuously and knock electrons out of the molecules in the air. Once an electron is released, it responds to an electrostatic force that is due to an electric field $\vec{E}$ produced in the atmosphere by other point charges. Near the surface of Earth, this electric field has a magnitude of $|\overrightarrow{E}|$ = 150 N/C and is directed downward, as shown in Fig. 17.30. Calculate the change in electric potential energy of a released electron when it moves vertically upward through a distance *d* = 650 m.

Figure 17.30

Solution:

$\Delta E_{el} = -e|\overrightarrow{E}|\Delta y$

$= (-1.6\text{x}10^{-19}\text{ C})(150\text{ N/C})(650\text{ m})$

$= -1.5\text{x}10^{-14}\text{ J}$

17.5. An ion is accelerated through a potential difference of 60 V, causing a decrease in its electric potential energy of 1.92×10^{-17} J. Calculate the charge the ion carries.

Solution:

$V = E_{el}/q$

$q = E_{el}/V$

$= 1.92 \times 10^{-17}$ J/ 60 $= 3.2 \times 10^{-19}$ C

---

17. 6. Fig. 17.33 shows three positive point charges at the corners of a rectangle. Find the electric potential at the upper right corner if q_1 = +8 μC, q_2 = +2 μC, and q_3 = +4 μC. The distances are d_1 = 6.0 cm and d_2 = 3.0 cm. The potential is defined such that it is 0 V at infinite distance from the point charge arrangement shown.

Figure 17.33

Solution:

$V = (1/4\pi\ \varepsilon_0)(q/r)$

$V = V_1 + V_2 + V_3$

$V_1 = (1/4\pi\ \varepsilon_0)(8\text{x}10^{-6}\text{C}/6\text{x}10^{-2}\ \text{m})$

$V_2 = (1/4\pi\ \varepsilon_0)(2\text{x}10^{-6}\text{C}\ /6.7\text{x}10^{-2}\ \text{m})$

$V_3 = (1/4\pi\ \varepsilon_0)(4\text{x}10^{-6}\text{C}\ /3\text{x}10^{-2}\ \text{m})$

$V = (1/4\pi\ \varepsilon_0)\ [(8\text{x}10^{-6}\text{C}\ /6\text{x}10^{-2}\ \text{m}) + (2\text{x}10^{-6}\text{C}\ /6.7\text{x}10^{-2}\ \text{m}) + (4\text{x}10^{-6}\text{C}\ /3\text{x}10^{-2}\ \text{m})]$

$= 2.66.\ \text{x}10^{6}$ V

17.15. An air-filled parallel plate capacitor has a plate area of 5.0 cm^2 and plate separation of 1.0 mm. It stores a charge of 0.4 nC. (a) What is the potential difference across its plates? (b) What is the magnitude of the electric field between its plates?

Solution:

$A = 5\ cm^2 \quad b = 1mm \quad q = 0.4\ nC \quad V = ?$

(a) $V = q/C = qb/\varepsilon_0 A = (0.4x10^{-9})(10^{-3})/(8.85x10^{-12})(5x10^{-4}) = 90.3\ V$

(b) $E = V/b = 90.3/10^{-3} = 9.3x10^{4}\ V/m$

17.16. An air-filled parallel plate capacitor has a plate area of 2.0 cm^2 and plate separation of 5.0 mm. If a 12.0 V battery is connected to its plates, how much energy does the device store?

Solution:

$E = ½\ qV$

$q = V.C = V\varepsilon_0 A/b = (12)(8.85x10^{-12})(2x10^{-4})/(5x10^{-3}) = 4.25x10^{-12}\ C$

$E = ½\ (42.48x10^{-13})(12) = 2.5\ x10^{-11}\ J$

SOL. PROB. OF CHAP. 18: The Flow of Charges

18.1. All commercial electric devices have identifying plates that specify their electrical characteristics. For example, a typical household device may be specified for a current of 6.0 A when connected to a 120 V source. What is the resistance of this device?

Solution:

$$\Delta V = IR,\ R = \frac{\Delta V}{I} = \frac{120}{6} = 20\Omega$$

18.3. A total charge of 8.0 mC flows through the cross-section of a metallic wire in 4s. What is the current in the wire?

Solution:

$$I = \frac{\Delta Q}{\Delta t} = \frac{8x10^{-3}}{4\ s} = 2\ mA$$

18.5. When used at 120 V, a resistor carries a current of 0.6 A. What current is carried if the potential difference is lowered to 70 V?

