Physics GRE Equations Sheet

Version 1.0

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Contents

1 Classical Mechanics

Equations

Kinematics:

$$\begin{aligned}
\Delta x &= v_0 t + \frac{1}{2}at^2 \\
v^2 &= v_0^2 + 2ad \\
v &= +at \\
\Delta x &= \frac{v_0 + v_f}{2}t
\end{aligned}$$

Newton's Second Law:

$$F = ma$$

Momentum:

$$P = mv$$

Centripetal Acceleration:

$$\begin{aligned}
a_c &= \omega^2 r \\
F &= mr\omega^2 \\
\omega &= \frac{2\pi}{T}
\end{aligned}$$

Gravitational Potential Energy:

$$\begin{aligned} U &= mgh \\ U &= -G\frac{m_1\ m_2}{R} \\ U &= -W \end{aligned}$$

Kinetic Energy:

$$\begin{aligned} U_k &= \frac{1}{2}mv^2 \\ U_k &= \frac{p^2}{2m} \\ U_{k-rotational} &= \frac{1}{2}I\omega^2 \end{aligned}$$

Parallel Axis Theorem:

$$I = I_{com} + Mh^2$$

Work:

$$W = \int F \cdot s$$

Moment of Inertia (Point Mass):

$$I = MR^2$$

Schwarzschild Radius:

$$R_e = \frac{2GM}{c^2}$$

Lagrangian:

$$L = T - V$$

Hamiltonian:

$$H = T + V$$

Angular Frequency:

$$\begin{aligned} \omega &= \frac{2\pi}{T} \\ \omega_{SHO} &= \sqrt{\frac{k}{m}} \end{aligned}$$

Period of a SHO:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

2 Electricity & Magnetism

Equations

Maxwell's Equations:

$$\begin{aligned}
\nabla \cdot \vec{E} &= \frac{\rho}{\epsilon_0} \\
\nabla \cdot \vec{B} &= 0 \\
\nabla \times \vec{E} &= -\frac{\partial \vec{B}}{\partial t} \\
\nabla \times \vec{B} &= \mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}
\end{aligned}$$

Coulombs Law:

$$\begin{aligned}
U &= \frac{1}{4\pi\epsilon_0} \frac{dQ}{R} \\
U &= \frac{1}{4\pi\epsilon_0} \frac{q_1 \; q_2}{R} \\
F &= \frac{1}{4\pi\epsilon_0} \frac{q_1 \; q_2}{R^2}
\end{aligned}$$

Hooke's Law:

$$F = -kx$$

Faraday's Law of Induction

$$|\varepsilon| = N \left| \frac{d\phi_B}{dt} \right|$$

Magnetic Flux:

$$\phi_B = \int \int_S \vec{B}(\vec{r}, t) \cdot dA$$

Malus' Law:

$$I = \frac{1}{2} c \epsilon_0 E_0^2 \cos^2(\theta)$$

Gauss' Law:

$$\vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$$

Larmor Formula:

$$P = \frac{q^2 a^2}{6\pi\epsilon_0 c^3}$$

Lorentz Force:

$$F = q \left(\vec{v} \times \vec{B} \right)$$

Hall Voltage:

$$V_H = -\frac{IB}{dne}$$

3 Optics

Equations

Photoelectric Equation:

$$U_k = h\nu - \phi$$

Snell's Law:

$$\frac{\sin(\theta_1)}{\sin(\theta_2)} = \frac{n_2}{n_1}$$

n-slit constructive interference:

$$d\sin(\theta_n) = n\lambda$$

n-slit destructive interference:

$$d\sin(\theta_n) = \left(n + \frac{1}{2}\right)\lambda$$

Photon Energy:

$$\begin{aligned} E &= h\nu \\ E &= \frac{hc}{\lambda} \end{aligned}$$

Interference of a thin film:

$$2nd = \left(m + \frac{1}{2}\right)\lambda$$

Light speed through a medium:

$$v = \frac{1}{\epsilon\mu}$$

Traveling wave:

$$y(x,t) = A\sin\left(\frac{2\pi}{\lambda}\right)(x \pm vt)$$

Drift velocity:

$$v_d = \frac{i}{nqA}$$

Compton Equation:

$$\lambda' - \lambda = \frac{h}{m_p c}\left(1 - \cos(\theta)\right)$$

4 Thermodynamics & Statistical Mechanics

Equations

Rydberg Formula:

$$\frac{1}{\lambda} = R_{\infty}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Rydberg Formula for Hydrogen like atoms:

$$\frac{1}{\lambda_{H-like}} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Moseley's Law:

$$\frac{1}{\lambda_{K-\alpha}} = R\left(Z - \beta\right)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Rydberg Energy:

$$\begin{aligned} E &= -\frac{m_e e^4}{2\hbar^2}\frac{Z^2}{n^2} \\ E &= E_0\left(\frac{1}{\lambda_1^2} - \frac{1}{\lambda_2}\right) \\ E &= n(13.6\ eV)\left(\frac{1}{\lambda_1^2} - \frac{1}{\lambda_2^2}\right) \end{aligned}$$

