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Midterm 1

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1 Unit 0: Electrostatics I and II

1. A 50 gram copper wire has a net charge of $2.00 \mu\text{C}$. What fraction of the copper's electrons has been removed? (Each atom has 29 protons, and the atomic mass is 63.5.)

$$9.09 \times 10^{-3} \text{ electrons lost}$$

2. A test charge of $+2 \mu\text{C}$ is placed halfway between a charge of $+6 \mu\text{C}$ and another of $+4 \mu\text{C}$ separated by 10 cm. (a) What is the magnitude of the net force on the test charge? (b) What is the direction of this force (away from or toward the $+6 \mu\text{C}$ charge)?

$$14.384 \text{ N},$$

away

3. What is the force on the charge located at $x = 8.00 \text{ cm}$ in Fig. 1(a) given that $q = 1.00 \mu\text{C}$?

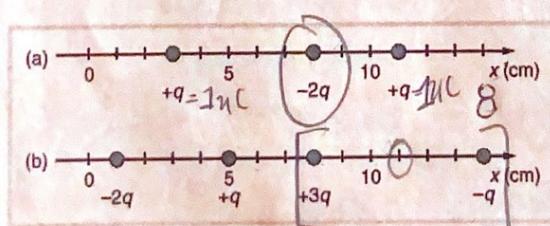


Figure 1: Linear arrangement of charges.

4. Find the total electric field at $x = 11.00 \text{ cm}$ in Fig. 1(b).

$$12.84 \text{ N}$$

5. Determine the direction of the force on q in Fig. 2 given that $q_a = q_b = +7.50 \mu\text{C}$ and $q_c = q_d = -7.50 \mu\text{C}$. (b) Calculate the force on the charge q , given that the square is 10.0 cm on a side and $q = 2.00 \mu\text{C}$.

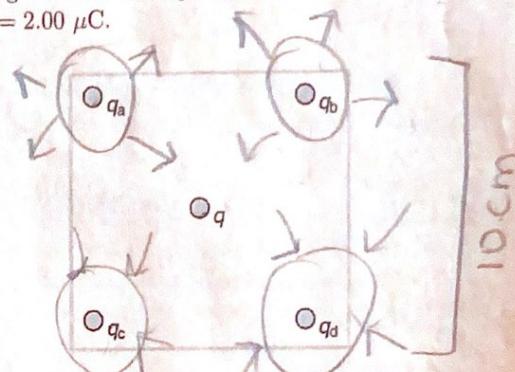


Figure 2: 2D arrangement of charges.

6. (a) An evacuated tube uses an accelerating voltage of 40 kV to accelerate electrons to hit a copper plate and produce x rays. Non-relativistically, what would be the maximum speed of these electrons? (b) Show that units of V/m and N/C for electric field strength are indeed equivalent. ~~or 21~~

$$@ 118,534,779.5 \text{ m/s}$$

7. The electric field strength between two parallel conducting plates separated by 4.00 cm is $7.50 \times$

$\text{N} \cdot \text{m}^{-1}$. (a) What is ΔV between the plates? (b) The plate with the lowest potential is taken to be at zero volts. What is the potential 1.00 cm from that plate (and 3.00 cm from the other)? (c) The voltage across a membrane forming a cell wall is 80.0 mV and the membrane is 9.00 nm thick. What is the electric field strength?

(A) 3000 V

(B) 750 V at 1 cm

(C) $8.88 \times 10^{-12} \text{ V/m}$

2. (a) What is the energy stored in the $10.0 \mu\text{F}$ capacitor of a heart defibrillator charged to $9.00 \times 10^3 \text{ V}$? (b) Find the amount of stored charge. (c) In open heart surgery, a much smaller amount of energy will defibrillate the heart. What voltage is applied to the $8.00 \mu\text{F}$ capacitor of a heart defibrillator that stores 40.0 J of energy? (d) Find the amount of stored charge.

(A) 405 J

(B) $.09 \text{ C}$

(C) 3162.28 V

(D) 0.025 C

8. A doubly charged ion is accelerated to an energy of 32.0 keV by the electric field between two parallel conducting plates separated by 2.00 cm. What is the electric field strength between the plates?

$$E = 8 \times 10^5 \frac{\text{V}}{\text{m}}$$

9. In one of the classic nuclear physics experiments at the beginning of the 20th century, an alpha particle was accelerated toward a gold nucleus, and its path was substantially deflected by the Coulomb interaction. If the energy of the doubly charged alpha nucleus was 5.00 MeV, how close to the gold nucleus (79 protons) could it come before being deflected?

$$r = 4.54 \times 10^{-4} \text{ m}$$

3. To build up the charge and energy required in part (a) of the previous problem, an AED designer decides to split the charge among four capacitors in parallel. Determine the required capacitance of each individual capacitor, and the charge stored on each, if the voltage remains $9.00 \times 10^3 \text{ V}$. Why would the designer choose not to connect the capacitors in series?

(A) Capacitance
 $= 2.5 \times 10^{-16} \text{ F}$

Charge stored
 $= 0.0225 \text{ C}$

4. If a 1.0 mm diameter copper wire can have a resistance of no more than 2.0Ω , (at 20 degrees C), how long can it be?

2 Unit 1: Capacitors, Current, and DC circuits

1. What capacitance is needed to store $3.00 \mu\text{C}$ of charge at a voltage of 120 V?

$$2.5 \times 10^{-8} \text{ F}$$

¹The value is surprisingly large, but correct.

5. An LED is connected in series with a $1 \text{ k}\Omega$ resistor. A 3.0V battery is connected to the resistor, the LED follows the resistor, and the LED is then

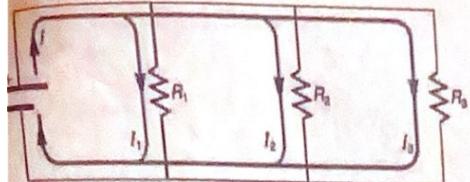


Figure 3: A DC circuit with three resistors.

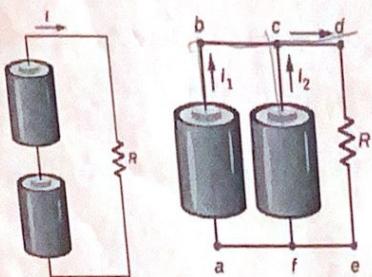


Figure 4: (Left) A DC circuit with two batteries in series, and a resistance $R = 0.5 \text{ k}\Omega$. (Bottom) A DC circuit with two batteries in parallel, and a resistance $R = 0.5 \text{ k}\Omega$.

connected to ground. The negative terminal of the battery is also connected to ground. (a) What current flows from the battery, if the LED resistance is 3Ω ? (b) How much power is consumed by the LED? (c) How many Coulombs of charge flow through the LED in 10 minutes?

