Equation Sheet for PHYS-203B College Physics

(Last updated: May 9, 2017)
This list will evolve during the semester.

1. Electrostatics:

   (a) Charge and masses:

$$e = 1.60 \times 10^{-19}\,\mathrm{C}, \quad m_e = 9.11 \times 10^{-31}\,\mathrm{kg}, \quad m_p = 1.67 \times 10^{-27}\,\mathrm{kg}. \tag{1}$$

   (b) Coulomb's law:

$$\vec{\mathbf{F}} = \frac{kq_1q_2}{r^2}\hat{\mathbf{r}}, \quad k = \frac{1}{4\pi\varepsilon_0}, \quad k = 8.99 \times 10^9 \frac{\mathrm{N\,m^2}}{\mathrm{C^2}}, \quad \varepsilon_0 = 8.85 \times 10^{-12} \frac{\mathrm{C^2}}{\mathrm{N\,m^2}}. \tag{2}$$

   (c) Electric fields:

$$\vec{\mathbf{E}} = \frac{kq}{r^2}\hat{\mathbf{r}}, \qquad \vec{\mathbf{F}} = q\,\vec{\mathbf{E}}. \tag{3}$$

   (d) Electric flux and Gauss' law:

$$\Phi_E = \vec{\mathbf{E}} \cdot \vec{\mathbf{A}} = EA\cos\theta, \qquad \Phi_E = \frac{Q_{\mathrm{en}}}{\varepsilon_0}. \tag{4}$$

   (e) Electric potential energy and electric potential:

$$U = \frac{kq_1q_2}{r}, \qquad V = \frac{kq}{r}, \qquad U = Vq. \tag{5}$$

   (f) Capacitance:

$$C = \frac{Q}{V}, \qquad U = \frac{1}{2}QV, \qquad u = \frac{1}{2}\varepsilon_0 E^2. \tag{6}$$

   (g) Parallel-plate capacitor:

$$E = \frac{Q}{\varepsilon_0 A}, \qquad C = \frac{\varepsilon_0 A}{d}, \qquad V = Ed. \tag{7}$$

2. Electrial circuits:

   (a) Current: $I = \dfrac{Q}{\Delta t}$, Resistance: $R = \dfrac{\rho l}{A}$, $\rho - \rho_0 = \alpha\rho_0(T - T_0)$,

   (b) Ohm's law: $V = IR$, Power: $P = IV = I^2R = \dfrac{V^2}{R}$.

   (c) Resistors:

$$R_{\mathrm{tot}} = R_1 + R_2 \qquad \text{(series)} \tag{8a}$$
$$\frac{1}{R_{\mathrm{tot}}} = \frac{1}{R_1} + \frac{1}{R_2} \qquad \text{(parallel)} \tag{8b}$$

   (d) Capacitors:

$$C_{\mathrm{tot}} = C_1 + C_2 \qquad \text{(parallel)} \tag{9a}$$
$$\frac{1}{C_{\mathrm{tot}}} = \frac{1}{C_1} + \frac{1}{C_2} \qquad \text{(series)} \tag{9b}$$

3. Magnetostatics:

   (a) Magnetic force:

$$|\vec{\mathbf{F}}| = qvB\sin\theta, \quad |\vec{\mathbf{F}}| = ILB\sin\theta, \quad \omega = \frac{q}{m}B. \tag{10}$$

   Right hand rule-1: Fingers-v/I, Palm-B, Thumb-F.

   (b) Torque on current loop:

$$\tau = NIAB\sin\theta. \tag{11}$$

   (c) Magnetic fields for some relevant configurations:

$$\text{Straight wire segment}: \qquad B = \frac{\mu_0 I}{4\pi r}(\sin\theta_1 + \sin\theta_2), \tag{12a}$$
$$\text{Infinite wire}: \qquad B = \frac{\mu_0 I}{2\pi r}, \tag{12b}$$
$$\text{Circular segment of wire}: \qquad B = \frac{\mu_0 I}{4\pi R}\theta, \tag{12c}$$
$$\text{Circular loop}: \qquad B = \frac{\mu_0 I}{2R}, \tag{12d}$$
$$\text{Solenoid}: \qquad B = \mu_0 In, \quad n = N/L. \tag{12e}$$

   Magnetic permeability: $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{Tm/A}$.

