Important Formulas and Values

$$\text{The electric force, } F = k_e \frac{|q_1||q_2|}{r^2}, k_e = 8.99 \times 10^9 \text{ Nm}^2\text{C}^{-2}$$

$$\text{The gravitational force, } F_g = G\frac{m_1 m_2}{r^2}, G = 6.67 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2}$$

$$\text{The electric field, } \vec{E} = \frac{\vec{F}}{q_0} = k_e \frac{|q|}{r^2}$$

Quick Quiz

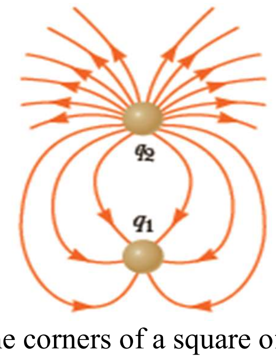
Quick Quiz 15.2 Object A has a charge of $+2\mu C$ and object B has a charge of $+6\mu C$. Which statement is true? (a) $\vec{F}_{AB} = -3\vec{F}_{BA}$ (b) $\vec{F}_{AB} = -\vec{F}_{BA}$ (c) $\overrightarrow{3F}_{AB} = -\vec{F}_{BA}$

Example

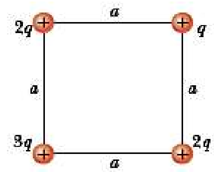
Example 15.1 The electron and proton of a hydrogen atom are separated (on the average) by a distance of about 5.3×10^{-11} m. (a) Find the magnitudes of the electric force and the gravitational force that each particle exerts on the other, and the ratio of the electric force F_e to the gravitational force F_g . (b) Compute the acceleration caused by the electric force of the proton on the electron. Repeat for the gravitational acceleration. ($F_e = 8.2 \times 10^{-8}\ N,\ F_g = 3.6 \times 10^{-47}\ N,\ a_e = 9 \times 10^{22}\ ms^{-2}, a_g = 4 \times 10^{-17}\ ms^{-2}$)

Problems

Problem 18.6 Figure shows the electric field lines for two point-charges separated by a small distance. (a) Determine the ratio q_1/q_2. (b) What are the signs of q_1 and q_2? ($\frac{q_1}{q_2} = -\frac{1}{3}$)

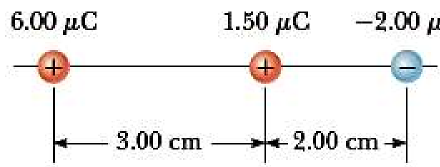


Problem 6 Four point charges are at the corners of a square of side a as shown in Figure. Determine the magnitude and direction of the resultant electric force on q, with k_e , q, and a left in symbolic form. ($F = 4.33\ k_e \frac{q^2}{a^2}, \theta = 45°\ above + x\ axis$)



Problem 25. A proton accelerates from rest in a uniform electric field of 640 N/C. At some later time, its speed is 1.20×10^6 m/s. (a) Find the magnitude of the acceleration of the proton. (b)How long does it take the proton to reach this speed? (c) How far has it moved in that interval? (d) What is its kinetic energy at the later time? ($a = 6.12 \times 10^{10}\ ms^{-2},\ \Delta t = 1.96 \times 10^{-5} ms^{-1}, \Delta x = 11.8\ m, KE = 1.2 \times 10^{-15} J$)

Problem 18. Determine the electric field strength at a point 1.00 cm to the left of the middle charge shown in Figure. (b) If a charge of $-2.00\ \mu$C is placed at this point, what are the magnitude and direction of the force on it? ($E = 2 \times 10^7\ NC^{-1}$ $to\ the\ right, \vec{F} = 40\ N\ to\ the\ left$)