A 0.00299 A
 B $P = 0.00897 \text{ W}$
 C 1.7946 C

3 Unit 2: DC circuits with resistors in series and parallel, RC circuits

1. In Fig. 3, let $R_1 = 10 \text{ k}\Omega$, $R_2 = 5 \text{ k}\Omega$, and $R_{\text{tot}} = 2 \text{ k}\Omega$. (a) What is the resistance of R_3 ? (b) If the battery has $\Delta V = 12 \text{ V}$, what current flows from the battery? (c) What are the individual currents, I_1 , I_2 , and I_3 ?

D $R_3 = 5 \text{ k}\Omega$

E $6 \times 10^{-3} \text{ A}$

F $I_1 = 1.2 \times 10^{-3} \text{ A}$
 $I_{23} = 2.4 \times 10^{-3} \text{ A}$

2. Consider Fig. 4. (a) Assuming no internal resistance, calculate the current and power through the resistance R if each battery has 1.5 V in the series circuit, and 3 V in the parallel circuit. (b) Now repeat part (a) for each circuit, assuming all batteries have an internal resistance of 5Ω .

G i) 0.006 A & $1.8 \times 10^{-2} \text{ W}$
 ii) 0.003 A & 0.0045 W

H i) 0.0588 A & 0.0716 W

I) 0.163 A & 0.904 W

3. A child's electronic toy is supplied by three 1.58-V alkaline cells having internal resistances of 0.02Ω in series with a 1.53-V carbon-zinc dry cell having a 0.10Ω internal resistance. The load resistance is 10.00Ω . (a) Draw a circuit diagram of the toy and its batteries. (b) What current flows? (c) How much power is supplied to the load? (d) What is the internal resistance of the dry cell if it goes bad, resulting in only 0.500 W being supplied to the load?

J) 0.167 A

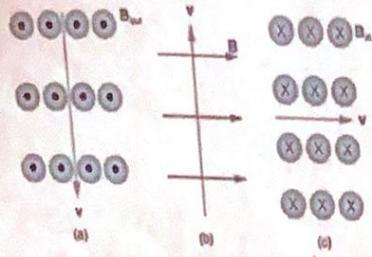
K) 3.808 W

L) 17.93Ω

4. A heart pacemaker fires 72 times a minute, each time a 25.0-nF capacitor is charged (by a battery in series with a resistor) to 0.632 of its full voltage. What is the value of the resistance?

$3.33443 \times 10^7 \Omega$

5. An ECG monitor must have an RC time constant less than $1.00 \times 10^2 \mu\text{s}$ to be able to measure



Right out down

figure 5: Three cases involving the particle velocity \vec{v} , and \vec{B} field.

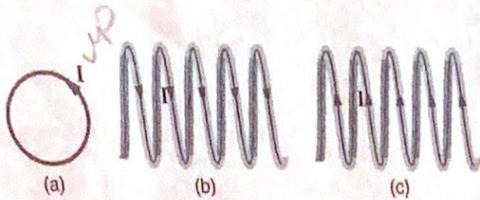


Figure 6: Three currents that create B-fields.

variations in voltage over small time intervals. If the resistance of the circuit (due mostly to that of the patient's chest) is $1.00 \text{ k}\Omega$, what is the maximum capacitance of the circuit?

$$1 \times 10^{-7} \text{ F}$$

4 Unit 3: Magnetism I

1. Consider Fig. 5. Fill in Tab. 1 of directions below for the Lorentz force, assuming a negatively charged particle. Let \hat{i} represent right, \hat{j} represent up, and \hat{k} represent out of the page.

2. An electron moving at $4.00 \times 10^3 \text{ m s}^{-1}$ in a 1.25-T magnetic field experiences a magnetic force of $1.40 \times 10^{-16} \text{ N}$. What angle does the velocity of the electron make with the magnetic field? There are two possible answers.

$$10.08^\circ \text{ & } 169.92^\circ$$

right
out
down

Case	v direction	B direction	F direction
(a)	$-\hat{i}$	$\hat{i}\hat{j}$	\hat{k}
(b)	\hat{j}	\hat{i}	\hat{i}
(c)	\hat{i}	$-\hat{i}$	$-\hat{j}$
(d)	NO D case		

Table 1: Table of directions for to Fig. 5.

3. (a) An oxygen-16 ion with a mass of $2.66 \times 10^{-26} \text{ kg}$ travels at $5.00 \times 10^6 \text{ m/s}$ perpendicular to a 1.20-T magnetic field, which makes it move in a circular arc with a 0.231-m radius. What positive charge is on the ion? (b) What is the ratio of this charge to the charge of an electron? (c) Discuss why the ratio found in (b) should be an integer. (d) A mass spectrometer is being used to separate common oxygen-16 from the much rarer oxygen-18, taken from a sample of old glacial ice. (The relative abundance of these oxygen isotopes is related to climatic temperature at the time the ice was deposited.) The ratio of the masses of these two ions is 16 to 18. Assuming the ions have the same charge, what would the radius of the circular arc be for the oxygen-18? Hint: this is a scaling problem.

Ⓐ $q = 4.79 \times 10^{-19} \text{ C}$

Ⓑ ≈ 3.00

Ⓓ 0.2598 m

4. What force is exerted on the water in an MHD drive utilizing a 25.0-cm-diameter tube, if 100-A current is passed across the tube that is perpendicular to a 2.00-T magnetic field? (The relatively small size of this force indicates the need for very large currents and magnetic fields to make practical MHD drives.)

$$F = 50 \text{ N}$$

5. For this exercise, we are designing an electric motor. Calculate the B-field strength needed on a 200-turn square loop 20.0 cm on a side to create a maximum torque of 300 N m if the loop has 25.0 A of current.

$$B = 1.5 \text{ T}$$

Case	B direction
(a)	↑
(b)	- ↗
(c)	↗

up
in
out

Table 2: Table of directions for to Fig. 6.

Consider Fig. 6. Fill in the B-field directions in Tab. 2 using Ampère's Law, and the appropriate right-hand rule. Let \hat{i} represent right, \hat{j} represent up, and \hat{k} represent out of the page.