Solution:

Using (i) $\Delta V = IR,\ R = \frac{\Delta V}{I} = \frac{120}{0.6} = 200\ \Omega$

Again, (ii) substituting R for I, $I = \frac{\Delta V}{R} = \frac{70}{200} = 0.35\ A = 0.4\ A$

18.7. A potential difference of 12 V causes a current of 0.4 A in a 3.2-m-long metallic wire with uniform radius 4.0 mm. What are (a) the resistance of the wire, and (b) the resistivity of the wire?

Solution:

(a) $\Delta V = IR,\ R = \frac{\Delta V}{I} = \frac{12}{0.4} = 30\ \Omega$

(b) From the radius value, the cross-sectional area A = 50.24×10^{-6} m^2, then,

$$\rho = \frac{RA}{l} = \frac{(30\ \Omega)(50.24)^{-6}}{3.2\text{m}} = 5\times 10^{-4}\ \Omega.\text{m}$$

18.13. You often see birds resting on power lines that carry currents of 50 A. The copper wire on which the bird stands has a radius of 1.1 cm. Assuming that the bird's feet are 4.0 cm apart, calculate the potential difference across its body.

Solution:

From the radius value, the cross-sectional area A = $3.8\text{x}10^{-4}$ m^2, and from the resistivity table, use ρ_{Cu} = ($1.7\text{x}10^{-8}$ Ω m.)

Also, current density J = $\frac{I}{A}$ = 13.16x104 A.m^{-2},

$$E = \rho J = (22.3\times10^{-4}\ \frac{V}{m})$$

$$\Delta V = E.l = (22.3\times10^{-4}\ \frac{V}{m})\ \text{x}\ (4\times10^{-2}) = 89.47\ \mu V = 89\ \mu V$$

SOL. PROB. OF CHAP. 19: The Atom

19.2. A hydrogen atom is in its first excited state (n = 2). Using Bohr's atomic model, calculate (a) the radius of the electron's orbit, (b) the potential energy of the electron, and (c) the total energy of the electron.

Solution:

(a) Radius of the electron's orbit is given by

$$r = n^2 \frac{\varepsilon_0 h^2}{me^2\pi}$$

$$r = n^2 r_{Bohr}$$

$$where\ r_{Bohr} = \frac{\varepsilon_0 h^2}{me^2\pi} = 5.29 \times 10^{-11} m$$

$$For\ n = 2, \mathrm{r} = 2^2 \times 5.29 \times 10^{-11} m$$

$$r = 21.16 \times 10^{-11} m = 0.212\ nm$$

(b) Potential energy of the electron is given by

$$E_{el} = k\frac{q_1 q_2}{r} = k\frac{e^2}{r}$$

$$E_{el} = 9 \times 10^9 \times \frac{(-1.6 \times 10^{-19})(1.6 \times 10^{-19})}{0.212 \times 10^{-9}} = -1.09 \times 10^{-18} J$$

(c) Total energy of the electron is given by

$$E_{total} = \frac{E_{el}}{2} = -5.43 \times 10^{-19} J$$

19.3. The size of Rutherford's atom is about 0.1 nm. (a) Calculate the attractive electrostatic force between an electron and a proton at that distance. (b) Calculate the electrostatic potential energy of that atom. Express the result in unit eV. (c) The size of Rutherford's atomic nucleus is about 1 fm. Calculate the repulsive electrostatic force between two protons at that distance. (d) Calculate the electrostatic potential energy of a pair of protons in such a nucleus. Express the result in unit MeV.

Solution:

(a) The attractive electrostatic force between an electron and a proton separated by 0.1 nm

$$F_{el} = k\frac{|q_1||q_2|}{r^2}$$

$$F_{el} = k\frac{e^2}{r^2}$$

$$F_{el} = 9 \times 10^9 \times \frac{(1.6 \times 10^{-19})^2}{(0.1 \times 10^{-9})^2} N = 2.304 \times 10^{-8} N$$

(b) The electrostatic potential energy for the atom with an electron and a proton separated by 0.1 nm

$$E_{el} = k\frac{q_1 q_2}{r}$$

$$E_{el} = 9 \times 10^9 \times \frac{(-1.6 \times 10^{-19})(1.6 \times 10^{-19})}{0.1 \times 10^{-9}} = -2.304 \times 10^{-18}\mathrm{J}$$

$$Since, 1eV = 1.6 \times 10^{-19} J$$

$$E_{el} = \frac{-2.304 \times 10^{-18}}{1.6 \times 10^{-19}} eV = -14.4\ eV$$

(c) The repulsive electrostatic force between two protons separated by a distance of 1 fm is

$$F_{el} = k\frac{|q_1||q_2|}{r^2} = k\frac{e^2}{r^2}$$

$$F_{el} = 9 \times 10^9 \times \frac{(1.6 \times 10^{-19})^2}{(1 \times 10^{-15})^2} = 230.4 \text{ N}$$