Important Formulas and Values

The electric current, $I \equiv \frac{\Delta Q}{\Delta t} = nqv_d A$

Number of electrons, $N = \frac{\Delta Q}{q_e}$

The resistance, $R \equiv \frac{\Delta V}{I} = \rho \frac{l}{A}$

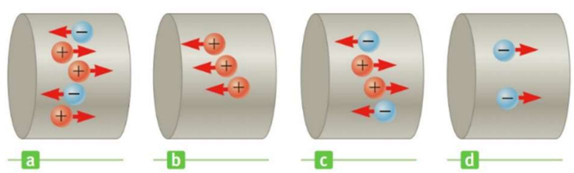
Temperature variation, $R = R_0[1 + \alpha(T - T_0)]$

Electrical power, $P = I\Delta V = I^2 R = \frac{\Delta V^2}{R}$

$1\text{kWh} = 3.6 \times 10^6 \text{J}$

Quick Quiz

Quick Quiz 17.1 Consider positive and negative charges all moving horizontally with the same speed through the four regions in Figure 17.2. Rank the magnitudes of the currents in these four regions from lowest to highest. (I_a is the current in Figure 17.2a, I_b the current in Figure 17.2b, etc.) (a) I_d, I_a, I_c, I_b (b) I_a, I_c, I_b, I_d (c) I_c, I_a, I_d, I_b (d) I_d, I_b, I_c, I_a (e) I_a, I_b, I_c, I_d (f) none of these.



Quick Quiz 17.9 Two resistors, A and B, are connected in a series circuit with a battery. The resistance of A is twice that of B. Which resistor dissipates more power? (a) resistor A does (b) resistor B does (c) more information is needed

Problems

Problem 5 If a current of 80.0 mA exists in a metal wire, (a) how many electrons flow past a given cross section of the wire in 10.0 min? (b) In what direction do the electrons travel with respect to the current? ($N = 3 \times 10^{20} \bar{e}$)

Problem 6 A copper wire has a circular cross section with a radius of 1.25 mm. (a) If the wire carries a current of 3.70 A, find the drift speed of electrons in the wire. (Take the density of mobile charge carriers in copper to be $n = 1.10 \times 10^{29}$ electrons/m3.) (b) For the same wire size and current, find the drift speed of electrons if the wire is made of aluminum with n = 2.11×10^{29} electrons/m3. ($v_d = 4.29 \times 19^{-5}\ ms^{-1}, v_d = 2.24 \times 10^{-5}\ ms^{-1}$)

Problem 25 At 20.0°C, the carbon resistor in an electric circuit connected to a 5.0 V battery has a resistance of $2.0 \times 10^2\ \Omega$. What is the current in the circuit when the temperature of the carbon rises to 80.0°C? ($\alpha = -0.5 \times 10^{-3}{}^\circ C^{-1}$) ($R = 194\ \Omega, I = 0.0257\ A$)

Problem 34 A length of aluminium wire has a resistance of 30.0 Ω at 20.0°C. When the wire is warmed in an oven and reaches thermal equilibrium, the resistance of the wire increases to 46.2 Ω. (a) Neglecting thermal expansion, find the temperature of the oven. (b) Qualitatively, how would thermal expansion be expected to affect the answer? ($\alpha = 3.9 \times 10^{-3}{}^\circ C^{-1}$) ($T = 1.6 \times 10^2$ ℃)

Important Formulas and Values

Resistors in series, $R_{eq} = R_1 + R_2 + R_3 + \cdots + R_n$

Resistors in parallel, $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}$

emf, $\Delta V = \varepsilon - Ir$

$Kirchhoff's\ Current\ Rule, \sum_{junc} I = 0$

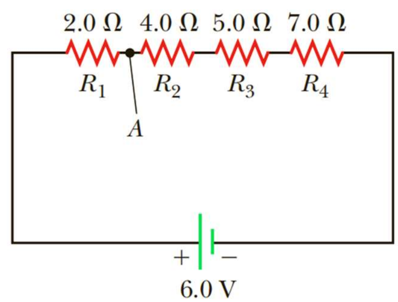
$Kirchhoff's\ Voltage\ Rule, \sum \Delta V = 0$