Calculate the size of the magnetic field 20 m below a high voltage power line. The line carries 450 MW at a voltage of 300,000 V.

$$B = 1.5 \times 10^3 \text{ T}$$

8. The B-field in the tokamak reactor in Fig. 7 is given by $B = \mu_0 NI/(2\pi r)$, where N is the total number of loops, I is the current, and r is the radius at which we evaluate the B-field. (a) Design your own reactor by specifying practical values of N , I , and r that achieve a 1.0 T B-field at a radius of 5.0 m. (b) With what frequency will a proton circle the toroidal B-field (1.0 T)? These ideas will help activate fusion reactors.

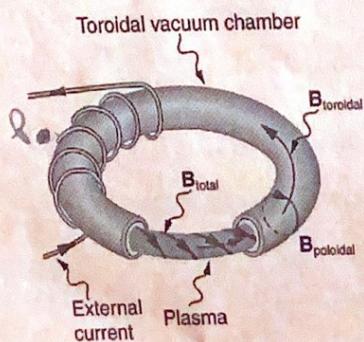


Figure 7: A generalized diagram of a tokamak.

- a any multiple of $NI = 25 \times 10^7$
 b $1.524 \times 10^7 \text{ Hz}$

Midterm 1 Prof. Jordan C. Hanson Mar 7, 2024 Susana Jaramillo

① $m = 50 \text{ g}$ Copper: 29 protons
 $C = 2.0 \text{ nC}$ atomic mass = 63.5 atomic mass
= protons + neutrons + electrons

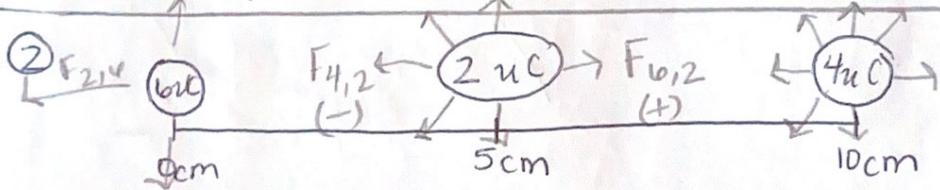
of moles: $\frac{\text{mass}}{\text{atomic mass}} = \frac{50 \text{ g}}{63.5 \text{ g/mol}} = 0.7874 \text{ mol}$

of atoms of copper: $\text{mol} \times \text{Avogadro's} = 0.7874 \frac{\text{mol}}{\text{mol}} \times 6.022 \times 10^{23} \frac{\text{atoms}}{\text{mol}}$
 $= 4.7417 \times 10^{23} \text{ atoms}$

of electrons = $4.7417 \times 10^{23} \frac{\text{atom}}{\text{atom}} \times 29 \frac{\text{electrons}}{\text{atom}}$
 $= 1.37510 \times 10^{25} e^-$

Charge = $\frac{2 \times 10^{-6} \text{ C}}{1.6 \times 10^{-19} \text{ C/e}} = 1.25 \times 10^{13} \text{ electrons in the charge}$

$$\frac{e-c}{e-tot} = \frac{1.25 \times 10^{13} e^-}{1.3751 \times 10^{25} e^-} \rightarrow 9.09 \times 10^{-13}$$



Coulomb's Law: $F = \frac{k |q_1 q_2|}{r^2}$ $k = 8.99 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2}$

② magnitude

$$F_{-6,12} = \frac{k |6 \text{nC} \cdot 2 \text{nC}|}{(0.05 \text{m})^2} = \left(8.99 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2}\right) \left(\frac{1.2 \times 10^{-12}}{0.0025 \text{m}^2}\right)$$
$$= 43.152 \text{ N}$$

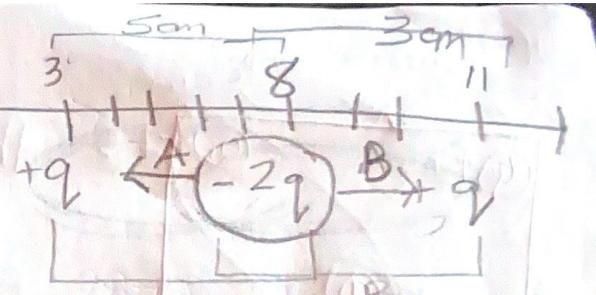
$$F_{-4,12} = \frac{k |2 \text{nC} \cdot 4 \text{nC}|}{(0.05 \text{m})^2} = \left(8.99 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2}\right) \left(\frac{8 \times 10^{-12} \text{ C}}{0.0025 \text{m}^2}\right)$$
$$= 28.768 \text{ N}$$

$$F_{\text{net}} = 43.152 \text{ N} + (-28.768 \text{ N}) = 14.384 \text{ N}$$

(3) Force, point charge

$$r = 8\text{cm} \quad Q = -2 \times 10^{-9}\text{C}$$

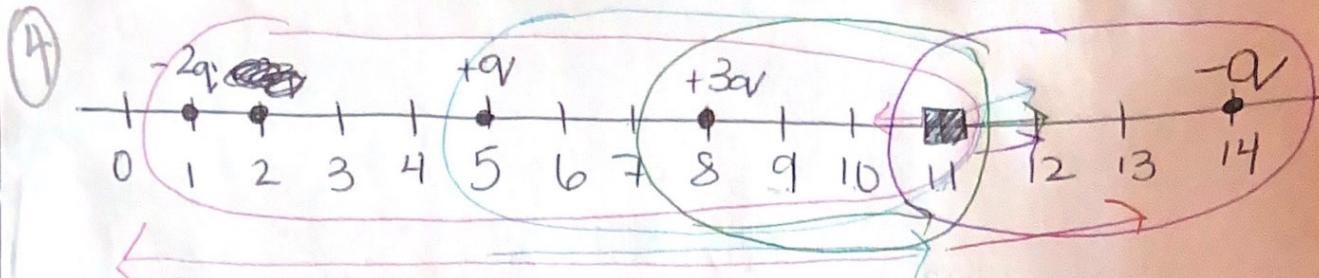
$$E = k \frac{|Q|}{r^2} \quad F = qE$$



$$-(F_A) = (8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \left(\frac{(1 \times 10^{-9} \text{ C} \times -2 \times 10^{-9} \text{ C})}{(0.005)^2 \text{ m}^2} \right)$$
$$= 7.129 \text{ N}$$

$$+(F_B) = (8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) \left(\frac{(1 \times 10^{-9} \text{ C} \times -2 \times 10^{-9} \text{ C})}{(0.03)^2 \text{ m}^2} \right)$$
$$= 19.97 \text{ N}$$