(d) The electrostatic potential energy of a pair of protons separated by a distance of 1 fm is

$$E_{el} = k\frac{e^2}{r} = 9 \times 10^9 \times \frac{(1.6 \times 10^{-19})^2}{1 \times 10^{-15}} = 2.304 \times 10^{-13}\text{J}$$

$$Since, 1eV = 1.6 \times 10^{-19}\text{J}$$

$$E_{el} = \frac{2.304 \times 10^{-13}}{1.6 \times 10^{-19}} eV = 1440000\ eV = 1.44 \text{ MeV}$$

19.4. Calculate the electric force on the electron in the ground state of the hydrogen atom.

Solution: For an electron in the ground state of the hydrogen atom (i.e. n=1) the electric force between electron and the proton in the nucleus is given by

$$F_{el} = k\frac{|q_1||q_2|}{r^2} = k\frac{e^2}{r_{Bohr}^2}$$

$$F_{el} = 9 \times 10^9 \times \frac{(1.6 \times 10^{-19})^2}{(5.29 \times 10^{-11})^2} = 8.23 \times 10^{-8}\text{N}$$

19.5. What is the wavelength of light that can cause a transition of an electron in the hydrogen atom from the orbit with n = 3 to n = 5?

Solution:

$$Frequency\ of\ the\ light, f = R_H\left|\frac{1}{n_i^2} - \frac{1}{n_f^2}\right|$$

$$f = 3.29 \times 10^{15} \times \left|\frac{1}{3^2} - \frac{1}{5^2}\right| = 2.34 \times 10^{14}\text{Hz}$$

$$Wavelength, \lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.34 \times 10^{14}} = 1.28 \times 10^{-6}\text{m} = 1280 \text{ nm}$$

19.7. Calculate the wavelength of an electron in a hydrogen atom that is in the orbit with n = 3.

Solution:

Two ways to find the wavelength of an electron:

1) $n\lambda = 2\pi r$

$$For\ n = 3,\ \ r = n^2 r_0\ \rightarrow r = 9\ \times (5.29\times10^{-11}) = 4.761 \times 10^{-10}\text{m}$$

$$\lambda = \frac{2\pi\ (4.761 \times 10^{-10})}{3} = 9.99 \times 10^{-10}\text{m} = 0.999\ \text{nm}$$

OR

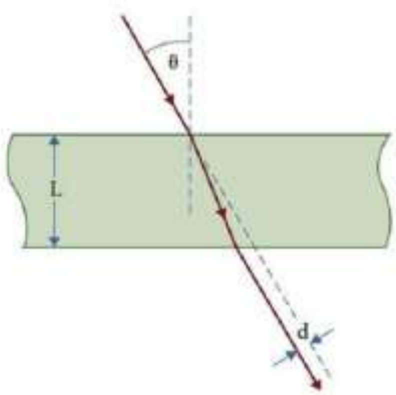
2) $\lambda = \frac{h}{\sqrt{2mE_{Kin}}}$

$$For\ n = 3, \qquad E_{kin} = k\frac{|q_1||q_2|}{2r} = 9 \times 10^9 \times \frac{(1.6 \times 10^{-19})^2}{2 \times 4.761 \times 10^{-10}} = 2.42 \times 10^{-19}\text{J}$$

$$\lambda = \frac{h}{\sqrt{2mE_{Kin}}} = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 2.42 \times 10^{-19}}} = 9.99 \times 10^{-10}\text{m} = 0.999\ \text{nm}$$

SOL. PROB. OF CHAP. 21: Geometric Optics

21.5. A light ray strikes a flat, L=2.0-cm-thick block of glass (n=1.5) in Fig. at an angle of $\theta = 30°$ with the normal. (a) find angles of incidence and refraction at each surface. (b) Calculate the lateral shift of the light ray d?