Quick Quiz

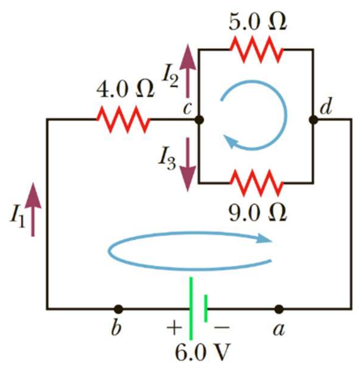
Quick Quiz 18.1 While discharging, the terminal voltage of a battery can never be greater than the emf of the battery, true or false?

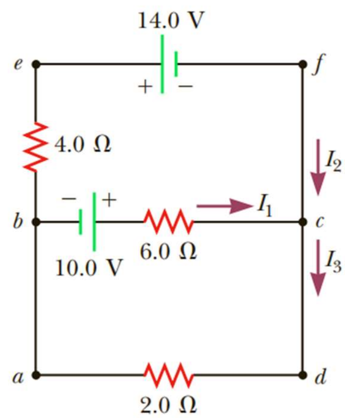
Example

Example 18.1 Four resistors are arranged as shown in the figure. Find (a) the equivalent resistance of the circuit and (b) the current in the circuit if the closed-circuit terminal voltage of the battery is 6.0 V. (c) Calculate the electric potential at point A if the potential at the positive terminal is 6.0 V. (d) Suppose the open circuit voltage, or emf ε, is 6.2 V. Calculate the battery's internal resistance. (e) What fraction f of the battery's power is delivered to the load resistors? ($R_{eq} = 18\ \Omega, I = 0.33\ A$, $V_A = 5.3\ V,\ r = 0.6\ \Omega, \frac{P_{delivered}}{P_{load}} = 0.97$)



Example 18.4 Find the currents in the circuit shown in the first figure by using Kirchhoff's rules. ($I_1 = 0.83\ A,\ I_2 = 0.53\ A,\ I_3 = 0.3\ A$)





Example 18.5 Find I_1, I_2, and I_3 in the second figure. ($I_1 = 2\ A,\ \ I_2 = -3\ A,\ \ I_3 = -1\ A$)

Problems

Problem 8 Three 9 Ω resistors are connected in series with a 12-V battery. Find (a) the equivalent resistance of the circuit and (b) the current in each resistor. (c) Repeat for the case in which all three resistors are connected in parallel across the battery. ($R_{eq} = 27\ \Omega, I = 0.44\ A, I_1 = I_2 = I_3 = 1.33\ A$)

Important Formulas and Values

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}, \qquad \Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}}$$

$$\text{Capacitive reactance}, X_C = \frac{1}{2\pi f C},$$

$$\text{Inductive reactance}, X_L = 2\pi f L$$

$$\text{The impedance}, Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\text{The phase angel}, \phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

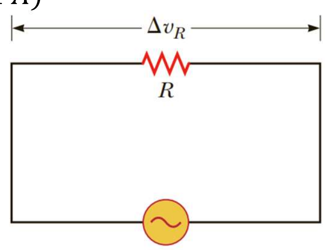
$$\text{The average power}, P_{av} = I_{rms}\Delta V_{rms}\cos\phi = i^2 R = I_{rms}^2 R$$

Quiz Question

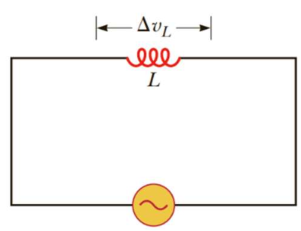
Question 21.3 True or False: A larger inductance or frequency results in a larger inductive reactance.