$$F_{\text{net}} = -7.129 \text{ N} + 19.97 \text{ N} = 12.84 \text{ N}$$



$$+E = \frac{kQ}{r^2} = \left(8.99 \times 10^9 \frac{N \cdot m^2}{C^2}\right) \left(\frac{2 \times 10^{-6} C}{(0.10 m)^2}\right) \\ = 1.798 \times 10^6 N$$

$$+E = \frac{kQ}{r^2} = \left(8.99 \times 10^9 \frac{N \cdot m^2}{C^2}\right) \left(\frac{1 \times 10^{-6} C}{(0.010)^2 m^2}\right) \\ = 2.4972 \times 10^6 N$$

$$+E = \frac{kQ}{r^2} \Rightarrow \left(8.99 \times 10^9 \frac{N \cdot m^2}{C^2}\right) \left(\frac{3 \times 10^{-6} C}{(0.03)^2 m^2}\right) \\ = 2.996 \times 10^7 N$$

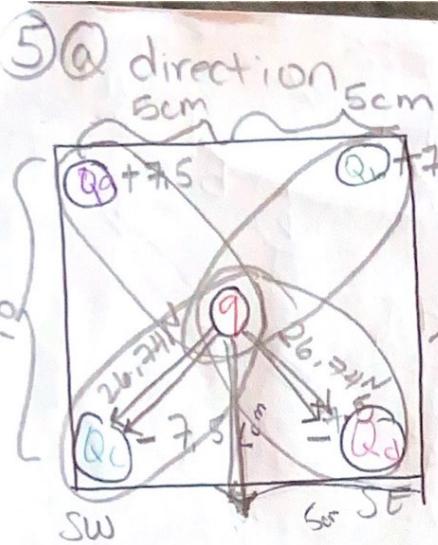
$$+E = \frac{kQ}{r^2} \Rightarrow \left(8.99 \times 10^9 \frac{N \cdot m^2}{C^2}\right) \left(\frac{1 \times 10^{-6} C}{(0.03)^2 m^2}\right) \\ = 9.988 \times 10^6 N$$

$$E_{net} = -E + E + E + E$$

$$= -1.798 \times 10^6 \frac{N}{C} + 2.4972 \times 10^6 \frac{N}{C} + 2.996 \times 10^7 \frac{N}{C} \\ + 9.988 \times 10^6 \frac{N}{C}$$

$$E_{net} = 4.0647200 \times 10^7 \frac{N}{C}$$

The E_{net} is $4.06472 \times 10^7 \frac{N}{C}$ is the right direction



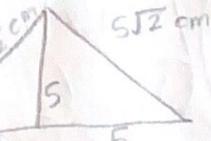
the general direction of this force would be south

$$F_{\text{net}} = SE + SW + SW + SE \\ S(E + W + W + E) \\ S(+1 - 1 - 1 + 1)$$

$$F_{\text{net}} = \text{South}$$

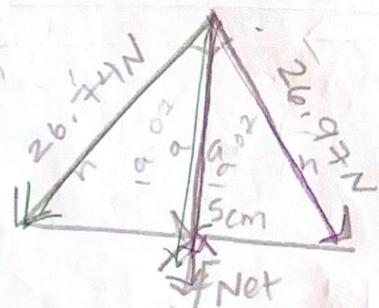
⑥ force on charge, q_1

$$F = k \frac{|q_1 \cdot q_2|}{r^2}, r = 0.0707 \text{ m}$$



$$F = \left(18.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2} \right) \left(\frac{(7.5 \times 2) \times 10^{-12} \text{ C}^2}{\left(\frac{5\sqrt{2}}{100} \right)^2 \text{ m}^2} \right) \\ = 26.97 \text{ N}$$

$F = 26.97$ for each of the 4 forces, $F_{a, b, c, d}$



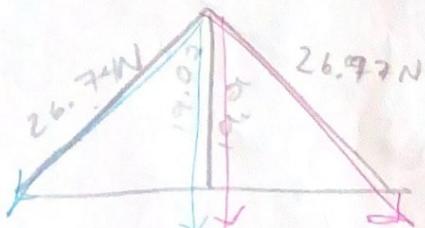
sohcahtoa

$$h \cdot \cos \theta = \frac{a}{h}$$

$$h \cos \theta = a$$

$$h \cos(45) = 26.97 \text{ N} \left(\frac{\sqrt{2}}{2} \right) = 19.0706$$

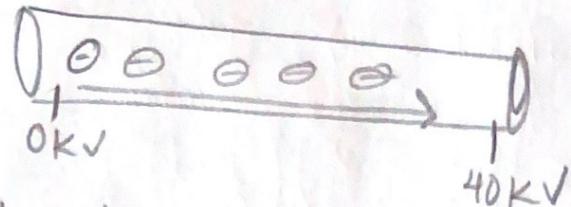
$$F_{\text{net}} = 19.07 \text{ N} \times 4$$



$$F_{\text{net}} = 76.28 \text{ N}$$

$$\textcircled{6} \quad V = 40 \text{ kV}$$

Velocity = ?



Speed @ 40 kV

Conservation of energy

$$0 = \Delta E = \Delta KE + \Delta PE$$

$$0 = \cancel{\frac{1}{2}mv_f^2} + q\frac{\Delta V}{40 \text{ kV}}$$

$$q/m = \text{mass} = 9.11 \times 10^{-31} \text{ kg}$$

q/e = charge of electron

$$0 = \frac{1}{2}mv_f^2 + (-1.6 \times 10^{-19} \text{ C})(40 \times 10^3) \text{ V} / \text{C}$$

$$0 = \frac{1}{2}(9.11 \times 10^{-31} \text{ kg})(v_f^2) + -6.4 \times 10^{-15}$$

$$\frac{2.64 \times 10^{-15}}{9.11 \times 10^{-31} \text{ kg}} \text{ J} = \frac{1}{2}(9.11 \times 10^{-31}) (v_f^2) + 6.4 \times 10^{-15} \text{ J}$$

$$\sqrt{1.4 \times 10^{16} \frac{\text{kg m}^2 \text{s}^{-2}}{\text{kg}}} = \sqrt{v_f^2}$$

