<u>Essential Physics II</u>

List of equations covered in this course.

Equations in boxes [ ] will be provided in the exam. Please check you know where/when/how to use these equations.

Students are expected to **know** equations not in boxes.

Part I: Electromagnetism

$$\bar{F}_{12} = \frac{kq_1q_2}{r^2}\hat{r}_{12}$$ Coulomb's law $$\boxed{k = 9.0 \times 10^9\,\mathrm{Nm^2/C^2}}$$

$$\bar{E} = \frac{kq}{r^2}\hat{r}$$

$$\bar{E} = \sum_i d\bar{E} = \int \frac{kdq}{r^2}\hat{r}$$

$$\boxed{p = qd}$$ Dipole moment

$$\boxed{\bar{\tau} = \bar{p} \times \bar{E}}$$ Torque on dipole

$$\boxed{U = -pE\cos\theta = -\bar{p}\cdot\bar{E}}$$ Potential energy

$$\Phi = |\bar{E}||\bar{A}|\cos\theta = \bar{E}\cdot\bar{A}$$ Electric flux

$$\boxed{\oint \bar{E}\cdot d\bar{A} = \frac{q_{\text{enclosed}}}{\epsilon_0}}$$ Gauss's Law (know solutions for sphere, spherical shell, line, plane and conductors) $$\boxed{\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/Nm}}$$

$$\Delta V_{AB} = \frac{\Delta U_{AB}}{q}$$ Electric potential difference

$$\boxed{\Delta V_{AB} = -\int_A^B \bar{E}\cdot d\bar{r} = -\bar{E}\cdot\Delta\bar{r}}$$

$$V(r) = \frac{kq}{r}$$ Point charge potential

$$\bar{F}_B = q\bar{v} \times \bar{B}$$

Magnetic force

Unit: [T] Tesla

$$\bar{F}_B = q\bar{E} + q\bar{v} \times \bar{B}$$

Electromagnetic force

$$\bar{F} = I\bar{l} \times \bar{B}$$

Magnetic force on a current

$$\boxed{d\bar{B} = \frac{\mu_0}{4\pi} \frac{Id\bar{l} \times \bar{r}}{r^2}}$$

Biot-Savart Law
(know solutions for current loop, straight wire)

$$\boxed{\mu_0 = 4\pi \times 10^{-7}\,\mathrm{N/A^2}}$$

$$\bar{B} = \int d\bar{B} = \frac{\mu_0}{4\pi} \int \frac{Id\bar{l} \times \hat{r}}{r^2}$$

$$\boxed{\bar{\mu} = NI\bar{A}}$$

Magnetic dipole moment

$$\boxed{\bar{\tau} = \bar{\mu} \times \bar{B}}$$

Torque on a current loop

$$\boxed{\oint \bar{B} \cdot d\bar{A} = 0}$$

Gauss's law for magnetism

$$\boxed{\oint \bar{B} \cdot d\bar{r} = \mu_0 I_{\text{enclosed}}}$$

Ampere's law for steady current (know solutions for inside and outside a wire, current sheet and solenoid)

$$\mathcal{E} = IR$$

Ohm's law

$\mathcal{E}$ electromotive force, EMF

$$\Phi_B = \int \bar{V} \cdot d\bar{A} = \bar{B} \cdot \bar{A}$$

Magnetic flux

$$\boxed{\oint \bar{E} \cdot d\bar{r} = -\frac{d\Phi_B}{dt}}$$

$$\boxed{\mathcal{E} = -\frac{d\Phi_B}{dt}}$$

Faraday's Law
(know solutions for a solenoid)

$$\boxed{\oint \bar{B} \cdot d\bar{r} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}}$$

Ampere's law with Maxwell modification

$$S = S_0 \cos^2 \theta$$

Law of Malus (Polarisation)

