

Exam 2 Solutions

1. (*WebAssign 26.6*) A current of 1.5 A flows in a copper wire with radius 1.25 mm. If the current is uniform, what is the electron drift speed in m/s? Copper has a density of 8960 kg/m^3 , atomic mass of 63.54 and one conduction electron per atom.

- (1) 2.2×10^{-5}
- (2) 3.6×10^{-4}
- (3) 5.4×10^{-3}
- (4) 7.4×10^{-4}
- (5) 3.0×10^{-5}

The current density j is given by $j = i / \pi r^2 = en_e v_d$, where n_e is the conduction electron density and v_d is the drift velocity. The electron number density for copper is the same as the atomic density since there is one conduction electron per atom. That calculation gives the electron number density $n_e = \rho_{\text{Cu}} N_0 / 10^{-3} \text{ A} = 8960 \times (6.02 \times 10^{23}) / 0.06354 = 8.49 \times 10^{28} / \text{m}^3$, where the factor of 10^{-3} is the conversion from g to kg in the atomic mass. Using $j = i / \pi r^2$, we obtain $v_d = 2.2 \times 10^{-5} \text{ m/s}$.

2. (*WebAssign 26.41*) A heating element is made by maintaining a potential difference of 60.0 V along the length of a Nichrome wire with radius 0.945 mm and a resistivity of $5.00 \times 10^{-7} \Omega \text{ m}$. If the element dissipates 5000 W, what is its length in m?

- (1) 4.0
- (2) 5.2
- (3) 2.2
- (4) 0.56
- (5) 0.22

The power dissipated is $P = i^2 R = V^2 / R$, where $R = \rho L / A$, ρ is the resistivity, L is the length and $A = \pi r^2$ is the cross sectional area. Putting in all the numbers yields $L = 4.0 \text{ m}$.

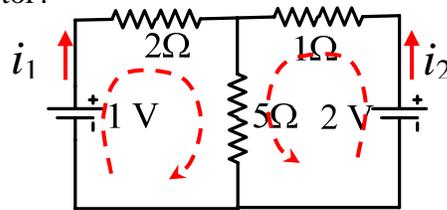
3. (*WebAssign 27.47*) A 18.0Ω resistor and a capacitor are connected in series and then a 13.0 V potential difference is suddenly applied across them. The potential difference across the capacitor rises to 7.00 V in $1.50 \mu\text{s}$. What is the capacitance in μF ?

- (1) 0.11
- (2) 2.3
- (3) 4.5
- (4) 6.8
- (5) 1.9

The voltage across an initially uncharged capacitor is $V(t) = V_0(1 - e^{-t/RC})$, where $V_0 = 13$ is the applied voltage. Rearranging yields the equation $\exp(-1.5 \times 10^{-6} / RC) = 1 - V / V_0 = 0.462$. Taking the log of both sides and solving for C yields $C = 0.11 \mu\text{F}$.

4. (*WebAssign 27.33*) Consider the circuit shown in the accompanying figure. What is the power dissipated (in watts) in the 5Ω resistor?

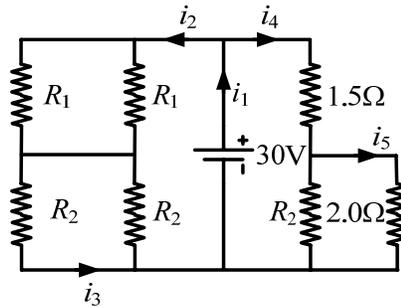
- (1) 0.43
- (2) 0.11
- (3) 0.28
- (4) 2.35
- (5) 0.069



The two equations from Kirchoff's rules are $1 - 2i_1 - 5(i_1 + i_2) = 0$ and $2 - i_2 - 5(i_1 + i_2) = 0$. Solving yields $i_1 + i_2 = 5/17 = 0.294 \text{ A}$. So the power is $0.294^2 \times 5 = 0.43 \text{ W}$.

5. (*WebAssign 27.77*) Consider the circuit shown in the accompanying figure, where $R_1 = 13.0 \Omega$ and $R_2 = 7.5 \Omega$. What is the current i_4 in A?

- (1) 9.74
- (2) 2.93
- (3) 1.46
- (4) 7.69
- (5) 12.2



The branch on the RHS of the battery involves a resistor of 1.5Ω in series with two resistors of 7.5Ω and 2.0Ω , yielding a total resistance of 3.079Ω . The voltage across this branch is $30V$, so the current is $30 / 3.079 = 9.74 A$.