$$118,534,779.5 = \text{m/s}$$

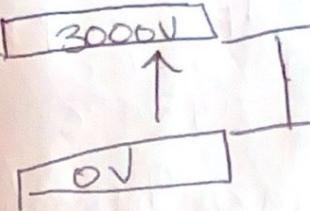
$$\textcircled{6} \quad \frac{V}{M} = \frac{N}{C}; \quad \boxed{\frac{V}{I} = \frac{J}{C}}, \quad \boxed{C = \frac{J}{V}}, \quad \boxed{J = NM}$$

$$\textcircled{a} \quad \frac{V}{M} = \left(\frac{J}{C} \right) \left(\frac{1}{N} \right) = \frac{J}{M} \cdot \frac{1}{C} \quad \textcircled{b} \quad \frac{N}{C} = \frac{V}{M}$$

$$\Rightarrow \frac{N(J)}{C} \Rightarrow \left(\frac{J}{M} \right) \left(\frac{1}{N} \right)$$

$$\Rightarrow \frac{J}{M} \cdot \frac{V}{J} \Rightarrow \boxed{\frac{V}{M}} = \boxed{\frac{N}{C}}$$

$$\boxed{\frac{V}{M}} = \boxed{\frac{N}{C}}$$

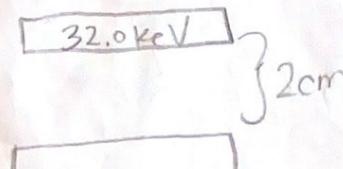
⑦ @  $E = 7.5 \times 10^4 \text{ V/m}$
 $d \cdot E = \frac{\Delta V}{d} \cdot d$
 $\Rightarrow \Delta V = Ed$

@ $\Delta V = \left(7.5 \times 10^4 \frac{\text{V}}{\text{m}} \right) (0.04 \text{ m})$
 $\Delta V = 3000 \text{ V}$

⑧ $\frac{3000 \text{ V}}{4 \text{ cm}} = 750 \frac{\text{V}}{\text{cm}}$

750V @ 1 cm

⑨ $E = \Delta V / d$
 $\Rightarrow (80 \text{ mV}) / (9 \text{ mm})$
 $= \frac{80 \times 10^3 \text{ V}}{9 \times 10^{-9} \text{ m}} \Rightarrow 8.88 \times 10^{-12} \frac{\text{V}}{\text{m}}$

⑩  Energy = $32 \times 10^3 \text{ eV}$
doubly charge = $2 \times 1.6 \times 10^{-19} \text{ C}$
 $= 3.2 \times 10^{-19} \text{ C}$

$$\frac{32 \times 10^3 \text{ eV}}{1 \text{ C}} \times \frac{1.6 \times 10^{-19} \text{ C}}{1 \text{ V}} = \frac{5.12 \times 10^{-15} \text{ J}}{\Delta PE}$$

$$\Delta V = \frac{\Delta PE}{C} = \frac{5.12 \times 10^{-15} \text{ J}}{3.2 \times 10^{-19} \text{ C}} = 1.6 \times 10^4 \text{ V}$$

$$E = \frac{V}{d} = \frac{1.6 \times 10^4 \text{ V}}{0.02 \text{ m}} = 8 \times 10^5 \frac{\text{V}}{\text{m}}$$

$$E = 5.0 \text{ MeV} ; 2q_1 ; d = ? ; C_{\text{gold}} = 79 \text{ protons}$$

$$E = 5 \times 10^6 \text{ V} \quad C_F = 2(1.6 \times 10^{-19} \text{ C})$$

$$= 5 \times 10^6 \frac{\text{J} \times 16 \times 10^{-19} \text{ C}}{8 \times 10^{-13} \text{ J}} \quad C_I = 3.2 \times 10^{-19} \text{ C}$$

$$V = \frac{8 \times 10^{-13} \text{ J}}{3.2 \times 10^{-19} \text{ C}} \quad r = \frac{kQ}{V} \quad r = \frac{8.99 \times 10^9 \text{ N m}^2}{1.26 \times 10^2 \frac{C^2}{N \cdot m}}$$

$$= 2.5 \times 10^6 \text{ V} \quad r = 4.54 \times 10^{-14} \text{ m}$$

$$\boxed{r = 4.54 \times 10^{-14} \text{ m}}$$

② UNIT 1: Capacitors, Current, and DC circuits.

③ $C = ?$; $3.0 \mu\text{C} = \text{charge}$; $V = 120.0 \text{ V}$

$$C = \frac{Q}{V} \quad 3 \times 10^{-6} \text{ C}$$

$$\frac{3 \times 10^{-6} \text{ C}}{120.0 \text{ V}} = 2.5 \times 10^{-8} \text{ F}$$

④ energy stored = ?

$$\text{Capacitance} = 10 \mu\text{F}$$

$$V = 9.0 \times 10^3 \text{ V}$$

$$E_{\text{cap}} = \frac{C V^2}{2} = \frac{(10 \times 10^{-6}) \text{ F} \cdot (9 \times 10^3 \text{ V})^2}{2} = 4.05 \text{ J}$$

$$E_{\text{cap}} = 405 \text{ J}$$

⑤ stored charge

$$\sqrt{C} = \frac{Q}{V} \Rightarrow$$

$$Q = C \cdot V$$

$$= (10 \times 10^{-6} \text{ F})(9 \times 10^3 \text{ V})$$

$$Q = 0.09 \frac{\text{A} \cdot \text{s}}{\text{V}} = C$$

$$\boxed{Q = 0.09 \text{ C}}$$

⑥ $V = ?$

$$C = 8.0 \mu\text{F}$$

$$E_{\text{cap}} = 40.0 \text{ J} = \frac{8.0 \times 10^{-6} \cdot V^2 \cdot 2}{2}$$

$$J = 40.0 \text{ J} \quad \sqrt{\frac{80.0 \text{ J}}{8.0 \times 10^{-6} \text{ F}}} = \frac{8.0 \times 10^{-6} \text{ F} \cdot V^2}{8.0 \times 10^{-6} \text{ F}}$$

$$V = 3162.28 \text{ V} \quad N = 3162.28 \quad \frac{J = V \cdot C}{R = \frac{V}{I}} = V$$

$$\textcircled{1} \quad V_C = \frac{Q}{C} \Rightarrow Q = CV \Rightarrow (8 \times 10^{-6})F(3162.28V) \\ Q = 0.025 \text{ C}$$