Part II: Thermodynamics

$T_C = T - 273.15$	Celsius to kelvin scale	
$T_F = \frac{9}{5}T_C + 32$	Fahrenheit to celsius scale	
$\Delta Q = mc\Delta T$	Heat capacity	c specific heat capacity
$H = \frac{dQ}{dt} = -kA\frac{dT}{dx}$	Conductive heat flow	
$H = \frac{T_1 - T_3}{R_1 + R_2}$	Composite slab	
$R = \frac{\Delta x}{kA}$	Thermal resistance	
$P = \epsilon\sigma AT^4$	Stefan-Boltzmann Law	$\sigma = 5.67 \times 10^{-8}\,\mathrm{Js^{-1}m^{-2}K^{-4}}$
$pV = nRT$	Ideal gas law	$R = 8.314\,\mathrm{J/K \cdot mol}$ $N_A = 6.023 \times 10^{23}$ atoms
$\frac{3}{2}kT = \frac{1}{2}m\bar{v}^2$	Kinetic theory of gases	
$v_{\mathrm{th}} = \sqrt{\frac{3kT}{m}}$	Thermal speed (typical molecular speed)	
$Q = Lm$	Energy required for a phase change	L heat of transformation
$\Delta U = Q + W$	1st Law of Thermodynamics	
$\frac{dU}{dt} = \frac{dQ}{dt} + \frac{dW}{dt}$		
$Q = -W = nRT\ln\left(\frac{V_2}{V_1}\right)$	Isothermal process (T = constant)	
$\Delta U = nC_v\Delta T$	Any process	

$$W = -p\Delta V$$

Isobaric gas (p = constant)

$$\boxed{Q = nC_P\Delta T = nC_V\Delta T + p\Delta V}$$

$$\boxed{C_P = C_V + R}$$

molar specific heat

$$\Delta U = W$$

Adiabatic process (Q = 0)

$$\boxed{pV^\gamma = \text{constant}}$$

$$\gamma = \frac{C_P}{C_V}$$

$$\boxed{TV^{\gamma-1} = \text{constant}}$$

$$\boxed{W = \frac{p_2V_2 - p_1V_1}{\gamma - 1}}$$

$$\frac{1}{2}kT$$

Average energy / molecule for each degree of freedom

Part III: Modern Physics

$\lambda_{\text{peak}} T = 2.898\,\text{mm}\cdot\text{K}$	Wien's law	
$P_{\text{blackbody}} = \sigma A T^4$	Stefan-Boltzmann law	$\sigma = 5.67\times10^{-8}\,\text{Js}^{-1}\text{m}^{-2}\text{K}^{-4}$
$R(\lambda, T) = \dfrac{2\pi c k T}{\lambda^4}$	Rayleigh-Jean law	
$R(\lambda, T) = \dfrac{2\pi h c^2}{\lambda^5\left(e^{hc/\lambda kT}-1\right)}$	Planck's law	
$E = hf$		
$K_{\text{max}} = hf - \phi$	Photoelectric effect	
$\dfrac{1}{\lambda} = R_H\left(\dfrac{1}{n_2^2}-\dfrac{1}{n_1^2}\right)$	Hydrogen spectrum	$R_H = 1.097\times10^7\,\text{m}^{-1}$
$r = n^2 a_0$	Allowed radii in Bohr atom	$a_0 = 0.0529\,\text{nm}$
$E = -\dfrac{ke^2}{2a_0}\left(\dfrac{1}{n^2}\right)$	Energy levels in Bohr atoms	
$\lambda = \dfrac{h}{p}$	de Broglie wavelength	
$\Delta x \Delta p \geq \hbar$	Uncertainty principal	
$-\dfrac{\hbar^2}{2m}\dfrac{d^2\psi(x)}{dx^2} + U(x)\psi(x) = E\psi(x)$	Schrodinger equation	$h = 6.63\times10^{-34}\,\text{J}\cdot\text{s}$
$P(x) = \psi^2(x)dx$	Probability of detecting a particle	
$E = \dfrac{n^2h^2}{8mL^2}$	Energy levels in an infinite square well	
$E = \left(n+\dfrac{1}{2}\right)\hbar\omega$	Energy levels in a harmonic oscillator	