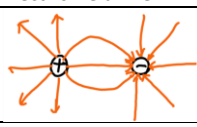
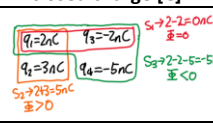
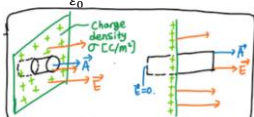
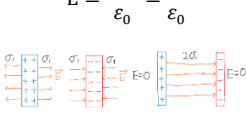
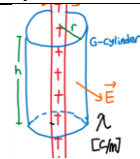
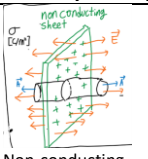
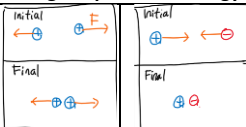
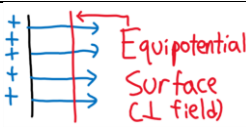
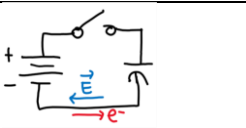
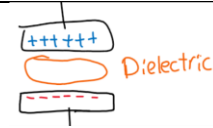
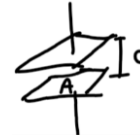
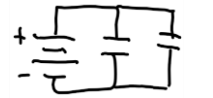

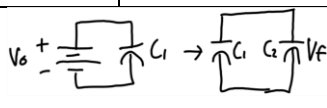



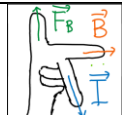

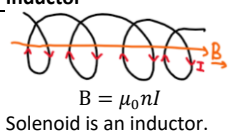


<b>Coulomb's Law</b> $F_{qQ} = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2} \hat{r}$ $\epsilon_0 = 8.854 \cdot 10^{-12} [C^2/Nm^2]$ $k = 8.99 \cdot 10^9 [Nm^2/C^2]$	<b>Electric Fields</b> $E_Q = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2} \hat{r}$	<b>Electric Field line</b> 	<b>Electric Flux [Nm²/C]</b> $\Phi_{net} = \oint_S E \cdot dA$ $= \oint_S E \cdot dA \cdot \cos(\theta)$	<b>Enclosed charge [C]</b>  $q_{enc} = \epsilon_0 \Phi_{net}$ $= \epsilon_0 \oint_S E \cdot dA$	<b>Gaussian surface</b> Sphere: 1 gaussian surf Cylinder: 3 gaussian surf Cube: 6 gaussian surf $dA = dA\hat{n} (\hat{n} \perp A)$	
<b>Isolated conductor</b> $E = 0$ Cavity walls, inside isolated conductor, in metal  (charges all reside at surface)	<b>External elec. field</b> $E = \frac{\sigma}{\epsilon_0} [N/C] \text{ or } [V/m]$ 	<b>Two conducting planes</b> $E = \frac{2\sigma_1}{\epsilon_0} = \frac{\sigma}{\epsilon_0}$ 	<b>Charge Density (linear, surface, volume)</b> Linear density $\lambda$ $q_{tot} = \int \lambda(x) dx$ Surface density $\sigma$ $q_{tot} = \iint \sigma(x,y) dxdy$ Volume density $\rho$ $q_{tot} = \iiint \rho(x,y,z) dxdydz$		<b>Spherical Symmetry</b> $E_{ext} = \left(\frac{q}{4\pi\epsilon_0 R^3}\right) r$ $r$ - radius of gauss surf $R$ - radius of sphere $q$ - charge enclosed $E_{int} = 0$	
<b>Cylindrical symmetry</b> $E = \frac{\lambda}{2\pi\epsilon_0 r}$  $q_{enc} = \lambda h$ $= \epsilon_0 \oint_S E \cdot dA$	<b>Planar symmetry</b>  Non-conducting sheet (charge density of $\sigma$ ) $E = \frac{\sigma}{2\epsilon_0}$ $\Phi = \Phi_1 + \Phi_2 = 2EA$	<b>Change in potential energy</b>  $\Delta U > 0$ $\Delta V > 0$ Force applied $\Delta U < 0$ $\Delta V < 0$ Field does work	<b>Potential Energy and Electric Potential</b> $\Delta U = U_f - U_i$ $= W_{qappl} = -W_{field} [J]$ $= q(V_f - V_i) = -qE\Delta S$ $\Delta V = V_f - V_i [V]$ $= \frac{\Delta U}{q} = - \int_i^f E dS = -E\Delta x$		$\Delta V = - \int_i^f E dS$ $= \frac{Q}{4\pi\epsilon_0} \left(\frac{1}{r_2} - \frac{1}{r_1}\right)$	