③ capacitors in parallel

Total Capacitance in Parallel = $C_P = C_1 + C_2 + \dots + C_n$

$$C_P = \frac{Q}{V} \quad Q = CV \quad V = 9.0 \times 10^3 \text{ V}$$

$$C_1 + C_2 + C_3 + C_4 = \frac{Q}{V} \quad \text{Capacitor} = 10 \mu\text{F}$$

$$\frac{4C_i}{4} = \frac{Q}{\sqrt{4}} \quad \text{energy stored} = 405 \text{ J}$$

$$C_i = \frac{Q}{4V} \quad Q = 0.025 \text{ C}$$

$$C_i = \frac{Q}{4V} \Rightarrow 10 \mu\text{F} \quad E_{cap} = \frac{4QV^2}{2} \cdot \frac{1}{4} \frac{1}{2}$$

$$E_{cap} = \frac{CV^2}{2V^2} \Rightarrow C_i = \frac{E_{cap}}{2V^2}$$

$$C_i = \frac{405 \text{ J}}{2(9 \times 10^3)^2 \text{ V}^2} = 2.5 \times 10^{-6} \frac{\text{J}}{\text{V}^2} \cdot \frac{\text{C}}{\text{V}^2} = \frac{2.5 \text{ C}}{\text{V}} = 2.5 \mu\text{F}$$

$$C_i = 2.5 \times 10^{-6} \text{ F}$$

$$Q = (2.5 \times 10^{-6} \text{ F})(9.0 \times 10^3 \text{ V}) \quad F = \frac{C}{V} \cdot V = C$$

$$Q = 0.0225 \text{ C}$$

If equally distributed each capacitor would get $2.5 \times 10^{-6} \text{ F}$ of capacitance & 0.0225 C of charge stored on each.

It would be better to use this design than the series because, parallel circuits use up the same amount of voltage rather than splitting it up.

$$\textcircled{A} \quad d = 1.0 \text{ mm} = 0.001 \text{ m}$$

$$\rho = 2.0 \cdot \Omega$$

Copper @ 20 °C

$$l = ?$$

$$\frac{A \cdot R}{P} = \frac{\rho L}{A} \cdot \frac{A}{P} \quad A = \frac{\pi D^2}{4}$$

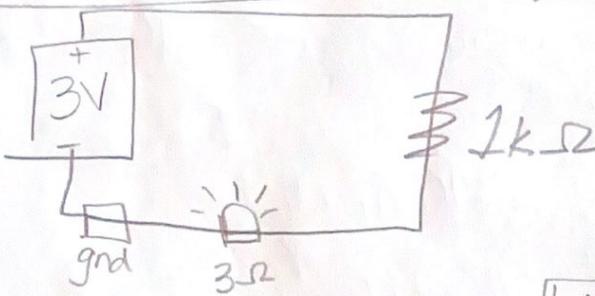
$$P = 1.72 \times 10^{-8} \Omega \cdot \text{m}$$

$$P = l \cdot \rho \cdot A$$

$$l = \frac{A \cdot R}{P} = \frac{\pi D^2 R}{4 P}$$

$$l = \frac{\pi (0.001)^2 (2.0 \cdot \Omega)}{4 (1.72 \times 10^{-8} \Omega \cdot \text{m})} = 91.325 \text{ m}$$

\textcircled{B}



\textcircled{B} current = ?

$$I = \frac{V}{R}$$

$$I = \frac{3.0 \text{ V}}{1 \text{ k}\Omega + 3 \Omega}$$

$$\boxed{0.00299 \text{ A}} = \frac{3.0 \text{ V}}{1003 \Omega} \text{ V/A}$$

\textcircled{B}

$$\text{Power} \Rightarrow P = V \cdot I = (3.0 \text{ V})(0.00299 \text{ A})$$

$$\boxed{P = 0.00897 \text{ W}} = 0.00897 \text{ VA}$$

\textcircled{C}

$$I = \frac{\Delta Q}{\Delta t} \cdot \Delta t \Rightarrow \Delta Q = (I)(\Delta t) = (0.00299 \text{ A})(600 \text{ s})$$

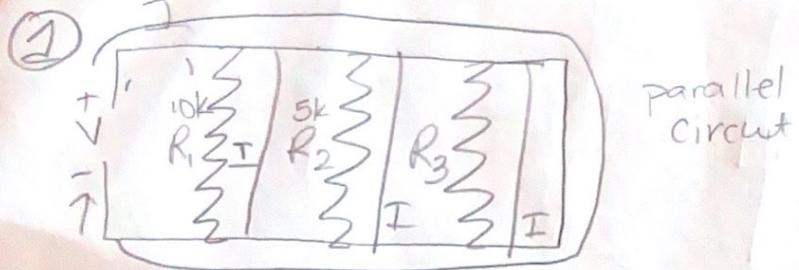
$$\tau = 10 \text{ min} = \frac{600 \text{ s}}{2 \text{ min}}$$

$$\Delta Q = 1.7946 \text{ C}$$

$$\frac{C}{A} \cdot 8$$

$$\boxed{\Delta Q = 1.7946 \text{ C}}$$

Unit 2: DC Circuits with resistors in series and parallel, RC Circuits



ⓐ What is the resistance of R_3 ?

$$R_1 = 10\text{k}\Omega, R_2 = 5\text{k}\Omega, R_3 = ?, R_T = 2\text{k}\Omega$$

* $R_{T\text{OT}}^{-1} = R_1^{-1} + R_2^{-1} + R_3^{-1}$ (R_T = parallel)

$$\frac{1}{2\text{k}\Omega} = \frac{1}{10\text{k}\Omega} + \frac{1}{5\text{k}\Omega} + \frac{1}{R_3}$$

$$\frac{1}{R_3} = \frac{1}{2\text{k}\Omega} - \frac{1}{10\text{k}\Omega} - \frac{1}{5\text{k}\Omega} = \frac{1}{5000\Omega} = \frac{1}{5 \times 10^3 \Omega}$$

$$R_3 = 5 \times 10^3 \Omega$$

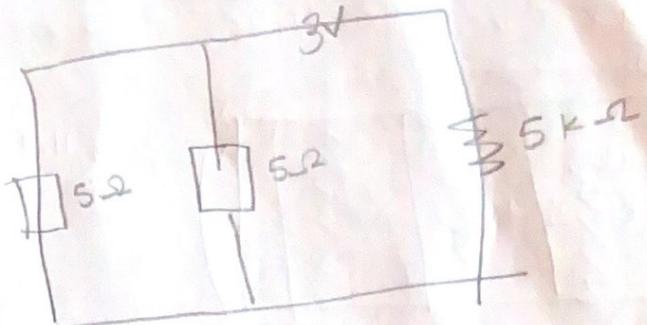
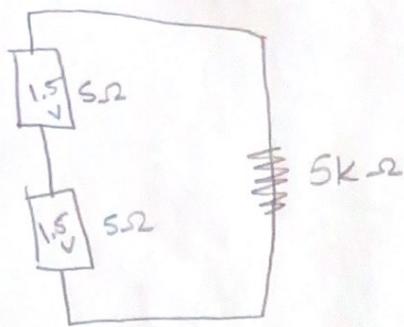
ⓑ $I = V/R \Rightarrow I = \frac{12V}{2 \times 10^3 \Omega} = 6 \times 10^{-3} A$

