Electric Fields

Coulomb's Law	$F_e = k_e \frac{q_1 q_2}{r^2}$ $\lvert e \rvert = 1.60219 \times 10^{-19}$ C $E = \frac{F_e}{q} = k_e \frac{q}{r^2}\vec{r}$
Continuous Charge Distribution	$dE = k_e \frac{dq}{r^2}\vec{r}$ $E = k_e \int \frac{dq}{r^2}\vec{r}$ $\rho = \frac{Q}{V}$ $\sigma = \frac{Q}{A}$ $\lambda = \frac{Q}{l}$ $\Delta q = \lambda \Delta x$ $dq = 2\pi r \sigma dr$
Motion of Charged Particles	$F = qE = ma$ $a = \frac{qE}{m}$
Gauss's Law	Electric Flux $\phi = \int_s E \cdot dA = EA\cos\theta$ $\phi_c = \oint E \cdot dA = 4\pi k_e q$
Electric Potential	$\Delta U = -q\int_A^B E \cdot ds$ $\Delta V = \frac{\Delta U}{q} = -\int_A^B E \cdot ds$ $V = k_e \frac{q}{r}$ Continuous Charge Distributions $v = k_e \int \frac{dq}{r}$
Variables	F_e = electric force k_e = coulomb constant (8.9875 x 10^9 N·m²/C²) E = electric field r = distance between 2 particles $\vec{r}$ = unit vector ρ = volume charge density A = area of surface λ = linear charge density l = length of a line Δq = small charge ϕ = electric flux s = surface ΔU = change in potential energy $\oint$ = integral over a closed surface e = charge of an electron q = positive test charge q_1 = charge on particle 1 q_2 = charge on particle 2 σ = surface charge density Q = charge V = volume Δx = change in position F = force m = mass a = acceleration V = electric potential ΔV = potential difference A = charge at a point B = charge at a point

Electricity and Magnetism

Magnetic Force	$F_m = qv \times B = qvB \sin\theta$ $F_m = (qvr \times B)\, nAL$ $F_m = IL \times B$
Continuous Field Distribution	$F = Ids \times B$ $F = I\int_a^b ds \times B$
Motion of Charged Particles	$F = qvB = \frac{mv^2}{r}$ $r = \frac{mv}{qB}$
Gauss's Law	$\phi_B = \int B \cdot dA = BA\cos\theta$ $\oint BdA = 0$
Currents in Wires	$\oint B \cdot ds = \mu_0 I$ $\oint Bds = B\oint ds = B\ell$ $\oint Bds = B\ell = \mu_0 nI$ $B = \mu_0 \frac{N}{\ell} I = \mu_0 nI$
Faraday's Law of Induction	$\mathcal{E} = -\frac{d\phi_B}{dt} = -N\frac{d\phi_B}{dt}$ $\mathcal{E} = -B\ell v$ $V = E\ell = B\ell v$ $\oint E \cdot ds = -\frac{d\phi_B}{dt}$
Variables	F_m = magnetic force v = velocity n = number of charges per unit volume q = charge θ = smaller angle between v and B $\oint$ = integral over a closed surface μ_0 = constant of permeability ($4\pi \times 10^{-7}$ T·m/A) $\mathcal{E}$ = emf E = induced electric field B = magnetic field vector A = cross-sectional area L = length. I = total continuous current ϕ_B = magnetic flux through the circuit n = number of turns per unit length ℓ = length N = number of turns V = potential difference

Electric Circuits

Resistors

$$I \equiv \frac{dQ}{dt}$$

$\Delta Q = (nAv_d\Delta t)q$

$$I = \frac{\Delta Q}{\Delta t} = nqv_d A$$

$$R = \frac{\ell}{\sigma A} = \frac{V}{I}$$

Color Coded:

Black	Violet
Brown	Gray
Red	White
Orange	Gold
Yellow	Silver
Green	Colorless
Blue	

Parallel Arrangement

$$R_{eq} = \left(\frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots} \right)$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \cdots = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots \right)$$

