Electricity and Magnetism Crash Course Example Problems

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Contents

All problems from Eighth edition of Serway and Jewett

1 The Electric Field

Fields, charges and forces

Consider two point charges q_1 and q_2 in empty space and some other point A that is an arbitrary distance away from the charges

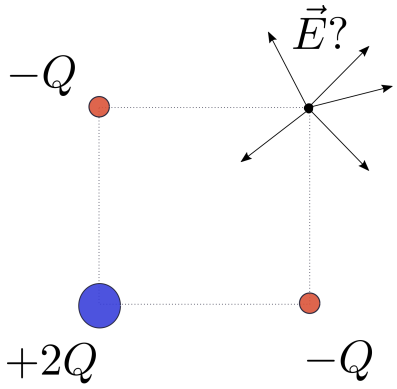
(a) Is there an electric field at A?

(b) Does charge exist at the point A?

(c) Does a force exist at the point A?

Charges on a square

There is a charge $+2Q$ in one corner and charges -Q on opposite corners of a square as in the figure below. What direction does the electric field point on the unoccupied corner?



What is the Force?

There is a charge of -3.00nC at postion (0m, -0.100m) on the cartesian plane and another charge of 6.00nC at position (0.300m, 0m) on the plane.

(a) What is the electric field from these two charges at the origin?

(b) If there was a particle of charge 5.00nC at the origin what would be the force on the particle?

2 Gauss's Law

Flux through a Box

There is a cubic box of side length l in an constant electric field $\vec{E}(x, y, z) = E_0\hat{x}$. What is the total electric flux over the surface of the box?

(a) Calculate using the definition of the flux

(b) How could you find the result using Gauss's law?

What's Coulomb's Law Again?

Using Gauss's Law to find the electric field from a point charge of charge Q.

Infinite charged plate

Given a surface charge density of σ on inifinite plate. What is the electric field a distance d away from the plate?

Infinite charged wire

Given a charged wire with charge density λ, what is the electric field a distance r away from the axis of the wire?

3 Electric Potential and Potential Energy

Charge Triangle

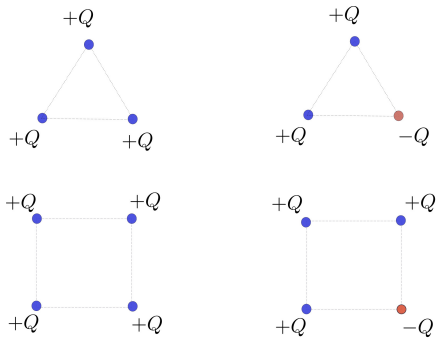
Three charges are localed on the corners of an equalateral triangle with edges of length d. Two charges of of charge $+Q$ and one is of charge $+2Q$.

(a) What is the electric potential at the centre of the triangle?

(b) What is the total potential energy of the triangle?

Rank the Energies

Rank the electric potential energy of the following configurations from highest to lowest:



Two Charges

Two particles, one of charge -15.0nC and one of 27.0nC are seperated by a distance $d = 2.00cm$.

(a) What is the electric potential at the midpoint between the two particles?

(b) If the particles form the base of an equilateral triangle, what is the electric potential at the tip of the triangle?

4 Conductors and Insulators

Conductors

- Can the electric field inside of a conductor be non-zero?
- Can the electric potential inside of a conductor be non-zero?
- What is electrostatic equilibrium?
- Where do excess charges reside on conductors?

Insulators

- Are insulators always in electrostatic equilibrium?
- Where are charges allowed to reside in insulating materials?
- Can the elctric field inside of an insulator be non-zero?
- Can the electric potential inside of an insulator be non-zero?

5 Capacitance and Dielectrics

Spherical Capacitor

A spherical capacitor consists of two concentric spherical shells. The inner shell has charge $+Q$ and the outer shell has charge $-Q$.

(a) What is the capacitance of the spherical capacitor?

(b) What is the total potential energy of the spherical capacitor?

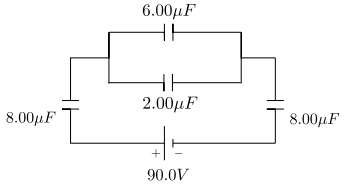
Two charged shells in such a configuration are very unstable. To keep the charged shells from colliding if nudged, we'll fill the space between the shells with Bakelite. Bakelite is a strong plastic dielectric with a dielectric constant of $\kappa = 4.9$.

(c) What is the new capacitance of the spherical capacitor?

(d) What is the new potential energy stored by the capacitor? (Hint: the stored charge does not change!)

Equivalent Capacitance

Look the following circuit diagram and compute the following:



(a) What is the equilvalent capacitance of the circuit?

(b) What is the charge on each capacitor?

(c) What is the potential difference across each capacitor?

6 Current and Resistance

Temperature Coefficient of Resistivity

A wire has resistance of 10.0Ω at 20.0^oC and a resistance of 10.6Ω at 90.0^oC. What is the resistance of this wire when the its temperature is -20.0^oC?