ⓒ $I_1 = \frac{V}{R_1} = \frac{12V}{10\text{k}\Omega} = 1.2 \times 10^{-3} A$

$$I_2 = \frac{V}{R_2} = \frac{12V}{5\text{k}\Omega} = 2.4 \times 10^{-3} A$$

$$I_3 = \frac{V}{R_3} = \frac{12V}{5\text{k}\Omega} = 2.4 \times 10^{-3} A$$

②



③

series

$$I = \frac{V}{R} = \frac{1.5V + 1.5V}{0.5 \times 10^3 \Omega} = \frac{3.0V}{500\Omega} = 0.006A$$

$$P = IV = (0.006A)(3.0V) = 1.8 \times 10^{-2}W$$

parallel

$$I = \frac{V}{R} = \frac{\left(\frac{3V}{2}\right)}{5k\Omega} = \frac{1.5V}{500} = 0.003V$$

$$P = (0.003A)(1.5V) = 0.0045W$$

④ series

$$R_s = R_1 + R_2 + R_n = 5\Omega + 5\Omega + 0.5k\Omega \Rightarrow 510\Omega$$

$$I = \frac{V}{R} = \frac{3.0V}{510\Omega} = 0.0588A$$

$$P = IV = (0.0588A)(3V) = 0.176W$$

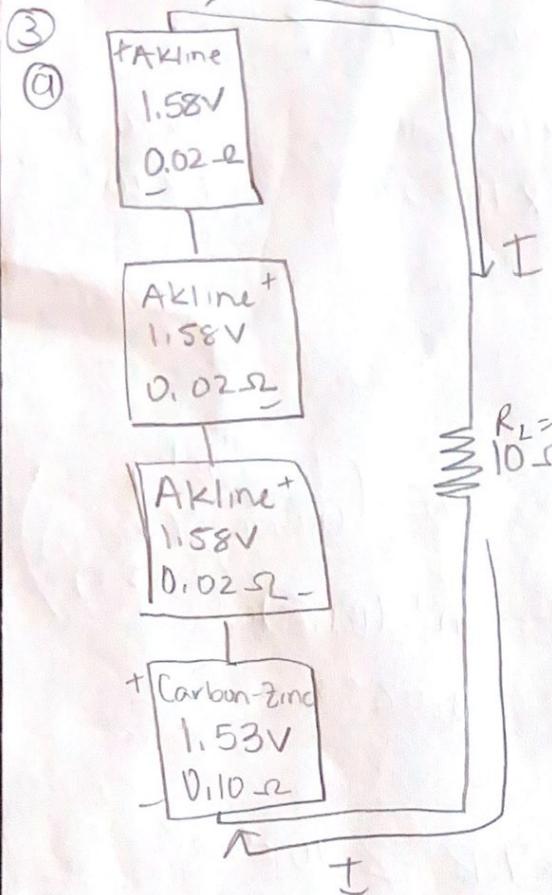
parallel

$$R_p^{-1} = R_1^{-1} + R_2^{-1} + R_n^{-1} = \left[\frac{1}{5} + \frac{1}{5} \right] + \frac{1}{500} + \frac{200}{500} - \left(\frac{201}{500} \right)^{-1} = R_p^{-1}$$

$$R_p = \frac{500}{201} = 2.487\Omega$$

$$I = \frac{V}{R} = \frac{1.5V}{2.487\Omega} = 0.603A$$

$$P = IV = (0.603A)(1.5V) = 0.904W$$



Ⓑ Current

$$I = \frac{V}{R} = \frac{6.27}{10.14} = 0.617 \text{ A}$$

$$V_s = 3(1.58\text{V}) + 1.53\text{V} = 6.27$$

$$R_s = 3(0.02\Omega) + 0.10\Omega + 10\Omega = 10.14$$

Ⓒ Power?

$$P = I^2 R_L \\ = (0.617\text{A})^2 (10\Omega) = 3.808\text{W}$$

Ⓓ (internal) resistance of dry cell

$$0.50\text{W}$$

$$P = \sqrt{I^2 R} = \frac{0.5\text{W}}{R} = \frac{0.5\text{W}}{10\Omega} = \sqrt{0.05\text{A}}$$

$$\frac{P}{I} = 0.224\text{A} = \frac{V}{R} = \frac{6.27}{10.06 + \text{dry cell}} \cdot \frac{R}{R}$$

$$R = \frac{6.27\text{V}}{0.224\text{A}} = 10.06 + \text{R}_{\text{dry-cell}} \\ - 10.06$$

$$\boxed{R_{\text{dry cell}} = 17.93\Omega}$$

④ 72 permintue; 25 nF charged $\rightarrow 0.632\text{V}$; $R = ?$

$$V = 0.632\text{V}_0$$

$$\text{emf} = V_0$$

$$t = \frac{5}{6} - \frac{60}{72} \\ C = 25 \times 10^{-9}\text{F}$$

$$(1 + \frac{V}{\text{emf}}) = 1 - \frac{e^{-t/\text{RC}}}{1}$$

$$R = \frac{-t}{\text{C} \ln(1 - \frac{V}{\text{emf}})}$$

$$(1 - \frac{V}{\text{emf}}) = \ln e^{-t/\text{RC}}$$

$$R = \frac{(S/V)s}{(25 \times 10^{-9}) \ln(1 - \frac{0.632\text{V}}{V_0})}$$

$$\boxed{R = 3.334413 \times 10^7 \Omega}$$

$$\frac{R \ln(1 - \frac{V}{\text{emf}})}{\ln(1 - \frac{V}{\text{emf}})} = \frac{-t \cdot \text{RC}}{\text{RC}}$$

$$\boxed{R = 3.334413 \times 10^7 \Omega}$$

$$\textcircled{5} \quad RC = 1.00 \times 10^2 \mu\text{s}, R = 1\text{k}\Omega; C = ?$$

$$\frac{T}{R} = \frac{RC}{R} \Rightarrow C = \frac{T}{R} = \frac{1 \times 10^2 \mu\text{s}}{1\text{k}\Omega} = \frac{1 \times 10^2 \times 10^{-6}\text{s}}{1 \times 10^3 \Omega} = \frac{1 \times 10^{-4}}{1 \times 10^3} \text{F}$$