$$n_{air} Sin\theta_{air} = n_{glass} Sin\theta_{glass}$$

$$Glass\ thickness\ L, n_{air} = 1, n_{glass} = 1.5, \theta_{air} = 30°$$

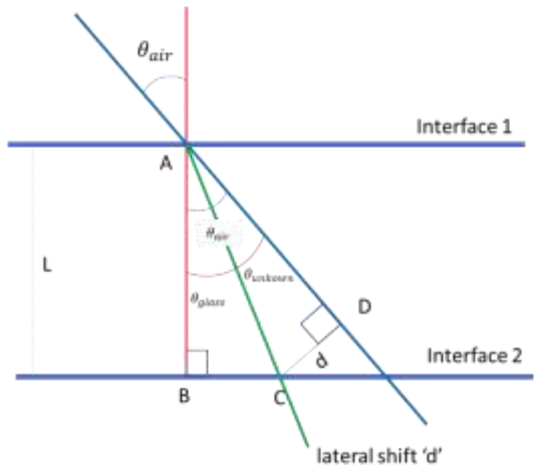
(a) At the first interface from air to glass

$$Sin\theta_{glass} = \frac{n_{air}}{n_{glass}} Sin\theta_{air}$$

$$Sin\theta_{glass} = \frac{1}{1.5} Sin30° = 0.333$$

$$\theta_{glass} = Sin^{-1}(0.333) = 19.5°$$

(b) As illustrated in the geometry of Fig below.



$$\theta_{air} = \theta_{glass} + \theta_{unknown}$$

$$\theta_{air} - \theta_{glass} = \theta_{unknown}$$

$$\theta_{unknown} = 30^{\circ} - 19.5^{\circ} = 10.5^{\circ}$$

From triangle ABC

$$Cos\theta_{glass} = \frac{AB}{AC} = \frac{2}{AD} \text{ (Where AC=AD)}$$

$$AD = \frac{2}{Cos19.5°} = 2.12 \text{ cm}$$

From triangle ACD

$$Sin\theta_{unknown} = \frac{CD}{AD} = \frac{d}{AD} \ (Where\ CD = d)$$

$$d = ADSin\theta_{unknown} = 2.12\ Sin10.5^{\circ} = 0.39 \text{ cm}$$

21.7. A light ray travels through air and then strikes the surface of mineral oil at an angle of 23.1° with the normal to the surface. What is the angle of refraction if the light ray travels at 2.17 ×10^8 m/s through the oil?

$$n_{air} Sin\theta_i = n_{oil} Sin\theta_r$$

$$\theta_i = 23.1°$$

$$\theta_r = ?$$

$$n_{air} = 1$$

$$n_{oil} = \frac{c}{v} = \frac{3 \times 10^8}{2.17 \times 10^8} = 1.382$$

$$Sin\theta_r = \frac{n_{air}}{n_{oil}} Sin\theta_i$$

$$Sin\theta_r = \frac{1}{1.382} Sin 23.1° = \frac{0.392}{1.382}$$

$$\theta_r = Sin^{-1}(0.2836) = 16.5^{\circ}$$

21.11. A light ray is incident from air onto a glass surface with index of refraction n = 1.56. Find the angle of incidence for which the corresponding angle of refraction is one- half the angle of incidence. Both angles are defined with the normal to the surface.

$$n_{air} Sin\theta_i = n_{glass} Sin\theta_r$$

$$n_{air} = 1, n_{glass} = 1.56$$

$$\theta_i = ?, \theta_r = \frac{\theta_i}{2}, or\ \theta_i = 2\theta_r$$

$$Sin\theta_i = \frac{n_{glass}}{n_{air}} Sin\theta_r$$

$$Sin2\theta_r = \frac{n_{glass}}{n_{air}} Sin\theta_r = \frac{1.56}{1} Sin\theta_r = 1.56 Sin\theta_r$$

$$2 Sin\theta_r Cos\theta_r = 1.56 Sin\theta_r$$

$$Cos\theta_r = \frac{1.56}{2} = 0.78$$

$$\theta_r = Cos^{-1}(0.78) = 38.7^{\circ}$$

$$\theta_i = 2\theta_r = 2(38.7^{\circ}) = 77.4^{\circ}$$

21.13. A converging lens has a focal length f = 20.0 cm. Locate the images for the object distances given below. For each case state whether the image is real or virtual and upright or inverted, and finds the magnification. (a) 40 cm; (b) 20 cm; (c) 10 cm.

