Equation Sheet
(you will also receive a table of physical constants during the exams)

Coulomb's law

$$\vec{F}_{12} = \frac{kq_1q_2}{r_{12}^2}\hat{r}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r_{12}^2}\hat{r}_{12}$$

Coulomb's law (Continuous Distribution)

$$\vec{E} = \int d\vec{E} = \int \frac{k\hat{r}}{r^2}dq$$

Electric field on test charge

$$\vec{E} = \frac{\vec{F}}{q_0}$$

Dipole Moment

$$\vec{p} = q\vec{L}$$

Electric Flux

$$\phi = \int_S \vec{E}\cdot\hat{n}dA$$

Gauss's Law

$$\phi_{net} = \oint_S \vec{E}\cdot\hat{n}dA = \oint_S E_n dA = \frac{Q_{inc}}{\varepsilon_0}$$

Mag Electric Field of:

Line charge of infinite length

$$E_R = \frac{1}{2\pi\varepsilon_0}\frac{\lambda}{R}$$

On the axis of a charged ring

$$E_z = \frac{kQz}{\left(z^2 + a^2\right)^{3/2}}$$

On the axis and close to a charged disk
A charged infinite plane

$$E_z = 2\pi k\sigma = \frac{\sigma}{2\varepsilon_0}$$

Potential

$$\Delta V = V_b - V_a = \frac{\Delta U}{q_0} = -\int_a^b \vec{E}\cdot d\vec{l}$$

Coulomb Potential

$$V = \frac{kq}{r}$$

Electric Field Given Potential Change

$$E_x = -\frac{dV(x)}{dl}$$

Definition of capacitance

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

Capacitance of a Parallel Plate Capacitor

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

Energy stored in a capacitor

$$U_C = \frac{1}{2}\frac{Q^2}{C}$$

Equivalent Capacitances

Parallel

$$C_{eq} = C_1 + C_2 + C_3 + \ldots$$

Series

$$C_{eq} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

Electric Field in Dielectric

$$E = \frac{E_0}{\kappa}$$

Dielectric and Capacitance

$$C = \kappa C_0$$

Current

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

Drift Velocity

$$I = qnAv_d$$

Resistance

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

Power dissipated by a resistor

$$P = IV = I^2R$$

Equivalent Resistance

Series

$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$

Parallel

$$R_{eq} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

Charging a Capacitor

$$Q(t) = Q_0 \exp(-t/\tau)$$

Discharging a Capacitor

$$Q(t) = Q_f\left(1 - \exp(-t/\tau)\right)$$

Magnetic force on moving charge

$$\vec{F} = q\vec{v}\times\vec{B}$$

Magnetic force on current element

$$d\vec{F} = Id\vec{l}\times\vec{B}$$

Equation Sheet
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Magnetic field due to moving point charge
$$\vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v}\times\hat{r}}{r^2}$$
Magnetic field due to current element
$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\hat{r}}{r^2}$$
Magnetic field on axis of a current loop
$$B_x = \frac{\mu_0}{4\pi}\frac{2\pi R^2 I}{\left(x^2+R^2\right)^{3/2}}$$
Magnetic field inside a solenoid, far from ends
$$B_x = \mu_0 n I$$
Magnetic field due to a straight wire segment
$$B = \frac{\mu_0}{4\pi}\frac{I}{R}\left(\sin\theta_2 - \sin\theta_1\right)$$
Definition of magnetic flux
$$\phi_m = \int_S \vec{B}\cdot\hat{n}dA$$
Gauss's law for magnetism
$$\phi_{m,net} = \oint_S B_n dA = 0$$
Amperes law (complete)
$$\oint_C \vec{B}\cdot d\vec{l} = \mu_0 I + \mu_0\varepsilon_0\frac{d}{dt}\int_S E_n dA$$
Faraday's law
$$\oint_C \vec{E}\cdot d\vec{l} = -\frac{d}{dt}\int_S B_n dA = \varepsilon = -\frac{d\phi_m}{dt}$$
Motional emf
$$\varepsilon = \oint_C \left(\vec{v}\times\vec{B}\right)\cdot d\vec{l}$$
Definition of self-inductance
$$L = \frac{\phi_m}{I}$$
Self-inductance of a solenoid
$$L = \mu_0 n^2 A l$$
Mutual inductance
$$M = \frac{\phi_{m2,1}}{I_1} = \frac{\phi_{m1,2}}{I_2}$$
Energy stored in an inductor
$$U_m = \tfrac{1}{2}LI^2$$

Potential difference across an inductor
$$\Delta V = -L\frac{dI}{dt}$$
Energizing an inductor with a battery
$$I = \frac{\varepsilon_0}{R}\left(1-e^{-t/\tau}\right)$$
Time constant for an inductor
$$\tau = \frac{L}{R}$$
De-energizing an inductor with a resistor
$$I = I_0 e^{-t/\tau}$$
Alternating current generator's emf
$$\varepsilon = \varepsilon_{peak}\sin\left(\omega t + \delta\right)$$
RMS current
$$I_{rms} = \sqrt{\left(I^2\right)_{av}}$$
RMS current compared to peak
$$I_{rms} = \frac{1}{\sqrt{2}}I_{peak}$$
RMS current for:

A resistor
$$I_{rms} = \frac{V_{R,rms}}{R}$$
An inductor
$$I_{rms} = \frac{V_{L,rms}}{X_L} = \frac{V_{L,rms}}{\omega L}$$
A capacitor
$$I_{rms} = \frac{V_{C,rms}}{X_C} = \frac{V_{C,rms}}{1/\omega C}$$
Reactance of:

An inductor
$$X_L = \omega L$$
A capacitor
$$X_C = \frac{1}{\omega C}$$
Average power dissipated by a resistor
$$P_{av} = I_{rms}^2 R$$
Angular frequency of a RL or RLC circuit
$$\omega = \frac{1}{\sqrt{LC}}$$

Equation Sheet
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Series RLC circuit driven by a applied potential drop of frequency ω

Applied potential drop

$$V_{app} = V_{app,peak} \cos \omega t$$

Current

$$I = \frac{V_{app,peak}}{Z} \cos(\omega t - \delta)$$

Impedance Z

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Phase angle

$$\tan \delta = \frac{X_L - X_C}{R}$$

Resonance requires

$$X_L = X_C$$

$$\omega = \omega_0 = \frac{1}{\sqrt{LC}}$$

$$\delta = 0$$

E and B amplitude relation in EM wave

$$E = cB$$

Intensity of EM wave

$$I = \frac{1}{2} \frac{E_0 B_0}{\mu_0} = |\vec{S}|_{av}$$

Poynting vector

$$\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$$

Photon energy

$$E = hf = \frac{hc}{\lambda}$$

Law of reflection

$$\theta_1' = \theta_1$$

Index of refraction

$$n = \frac{c}{v}$$

Law of refraction

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Malus's law

$$I = I_0 \cos^2 \theta$$

Mirror equation

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

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

Focal length of a thin lens

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Thin lens equation

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

Magnification

$$m = \frac{y'}{y} = -\frac{s'}{s}$$

Phase difference due to path difference

$$\frac{\delta}{2\pi} = \frac{\Delta r}{\lambda}$$

Two slits

Interference maximum

$$d \sin \theta_m = m\lambda$$

$$m = 0, 1, 2, \ldots$$

Interference minimum

$$d \sin \theta_m = \left(m - \tfrac{1}{2}\right)\lambda$$

$$m = 1, 2, 3\ldots$$

Single slit

Interference minima

$$a \sin \theta_m = m\lambda$$

$$m = 1, 2, 3, \ldots$$