\textcircled{4} Magnetism I

$$\textcircled{2} \quad F = qvB \sin\theta; \theta = ?$$

$$\frac{qvB}{qvB} \frac{\sin\theta}{\sin\theta} = \frac{F}{qvB} \Rightarrow N = \frac{1.6 \times 10^{-19}}{4 \times 10^3 \text{ m/s}} = 4 \times 10^3 \text{ m/s}$$

$$B = 1.25 \text{ T}$$

$$\theta = \sin^{-1} \left(\frac{1.4 \times 10^{-16} \text{ N}}{(1.6 \times 10^{-19})(4 \times 10^3 \text{ m/s})} \right) = 10.08^\circ$$

$$\theta = \sin^{-1} \left(\frac{F}{qvB} \right) \quad F = 1.40 \times 10^{-16} \text{ N} \quad \theta = \sin^{-1} (0.175)$$

$$\theta = ?$$

$$\theta = 10.08^\circ$$

$$180^\circ - \theta = 180^\circ - 10.8 = 169.92^\circ$$

The two possible angles are 169.92° & 10.08°

$$\textcircled{3} \quad m = 2.66 \times 10^{-26} \text{ kg} \quad q \frac{Bv}{Br} = \frac{mv}{q} \frac{B}{Br}$$

$$v = 5 \times 10^6 \text{ m/s}$$

$$B = 1.2 \text{ T}$$

$$0.23 \text{ m-radius} \quad +q = ?$$

$$q = \frac{mv}{Br} = \frac{(2.66 \times 10^{-26} \text{ kg})(5 \times 10^6 \text{ m/s})}{(1.2 \text{ T})(0.23 \text{ m})}$$

$$\textcircled{4} \quad q = 4.79 \times 10^{-19} \text{ C}$$

$$\textcircled{5} \quad \frac{C-q}{Ce} = \frac{4.79 \times 10^{-19} \text{ C}}{1.6 \times 10^{-19} \text{ C}} = 2.998 \approx 3.00$$

\textcircled{6} electrons and charges are of a uniform quantity.

$$\textcircled{7} \quad \text{ratio mass } \frac{16}{18} \rightarrow \frac{\text{oxygen-16}}{\text{oxygen-18}} \rightarrow \frac{2.66 \times 10^{-26}}{3.02 \times 10^{-26}} \frac{18 \text{ m}_16}{16} \frac{m_{16}}{m_{18}} \cdot \frac{m_{18}}{m_{16}} \cdot \frac{18}{16} = \frac{18}{16}$$

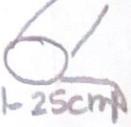
$$r_{16} = \frac{m_{16}V}{q_{16}B} \Rightarrow r_{18} = \frac{q_{16}m_{16}V}{q_{16}B} \Rightarrow \frac{q}{8}[r_{16}] = R_{18}$$

$$\frac{m_{18}}{m_{16}} = \frac{m_{16}q}{2.66 \times 10^{-19}} = \frac{18}{16} \cdot \frac{q}{2.66 \times 10^{-19}}$$

$$R_{18} = \frac{q}{8}[0.23 \text{ m}] \Rightarrow 0.2598 \text{ m}$$

$$8 \left[\frac{3.02}{24} \cdot \frac{16}{16} \right] = 0.2598 \text{ m}$$

$$\textcircled{4} \quad F = ? , d = 25\text{cm}, \text{Current} = 100\text{A}; B = 2.0\text{T}$$


 $F = IlB\sin\theta$

$r = \frac{25}{2}$

$$= (100\text{A})(0.25\text{m})(2.0\text{T})(\sin 90^\circ)$$
 $= 100\text{A}(0.25\text{m}) \cancel{\frac{N}{\text{Am}}} \quad 1$

$$\boxed{F = 50\text{N}}$$

$$\textcircled{5} \quad B = ? \quad \square \times 200 \quad \tau = 300\text{N} \quad I = 25.0$$



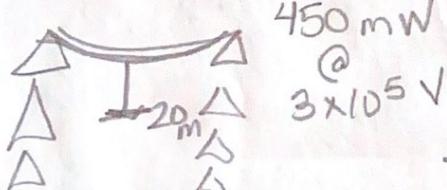
$$\begin{array}{r} 0.2 \\ 0.2 \\ \hline 20.4 \\ 25 \end{array}$$

$$\tau = NIAB\sin 90^\circ$$

$$(200)(25\text{A}) \cancel{\frac{0.04}{(0.2\text{m})^2}} (B) \sin 90^\circ = \frac{300\text{N}}{1.00}$$

$$\frac{200}{200} B = \frac{300\text{N}}{200} \Rightarrow B = \frac{3}{2} = 1.5\text{T}$$

$$\textcircled{6} \quad B = ?$$



$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} T\text{m}}{2\pi} \cdot \frac{1.5 \times 10^5 A}{20\text{m}}$$

$$\frac{P}{V} = \frac{VI}{V}$$

$$I = \frac{450 \times 10^{-3} \text{W}}{3 \times 10^5 \text{V}} \boxed{B = 0.0015\text{T}}$$

$$= 1.5 \times 10^{-5} \text{A}$$

$$\textcircled{7} \quad B = \frac{\mu_0 NI}{2(\pi)r}$$

$NI = 2.5 \times 10^7$, The product of NI must be 2.5×10^7 to

$$I = \frac{\mu_0 NI}{2\pi(5.0\text{m})}$$

case 1: $N = 250$ turns counter balanced
 $I = 10^5 \text{Amps}$ the magnetic field to become 1T.

$$= \frac{(4\pi \times 10^{-7})(NI)}{(2\pi \times 5\text{m})}$$

$$I = 5 \times 10^4 \text{A}$$

$$I = (4 \times 10^{-8})(N)$$

$$\text{case: } 400 \text{ turns} = N$$

$$I = 6.25 \times 10^4 \text{A}$$

⑥ frequency = ?

$$f = \frac{qB}{2\pi m} \quad q = 1.6 \times 10^{-19} C \quad B = 1 T \\ 2 * \pi * 1.67 \times 10^{-27} \text{ Kg}$$

$$f = 1.524 \times 10^7 \text{ Hz}$$