(a) 0.700Ω

(b) 9.66Ω

(c) 10.3Ω

(d) 13.8Ω

(e) 6.59Ω

Current in a Cone

A conductor in the shape of a cone is carrying a current along it. At a point on the cone where the radius is 0.400cm the total current is 5.00A. What is the current density at this point? Further along the cone, the radius has increased. Is the current larger, smaller or the same at this point? What about the current density?

Assuming that at the second point the area is related to the original area by $A_2 = 4A_1$, what is the radius at this point? What is the current? and what is the current density?

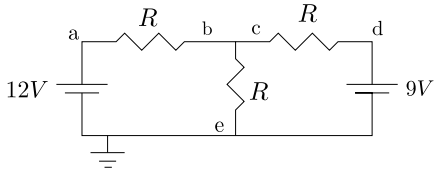
Waffle Iron

A waffle iron is rated to 1.00kW when connected to a 120V source. What current does the waffle iron carry? What is the resistance of the waffle iron?

7 DC Circuits

Rank the potentials

Look at the circuit diagram below and rank the potentials labelled from highest to lowest potential.

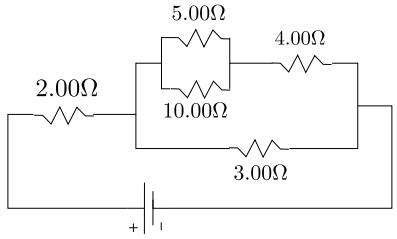


Parachutist

Suppose a parachutist has the misfortune of landing on a high voltage transmission cable on their way back to the earth. Will the parachutist be electructed? Their weight on the cables causes a cable to break, should the parachute hold onto the cable as it swings towards the ground? Why? Why not?

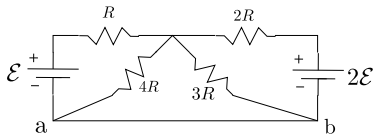
So many resistors

Find the voltage and current across the 3.00Ω resistor.



Current at a Node

In the following figure, what is the current between node a and node b



Capacitor Discharge

A single capacitor and resistor are in a circuit. The time constant is 1.50 seconds and the capacitor is charged to Q. How long until the capacitor discharges to 75% of its original charge? If R = 250Ω what is the value of C?

8 Magnetic Fields

Tropical Electron

An electron is moving at speed of $2.50 \times 10^6 m/s$ in the direction 35.0^o North of East. At this point the magnetic field due to the earth is $3.00 \times 10^{-5} T$ due North. What is the force on the electron due to the earth's magnetic field?

Proton Force

A proton moves with velocity $\vec{v} = (2\hat{x} - 4\hat{y} + \hat{z}) m/s$ in a region of space with a magnetic field of $\vec{B} = (\hat{x} + 2\hat{y} - \hat{z}) T$. What is the magnitude of the force on the proton?

9 Sources of the Magnetic Field

Magnetic field from a wire

An infinite wire carrying a current of I produces a magnetic field $\vec{B}$. Use Ampere's Law to find the magnitude of the magnetic field at a distance s away from the wire.

Inifinite Sheet of current

Imagine an infinite sheet in the x-y plane carrying a surface current density of κ in the x direction. This means that if we multiply the current density by some line that it goes through we can find the total current. What is the Magnetic field produced by this current density?

Solenoid

A solenoid is formed from a wire wrapped around a cylinder many many times. If a current is passed through the wire a magnetic field is produced. Imagine for a moment that the solenoid was infinitely long. What is the magnetic field due to the wire inside the solenoid? Outside the solenoid? (Hint: Use Ampere's Law!)

10 Faradays Law

Bar and Rails

A bar connects two parallel rails and is allowed to slide along them. At one end the rails are connected by a resistor of resistance R. If a uniform magnetic field is applied to the whole apparatus (into the page) and the rail is pulled away from the resistor as a speed $\vec{v}$, which of the following will be true?

(a) There will be no induced current

(b) There will be a clockwise induced current

(c) There will be a counter clockwise induced current

(d) There will be a force on the bar causing it to slow down

(e) There will be no force on the bar at all.

Dropping Aluminium

A piece of aluminium is dropped between the poles of an electromagnet. Does the magnetic field affect the velocity of the aluminium?

Flatten a Loop

If a flexible loop of wire starts as a circle of radius 12.0cm in a magnetic field of 0.150T and is pulled at opposite ends until nearly straight, in a time of 0.200 seconds what is the average induced emf during this time interval?

Current and Field

A circular loop of wire of resistance R = 0.500Ω and radius 8.00cm is placed in a uniform magnetic field directed out of the page. If a clockwise current of I=2.50mA is induced in the loop by changing the magnetic field, is the field increasing or decreasing? And, what is the rate of change of the magnetic field?

11 Inductance

500 Coils

An emg of 24.0mV is induced in a 500-turn coil when the current is changed at a rate of 10.0 A/s. What is the magnetic flux through the each turn of the coil when the current is 4.00 A?

RL versus RC

A series RL circuit with L = 3.00H and a series RC circuit with C = 3.00μF have equal time constants. If the they have the same resistance, what is the value of the resistance and what is the time constant?