Series Arrangement

$V = IR_1 + IR_2 + \ldots$

$R_{eq} = R_1 + R_2 + \ldots$

Power

$$P = \frac{\Delta U}{\Delta t} = IV = I^2 R = \frac{V^2}{R}$$

Capacitors

$$C \equiv \frac{Q}{V}$$

$$E = \frac{Q}{A}\frac{1}{\varepsilon_0}$$

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{d}$$

$V = Ed$

Parallel Arrangement

$Q = Q_1 + Q_2$

$Q_1 = C_1V,\ Q_2 = C_2V$

$Q = C_{eq}V$

$C_{eq}V = C_1V + C_2V + \ldots$

$C_{eq} = C_1 + C_2 + \ldots$

Series Arrangement

$V = V_1 + V_2$

$$V = \frac{Q}{C_{eq}}$$

$$V_1 = \frac{Q}{C_1}, V_2 = \frac{Q}{C_2}$$

$$C_{eq} = \left(\frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \cdots} \right)$$

$$\frac{Q}{C_{eq}} = \frac{Q}{C_1} + \frac{Q}{C_2} + \cdots$$

Energy

$$dW = Vdq = \frac{q}{C}dq$$

$$W = \int_0^Q \frac{q}{C}dq = \frac{Q^2}{2C}$$

$$U = \frac{Q^2}{2C} = \frac{1}{2}QV = \frac{1}{2}CV^2$$

Inductors

$$\mathcal{E} = -L\frac{dI}{dt} = -N\frac{d\phi_B}{dt}$$

$$L = \frac{N\phi_B}{I}$$

Energy $U = \frac{1}{2}LI^2$

Electric Circuits

Kirchoff's Law	$\sum I_{into\ node} = \sum I_{leaving\ node}$ $\sum \Delta V_{closed\ circuit} = 0$
RC Circuits	Charging $\varepsilon - IR - \frac{q}{C} = 0$ $I = \left(\varepsilon - \frac{q}{C}\right)\frac{1}{R}$ $I(t) = \frac{\varepsilon}{R}e^{-\frac{t}{RC}}$ $\frac{dq}{(q - C\varepsilon)} = -\frac{1}{RC}dt$ $q(t) = C\varepsilon\left[1 - e^{-\frac{t}{RC}}\right]$ $\ln\left(\frac{q - C\varepsilon}{-C\varepsilon}\right) = -\frac{t}{RC}$
	Discharging $IR = \frac{q}{C}$ $-R\frac{dq}{dt} = \frac{q}{C}$ $\frac{dq}{q} = -\frac{1}{RC}dt$ $\ln\left(\frac{q}{Q}\right) = -\frac{t}{RC}$ $q(t) = Qe^{-\frac{t}{RC}}$ $I(t) = -\frac{dq}{dt} = I_0 e^{-\frac{t}{RC}}$
RL Circuits	Charging $\varepsilon - IR - L\frac{dI}{dt} = 0$ $\frac{dI}{dt} = \frac{\varepsilon}{L}e^{-\frac{Rt}{L}}$ $I = \frac{\varepsilon}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$
	Discharging $I(t) = \frac{\varepsilon}{R}e^{-\frac{Rt}{L}}$ $\frac{dI}{dt} = \frac{\varepsilon}{L}e^{-\frac{Rt}{L}}$
LC Circuits	$U = \frac{Q^2}{2C} + \frac{1}{2}LI^2$ $\varpi = \frac{1}{\sqrt{LC}}$ $I = \frac{dQ}{dt} = -\omega Q_{max}\sin(\omega t + \phi)$ $Q = Q_{max}\cos(\omega t + \varphi)$
RLC Circuits	$\frac{dU}{dt} = -I^2R$ $L\frac{d^2Q}{dt^2} + R\frac{dQ}{dt} + \frac{Q}{C} = 0$ $LI\frac{dI}{dt} + \frac{Q}{C}\frac{dQ}{dt} = -I^2R$

Variables			
	I = electric current	ΔQ = change in charge	v_d = drift velocity
	n = density of charge carriers	A = cross-sectional area	Δt = change in time
	q = charge on each carrier	V = potential difference	ℓ = length of conductor
	σ= conductivity of the material of which it is made		R = resistance
	I = current	R_1 = resistor	R_2 = resistor
	R_{eq} = equivalent resistance	ΔU = change in potential energy	P = power
	Q = magnitude of a charge	E = Electric Field	C = capacitance
	ε_0 = permittivity of free space	$8.854187817 \times 10^{-12}$ C²/Nm² (exact)	d = distance
	Q = total charge on capacitor	Q_1 = max charge on a capacitor	Ceq = capacitance
	Q_2 = max charge on different capacitor		C_1 = capacitance
	V_1 = potential difference across capacitor 1		C_2 = capacitance
	V_2 = potential difference across capacitor 2		W = work
	U = potential energy	$\mathcal{E}$ = emf of battery	L = inductance
	N = number of turns of a coil	ϕ_B = magnetic flux	ϖ = angular frequency
	e = (e^) button on calculator	t = time	ϕ = phase angle