6. (*Chapter problem 28.9*) A positive ion with a charge of $+2e$, traveling at 3.4 km/s in the x direction, enters a region of uniform magnetic field $B = 2.5 \text{ T}$, which points in the y direction. In order to force the ion to travel on a straight trajectory, how large an electric field (in V/m) has to be applied in the $-z$ direction?

- (1) 8.50×10^3
- (2) 1.36×10^{-3}
- (3) 5.31×10^{10}
- (4) 1.96×10^1
- (5) 3.27×10^6

To balance the forces, we must have $qE = qvB$, or $E = vB = 8500 \text{ V/m}$.

7. (*Like chapter problem 28.15*) In a uniform magnetic field, an electron undergoes a circular motion with a kinetic energy of 400 eV . The radius of the orbit is 5.0 mm . What is the magnetic field in T ?

- (1) 1.35×10^{-2}
- (2) 3.20×10^{-4}
- (3) 1.28×10^{-7}
- (4) 3.52×10^{-5}
- (5) 2.96×10^{-3}

The equation describing circular motion is $mv^2 / R = qvB$ or $B = mv / qR$. The kinetic energy K is $K = \frac{1}{2}mv^2$, so we can write $mv = \sqrt{2mK}$ and thus $B = \sqrt{2mK} / qR$. Using $K = 400 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-17} \text{ J}$ and the values for the electron charge and mass, we get $B = 0.0135 \text{ T}$.

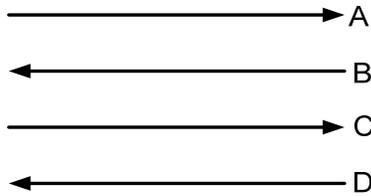
8. (*Lecture problem*) A uniform current flows in a long straight copper wire whose radius is 5.0 mm. Inside the wire, at a distance of 1.0 mm from its center, the magnetic field due to the current is 3.0×10^{-4} T. What is the current in A?

- (1) 37.5
- (2) 260
- (3) 105
- (4) 65.0
- (5) 18.5

From Ampere's law, $B(2\pi r) = \mu_0 i_{enc}$, where i_{enc} is the enclosed current. Solving for i_{enc} yields $i_{enc} = 1.5$ A. Since the current is uniform throughout the wire cross section, the total current i can be found from the ratio of areas or $i = 5^2 \times i_{enc} = 37.5$ A.

9. (*WebAssign 29-29*) Four long parallel wires are arranged on a plane, as shown in the attached figure, with 2.0 cm gaps between them. Each wire carries a 3.0 A current in the direction indicated by the arrow. On the wire labeled C, what is the magnetic force per meter in N/m?

- (1) 4.5×10^{-5}
- (2) 1.4×10^{-4}
- (3) 3.0×10^{-3}
- (4) 2.3×10^{-4}
- (5) 6.5×10^{-2}



We first note that wire C is repelled from both B and D, so there is no net effect from them. The only net force is with A. A quick calculation yields the value of the force per unit length as

$$F/L = \mu_0 i_A i_C / 2\pi d = (4\pi \times 10^{-7}) \times 3 \times 3 / (2\pi \times 0.04) = 4.5 \times 10^{-5} \text{ N/m.}$$

10. (*Chapter problem 29.53*) A wire carrying a 4.0 A current forms a circular loop, 5.0 mm in radius. At the center of the loop is a very tiny current loop, radius 98 nm and current 1 μ A, oriented perpendicular to the direction of the magnetic field produced by the larger loop. What is the torque on the smaller loop in N m?

- (1) 1.5×10^{-23}
- (2) 1.2×10^{-19}
- (3) 7.5×10^{-20}
- (4) 6.1×10^{-21}
- (5) 0

The torque τ is $\tau = \mu B$, where μ is the dipole moment of the inner current and B is the B field generated by the outer current near the center. Here $\mu = A_{\text{in}} i_{\text{in}} = \pi r_{\text{in}}^2 i_{\text{in}}$ and $B = \mu_0 i_{\text{out}} / 2r_{\text{out}}$, where “in” and “out” refer to the respective loops. Solving yields $\tau = 1.5 \times 10^{-23}$ N m.