<b>Voltage and Potential Energy</b> $V_{r>\infty} = \frac{Q}{4\pi\epsilon_0 r}$ $U = \frac{Qq}{4\pi\epsilon_0 r}$ Voltages can be added up each other (scalar)	<b>Equipotential surface pic</b> 	<b>Basic Circuit with capacitor</b> 	<b>Capacitor</b>  *Metal plates > separation of charge *Dielectric > increase capacitance *Capacitor is charged	<b>Capacitance</b> $C = \frac{q}{V} [F]$ $q$ - charge stored in one plate: not total charge!		
<b>Parallel plate capacitor</b> $E = \frac{Q}{A\epsilon_0}$ $V = \frac{Q}{A\epsilon_0} d$ $C_{pp} = \frac{A\epsilon_0}{d}$ (Ignore dielectric) 	<b>Cylindrical Capacitor</b> $E = \frac{Q}{2\pi\epsilon_0 Lr} \hat{r}$ $V = \frac{Q}{2\pi\epsilon_0 L} \ln\left(\frac{b}{a}\right)$ $C_{cyl} = \frac{2\pi\epsilon_0 L}{\ln(b/a)}$  $a$ is smaller radius, $b$ is larger radius, $L$ is height, $r$ is radius of gaussian surface	<b>Spherical capacitor</b> $E = \frac{Q}{4\pi\epsilon_0 r^2} \hat{r}$ $V = \frac{Q}{4\pi\epsilon_0} \left(\frac{1}{a} - \frac{1}{b}\right)$ $C_{sphy} = \frac{4\pi\epsilon_0 ab}{a-b}$ $C_{single\_sphy} = 4\pi\epsilon_0 r$	<b>Parallel Capacitor</b>  $Q_T = Q_1 + Q_2 + \dots$ $V_T = V_1 = V_2 = \dots$ $Q_T = C_T V$ $C_T = C_1 + C_2 + \dots$	<b>Series Capacitor</b>  $Q_T = Q_1 = Q_2 = \dots$ $V_T = V_1 + V_2 + \dots$ $\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$	<b>Energy in capacitor</b> $U = \int dU = \int q dV = \int CV dV$ $U = \frac{1}{2} CV^2 = \frac{1}{2} \frac{q^2}{C}$ $= \frac{1}{2} qV$	
<b>Energy Density</b> $U_{pp} = \frac{U}{Volume} = \frac{U}{Ad} = \frac{CV^2}{2Ad}$ $= \frac{kA\epsilon_0 E^2 d^2}{2d Ad} = \frac{1}{2} k\epsilon_0 E^2$	<b>Capacitance + dielectric</b> Increase area + decrease distance + dielectric = <u>high capacitance</u>  $V_f = \frac{c_1}{c_1 + c_2} V_0$		$C_{pp} = \frac{k\epsilon_0 A}{d}$ $C_{cyl} = \frac{2\pi k\epsilon_0 L}{\ln\left(\frac{b}{a}\right)}$ $C_{sphy} = \frac{4\pi k\epsilon_0 ab}{a-b}$ $k$ : dielectric constant ( $k > 1$ )			
<b>Power in Electric Fields</b> $U = qRI$ $Power = \frac{dU}{dt}$ $Power = I^2 R = \frac{V^2}{R} = VI [W]$	<b>Parallel Circuit (  )</b> 	<b>Series Circuit (&lt;-&gt;)</b> 	<b>Magnetic Force</b> $F_B = q(\mathbf{v} \times \mathbf{B})$ $= Bqv \sin \theta$ $\theta$ is $\angle(\mathbf{v}, \mathbf{B})$	<b>Magnetic Field</b>  Measured in [T]	<b>Magnetic field 'inside'?</b> $I_{tot} = \pi R^2 J_0$ $I_{enc} = \iint J dA = \pi r^2 J_0$ $(dA = r dr d\theta)$ $\oint_C \mathbf{B} dS = \mu_0 I_{enc} = 2\pi Br$ $B = \frac{\mu_0 I_{tot} r}{2\pi R^2}$	