Example

Example 21.1 An AC voltage source has an output of $\Delta v = (2 \times 10^2\ V)\sin 2\pi f t$. This source is connected to a $1 \times 10^2\ \Omega$ resistor as in the figure. Find the rms voltage and rms current in the resistor. ($\Delta V_{rms} = 141\ V,\ I_{rms} = 1.41\ A$)



Example 21.3 In a purely inductive AC circuit in the figure, $L = 25.0\ mH$ and the rms voltage is $1.50 \times 10^2\ V$. Find the inductive reactance and rms current in the circuit if the frequency is 60.0 Hz. ($X_L = 9.42\ \Omega,\ I_{rms} = 15.9\ A$)



Example 21.4 A series RLC AC circuit has resistance $R = 2.5 \times 10^2\ \Omega$, inductance $L = 0.6\ H$, capacitance $C = 3.5\ \mu F$, frequency of $f = 60\ Hz$, and maximum voltage $\Delta V_{max} = 1.5 \times 10^2\ V$. Find (a) the impedance of the circuit, (b) the maximum current in the circuit, (c) the phase angle, and (d) the maximum voltages across the elements. ($Z = 588\ \Omega,\ I_{max} = 0.255\ A,\ \phi = -64.8°$, $\Delta V_{R,max} = 63.8\ V,\ \Delta V_{L,max} = 57.6\ V,\ \Delta V_{C,max} = 193\ V$)

Problems

Problem 2 A certain lightbulb is rated at 60.0 W when operating at an rms voltage of 120 V. (a) What is the peak voltage applied across the bulb? (b) What is the resistance of the bulb? (c) Does a 100. - W bulb have greater or less resistance than a 60.0 - W bulb? Explain. ($\Delta V_{max} = 170\ V$, $R = 240\ \Omega$)

Important Formulas and Values

Young's Double-Slit Experiment

$$\delta = d\sin\theta_{bright} = m\lambda \ (m = 0, \pm1, \pm2, \ldots)$$

$$\delta = d\sin\theta_{dark} = \left(m + \frac{1}{2}\right)\lambda \ (m = 0, \pm1, \pm2, \ldots)$$

$$y_{bright} = \frac{\lambda L}{d}m, \qquad y_{dark} = \frac{\lambda L}{d}\left(m + \frac{1}{2}\right)$$

Single-Slit Diffraction

$$\sin\theta_{dark} = \frac{m\lambda}{a} \ (m = \pm1, \pm2, \ldots)$$

Diffraction Grating

$$d\sin\theta_{bright} = m\lambda \ (m = 0, \pm1, \pm2, \ldots)$$

$$d = \frac{1}{amount\ in\ lines\ per\ cm}$$

$$\tan\theta = \frac{y}{L}$$

Example

Example 24.1 A screen is separated from a double-slit source by 1.20 m. The distance between the two slits is 0.030 0 mm. The second-order bright fringe ($m = 2$) is measured to be 4.50 cm from the centerline. Determine (a) the wavelength of the light and (b) the distance between adjacent bright fringes. ($\lambda = 5.63 \times 10^{-7}\ m, \Delta y = 2.25 \times 10^{-2}\ m$)

Example 24.6 Light of wavelength 5.8×10^2 nm is incident on a slit of width 0.300 mm. The observing screen is placed 2.00 m from the slit. Find the positions of the first dark fringes and the width of the central bright fringe. ($y_1 = \pm3.86 \times 10^{-3}\ m, width = 7.72 \times 10^{-3}\ m$)

Example 24.7 Monochromatic light from a helium–neon laser ($\lambda = 632.8$ nm) is incident normally on a diffraction grating containing 6.00×10^3 lines/cm. Find the angles at which one would observe the first - order maximum, the second-order maximum, and so forth. ($\theta_1 = 22.3°, \theta_2 = 49.3°, no\ solution\ for\ \theta_3$)

Problems

Problem 3 A laser beam is incident on two slits with a separation of 0.200 mm, and a screen is placed 5.00 m from the slits. If the bright interference fringes on the screen are separated by 1.58 cm, what is the wavelength of the laser light? ($\lambda = 632\ nm$)