Electromagnetic Waves

Electric Waves	$\oint E \cdot ds = -\frac{d\phi_B}{dt}$ $\frac{\partial^2 E}{\partial x^2} = -\frac{\partial}{\partial t}\left(-\mu_0 \varepsilon_0 \frac{\partial E}{\partial t}\right) = -\mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2}$ $\frac{\partial E}{\partial x} = -\frac{\partial B}{\partial t}$

Magnetic Waves	$\oint B \cdot ds = \mu_0 \varepsilon_0 \frac{d\phi_e}{dt}$ $\frac{\partial B}{\partial x} = -\mu_0 \varepsilon_0 \frac{\partial E}{\partial t}$ $\frac{\partial^2 B}{\partial x^2} = \frac{\partial}{\partial t}\left(-\mu_0 \varepsilon_0 \frac{\partial E}{\partial x}\right) = \mu_0 \varepsilon_0 \frac{\partial^2 B}{\partial t^2}$ $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

Poynting Vector	$S \equiv \frac{1}{\mu_0} E \times B$

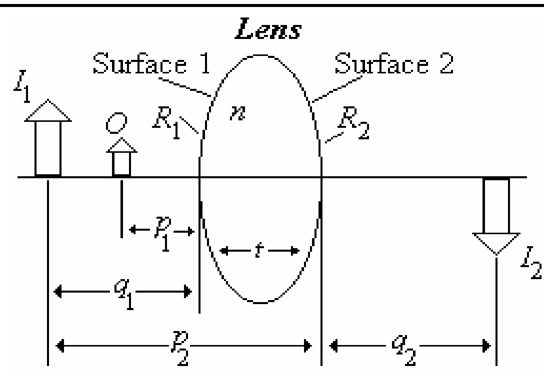
Variables	$\oint$ = integral over a closed surface	∂ = partial derivative of …
	x = position	$\mu_0 = 4\pi \times 10^{-7}$ T·m/A
	$\varepsilon_0 = 8.85419 \times 10^{-12}$ C²/Nm²	E = electric field
	ϕ_B = magnetic flux	ϕ_e = electric flux
	B = magnetic field	t = time
	c = speed of light (2.99792×10^{8} m/s)	S = poynting vector

Optics

Reflection & Refraction	Snells Law	$\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \text{constant}$
	Index of Refraction	$n = \frac{c_{vacuum}}{c_{medium}}$ $v = f\lambda$
	$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$	$\lambda_1 n_1 = \lambda_2 n_2$ $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$

Mirrors	$\theta = \frac{h}{p} = -\frac{h'}{p}$	$M = \frac{h'}{h} = -\frac{q}{p}$	$\tan\alpha = \frac{h}{p-R} = -\frac{h'}{R-q}$
	$\frac{h'}{h} = -\frac{R-q}{p-R} = \frac{q}{p}$	$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$	$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$

Lenses



$$\frac{n}{p_2} + \frac{1}{q_2} \frac{1-n}{R_2}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{p_1} + \frac{n}{q_1} = \frac{n-1}{R_1}$$

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Variables

θ = angle between principle axis and line of reflection; α = angle

θ_1 = angle of incidence; θ_2 = angle of refraction; f = frequency

v_1 = speed of light in 1st medium; v_2 = speed of light in 2nd medium; v = velocity

c_{vacuum} = speed of light in a vacuum; c_{medium} = speed of light in a medium

λ = wavelength of light in vacuum; λ_1 = wavelength in 1st medium

λ_2 = wavelength in 2nd medium; n = index of refraction

n_1 = index of refraction of 1st medium; n_2 = index of refraction of 2nd medium

h = object height; h' = image height; M = lateral magnification

p = object distance; q = image distance; R = radius of curvature

$1/f$ = 1/focal length; R_1 & R_2 = radii of spherical surface

p_1 = distance between object and 1st lens; p_2 = distance between object and 2nd lens

q_1 = image distance from surface 1; q_2 = image distance from surface 2