<b>Biot-Savart Law</b> $d\mathbf{B} = \frac{\mu_0 I (d\mathbf{S} \times \hat{r})}{4\pi r^2}$ $\mu_0 = 4\pi \cdot 10^{-7} [H/m]$	$V_T = V_1 = V_2 = \dots$ $I_T = I_1 + I_2 + \dots$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$ $\Sigma I = 0$	$V_T = V_1 + V_2 + \dots$ $I_T = I_1 = I_2 = \dots$ $R_T = R_1 + R_2 + \dots$ $\Sigma V = 0$	<b>Magnetic force (wire)</b> $F_B = I(\mathbf{L} \times \mathbf{B})$ $= BIL \sin \theta$ $\theta$ is $\angle(\mathbf{L}, \mathbf{B})$			
<b>Ampere's Law</b>	<b>Magnetic field due to current</b> <b>Infinite wire</b> $B = \frac{\mu_0 I}{2\pi r}$  <b>Semi-infinite wire</b> $B = \frac{\mu_0 I}{4\pi r} \int_0^\infty \frac{\sin \theta}{r^2} dx$ $B = \frac{\mu_0 I}{4\pi R}$			<b>Centre of loop</b> $B = \frac{\mu_0 I \Phi}{4\pi R}$ $\Phi$ - angle of loop (partial circular loop)	<b>Force between two parallel currents</b> $F = \frac{\mu_0 L I_a I_b}{2\pi d}$ $\frac{\mu_0}{2\pi} = 2 \cdot 10^{-7}$	<b>Solenoids</b> $I_{enc} = nhl$ $\mu_0 I_{enc} = \mu_0 nhl = Bh$ $B = \mu_0 nI$ $(n = \text{number of loops})$ $(I = \text{current on the loop})$
<b>Magnetic flux</b> $\Phi_B = \iint \mathbf{B} dA [Wb]$ $\Phi_B = BA = \mu_0 nIA$	<b>EMF (Faraday/Lenz)</b> $\epsilon = -(N) \frac{\partial \Phi_B}{\partial t} = -(N) \frac{\partial}{\partial t} \iint \mathbf{B} dA$		<b>Faraday's law</b> - $\epsilon \propto \frac{\partial \Phi_B}{\partial t}$ <b>Lenz's law</b> - Direction of induced $I$ and $\epsilon$ <u>against</u> induced $B$	<b>EMF/current in loops</b> $\epsilon = (-)(N) B v_x l$ $I = \frac{(N) B v_x l}{R}$ $I$ is induced by induced $B$	<b>Power dissipated</b> $P = VI = \frac{V^2}{R} = I^2 R = \frac{N^2 B^2 v^2 l^2}{R}$	<b>Series Inductor</b> $V_T = L_T \frac{dl}{dt}$ $L_T = L_1 + L_2 + \dots$
<b>Inductor</b>  $B = \mu_0 nI$ Solenoid is an inductor.	<b>Inductance</b> $L = \frac{N\Phi_B}{I} [H]$ $L = n^2 A l \mu_0$ $L = \frac{BAN}{l} = NAl\mu_0$ $(N = nl)$	<b>Self-induction (<math>\epsilon_L</math>)</b> $\epsilon_L = -N \frac{\partial \Phi_B}{\partial t}$ $= -L \frac{dI(t)}{dt}$ $V_L = -\epsilon_L = L \frac{dI(t)}{dt}$	<b>Energy in magnetic field</b> $U = qV$ $dU = Vdq = qdV$ $Power = \frac{dU}{dt} = IV$ $dU = ILdl$ $U = \frac{1}{2} LI^2$	<b>Ohm's law &amp; power</b> $V(t) = R I(t)$ $P(t) = V(t)I(t) = R(I(t))^2 = \frac{(V(t))^2}{R}$ $R > 0 > V(t) = R I(t) = 0$ $R = \infty > I(t) = \frac{V(t)}{R} = 0$	<b>Parallel inductor</b> $V = L \frac{dl}{dt}$ $\frac{V}{L_T} = \frac{V}{L_1} + \frac{V}{L_2} + \dots$ $\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \dots$	

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