Heat Capacity:

$$\begin{aligned} C &= \frac{\Delta Q}{\Delta T} \\ C &= \frac{\partial Q}{\partial T} \\ C &= T\frac{\partial S}{\partial T} \\ C_V &= \left(\frac{\partial Q}{\partial T}\right)_V = \left(\frac{\partial U}{\partial T}\right)_V \\ C_p &= \left(\frac{\partial Q}{\partial T}\right)_p = \left(\frac{\partial H}{\partial T}\right)_p \end{aligned}$$

Heat:

$$Q = cm\Delta T$$

First Law of Thermodynamics:

$$\begin{aligned} dU &= dQ + dW \\ dU &= dQ - PdV \end{aligned}$$

Ideal Gas Law:

$$pV = nRT$$

Thermodynamic Work:

$$W = \int_{V_i}^{V_f} PdV$$

Entropy:

$$\Delta S = \int_{T_1}^{T_2} \frac{dq}{T}$$

Fourier's Law of Heat Conduction:

$$\frac{\partial Q}{\partial t} = -k \oint_s \nabla T \cdot d\vec{A}$$

Mean free path:

$$P(x) = n\sigma dx$$

Stefan-Boltzmann's Law:

$$j^* = \sigma T^4$$

5 Quantum Mechanics

Equations

Particle Location (Probability):

$$P_{ab} = \int_a^b |\psi(x)|^2 \, dx$$

Infinite Square Well/Particle in a box:

$$\psi_n(x,t) = A sin(k_n x) e^{-i\omega_n t}$$

Planck Length:

$$l_p = \sqrt{\frac{G\hbar}{c^3}}$$

Expectation Value:

$$\langle A \rangle = \int \langle \psi \, |A| \, \psi \rangle$$

Heisenberg Uncertainty Principle:

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

Spin Operator:

$$S_1^2 \psi_1 = S_1(S_1+1)\psi_1$$

Probability Current:

$$\vec{J}(x,t) = \frac{\hbar}{2mi}\left(\psi^* \frac{\partial \psi}{\partial x} - \frac{\partial \psi^*}{\partial x}\psi\right)$$

Quantum Harmonic Oscillator

$$E_n = \hbar\omega\left(n + \frac{1}{2}\right)$$

Wave Speed (de Broglie relations):

$$\begin{aligned} v_p &= \frac{E}{p} \\ v_p &= \frac{c^2}{v} \end{aligned}$$

Time-Independent Schrodinger Equation:

$$E \ \psi(x) = -\frac{\hbar^2}{2m}\nabla^2 \ \psi(x) + V(x) \ \psi(x)$$

6 Special Relativity

Equations

Rest Energy:

$$E = m_0 c^2$$

Lorentz Factor:

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Relativistic Energy:

$$E_R = \gamma m c^2$$

Relativistic Momentum:

$$p_{rel} = \gamma m_0 v = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Relativistic Energy-Momentum:

$$E^2 = \left(mc^2\right)^2 + (pc)^2$$

Relativistic sum of velocities:

$$\begin{aligned} u' &= \frac{u + v}{1 + \frac{vu}{c^2}} \\ u &= \frac{u' + v'}{1 + \frac{v'u'}{c^2}} \end{aligned}$$

Proper Time:

$$\begin{aligned} \Delta\tau^2 &= \Delta t^2 - \Delta x^2 \\ \Delta t^2 &= \Delta\tau^2 + \Delta x^2 \end{aligned}$$

Space-Time Interval:

$$\Delta S^2 = -(C\Delta t)^2 + \Delta x^2$$

7 Electronics

Equations

Ohm's Law:

$$V = IR$$

Kirchoff's First Law:

$$\sum_{k=1}^{n} I = 0$$

Kirchoff's Second Law:

$$\sum_{k=1}^{n} V = 0$$

Current:

$$i = \frac{dq}{dt}$$

Faraday's law of induction:

$$\varepsilon = \left| \frac{d\phi_B}{dt} \right|$$

Capacitance

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

Frequency of an RLC Circuit

$$f = \frac{1}{4\pi\sqrt{LC}}$$

8 Special Topics

Equations

Acoustic Beats:

$$\text{beats} = |f_2 - f_1|$$

Doppler Effect:

$$f = \left[\frac{1}{1 \pm \frac{v_source}{v_wave}} \right] f_0$$