Converging lens

$f = 20.0\ cm, q = ?$ (Image)

(a) $p = 40\ cm$ (Object)

$$\frac{1}{f} = \frac{1}{q} + \frac{1}{p}$$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p}$$

$$q = \frac{fp}{p - f}$$

$$q = \frac{20 \times 40}{40 - 20} = \frac{800}{20} = +40cm$$

$$Magnification, M = -\frac{q}{p} = -\frac{40}{40} = -1.0 (image\ is\ real\ and\ inverted)$$

(b) $$p = 20\ cm$$

$$q = \frac{fp}{p-f} = \frac{20 \times 20}{20-20} = \frac{400}{\infty} = \infty$$

$$No\ image\ is\ formed, light\ rays\ travel\ parallel\ to\ each\ other$$

(c) $$p = 10\ cm$$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} \rightarrow \frac{1}{q} = \frac{1}{20} - \frac{1}{10} = \frac{-10}{200}$$

$q = -20$ cm , the negative value indicates that image is virtual and upright

$$Magnification, M = -\frac{q}{p} = -\frac{-20}{10}$$
$$= +2.0, hence, the\ image\ height\ \ is\ two\ times\ larger\ than\ the\ object\ height$$

21.17. A contact lens is made of plastic with an index of refraction of n = 1.58. The lens has a focal length of *f* = +25.0 cm and its inner surface has a radius of curvature of +22.0 mm. What is the radius of curvature of the outer surface?

$$Focal\ length\ and\ refractive\ index\ of\ a\ contact\ lens$$

$$f = +25.0\ cm, n = 1.58$$

Radius of curvature of the inner surface $R_2 = +22.0\ mm = +2.2\ cm$

Radius of curvature of the outer surface $R_1 =?$

Combination of thin lens formula and lens maker formula

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

Rearranging the above equation

$$\frac{1}{R_1} = \frac{1}{(n-1)}\left[\frac{1}{f} + \frac{(n-1)}{R_2}\right]$$

$$\frac{1}{R_1} = \frac{1}{(n-1)}\left[\frac{R_2 + f(n-1)}{fR_2}\right]$$

$$R_1 = \frac{R_2 f(n-1)}{R_2 + f(n-1)}$$

$$R_1 = \frac{(0.58)(25)(2.2)}{2.2 + 25(0.58)} = \frac{31.9}{16.7} = +1.9\ cm$$

SOL. PROB. OF CHAP. 22: The Atomic Nucleus

22.2. The nucleus of the deuterium atom consists of one proton and one neutron. What is the binding energy of this nucleus if the mass of the deuterium nucleus is given as 2.014102 u? Note that the atomic unit u has a value u = $1.6605677 \times 10^{-27}$ kg.

Solution:

$m(^2H)c^2 = m(p)c^2 + m(n)c^2 - B.E(^2H)$

$m(p) = 1.6736x10^{-27}$ kg, $m(n) = 1.6750x10^{-27}$ kg, $m(^2H) = 3.3446x10^{-27}$ kg

$B.E(^2H) = 4x10^{-30}$ kg.c^2 = 2.24 MeV (1 MeV/c^2 = $1.783x10^{-30}$ kg)

22.3. Nuclear waste from power plants may contain ^{239}Pu, a plutonium isotope with a half-life of 24000 years. How long does it take for the stored waste to decay to 10% of its current activity level?

Solution:

$A(t) = A_0e^{-\lambda t} = A_0/10$ and $\lambda = \ln(2)/T_{1/2}$

$t = (\ln(10)/\ln(2)) \times T_{1/2}$

t = 79726 years

22.7. Calculate the mass of the neutron produced during the reaction $^{11}_{5}B + ^{4}_{2}He \rightarrow ^{14}_{7}N + ^{1}_{1}n^0$. In order to find the mass of the neutrons, you are given the masses of boron, nitrogen, and alpha particle, which are 11.01280 amu, 14.00752 amu, and 4.00387 amu, respectively. Moreover, you are also given the kinetic energy of the incident α-particle, 5.250 MeV. The energies of the resultant neutron and nitrogen atom are to be 3.260 MeV and 2.139 MeV.

Solution:

Conservation of energy:

$m(^{11}B)c^2 + m(^4He)c^2 + K.E(^4He) = m(^{14}N)c^2 + m(n)c^2 + K.E(^{14}N) + K.E(n)$

$m(n)c^2 = m(^{11}B)c^2 + m(^4He)c^2 - m(^{14}N)c^2 + K.E(^4He) - K.E(^{14}N) - K.E(n)$

$1\ amu = 935.5\ MeV/c^2$

$m(n) = 1.00899\ amu$

22.12. The activity of a radioisotope is found to decrease by 40% of its original value in 20 days. (a) Calculate the decay constant. (b) What is the half-life?

Solution:

a) $A(t) = A_0 e^{-\lambda t}$ at t = 20 days, $A(t) = (6/10) x A_0$

$\lambda = \ln(10/6)/t$

$\lambda = 2.95x10^{-7}\ s^{-1}$

b) $T_{1/2} = \ln(2)/\lambda = 27.18$ days