   (d) Ampere's law:

$$\sum B\Delta l\cos\theta = \mu_0 I_{\mathrm{en}}. \tag{13}$$

4. Faraday's law of induction:

   (a) Magnetic flux:

$$\Phi_B = BA\cos\theta. \tag{14}$$

   (b) Induced voltage:

$$V_{\mathrm{eff}} = -N\frac{\Delta\Phi_B}{\Delta t}. \tag{15}$$

   Electric generator: $V = NAB\omega\sin\omega t$.
   Transformer: $\dfrac{V_p}{V_s} = \dfrac{N_p}{N_s} = \dfrac{I_s}{I_p}$.

   (c) Inductance:

$$V = L\frac{\Delta I}{\delta t}, \quad L = \mu_0 n^2 Al, \quad U = \frac{1}{2}LI^2, \quad u = \frac{1}{2\mu_0}B^2. \tag{16}$$

5. Electromagnetic waves:

   (a) Speed of light: $c = 2.998 \times 10^8\,\mathrm{m/s}$.

   (b) Energy density: $u = \dfrac{1}{2}\varepsilon_0 E^2 + \dfrac{1}{2\mu_0}B^2 = \varepsilon_0 E^2 = \dfrac{1}{\mu_0}B^2$.

   (c) Doppler effect: $f' = f\left(1 \pm \dfrac{v_{\mathrm{rel}}}{c}\right)$, for $v_{\mathrm{rel}} \ll c$.

   (d) Polarization:

$$I' = \begin{cases} \frac{1}{2}I_0, & \text{for unpolarized light,} \\ I_0\cos^2\theta, & \text{for polarized light.} \end{cases} \tag{17}$$

6. Ray optics:

   (a) General equations:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}, \qquad R = 2f, \qquad m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}. \tag{18}$$

   (b) Refraction:

$$n_1\sin\theta_1 = n_2\sin\theta_2, \qquad n = \frac{c}{v}, \qquad c = 2.997 \times 10^8\,\mathrm{m/s}. \tag{19}$$

Equation Sheet for PHYS-203A College Physics

(Last updated: August 23, 2016)
This list will evolve during the semester.

1. General mathematics:

   (a) Units:

$$c = 10^{-2}, \quad m = 10^{-3}, \quad \mu = 10^{-6}, \quad n = 10^{-9}, \quad p = 10^{-12}. \tag{1a}$$
$$d = 10^{2}, \quad k = 10^{3}, \quad M = 10^{6}, \quad G = 10^{9}, \quad T = 10^{12}. \tag{1b}$$

   (b) Trigonometry:

$$\sin\theta = \frac{\text{opp. to angle}}{\text{hypotenuse}}, \quad \cos\theta = \frac{\text{adj. to angle}}{\text{hypotenuse}}, \quad \tan\theta = \frac{\text{opp. to angle}}{\text{adj to angle}}. \tag{2}$$

   (c) Pythagorean theorem: $A^2 = A_x^2 + A_y^2$.

   (d) Quadratic equation: $a\,x^2 + b\,x + c = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}. \tag{3}$$

2. Kinematic equations:

   (a) Constant speed ($a = 0$): $\Delta x = v\Delta t$.

   (b) Constant acceleration:

$$v_f = v_i + a\,\Delta t; \qquad \Delta x = v_i\Delta t + \frac{1}{2}a\,\Delta t^2; \qquad v_f^2 = v_i^2 + 2\,a\,\Delta x; \tag{4a}$$
$$\frac{\Delta x}{\Delta t} = \frac{v_i + v_f}{2}; \qquad \Delta x = v_f\Delta t - \frac{1}{2}a\,\Delta t^2. \tag{4b}$$

   (c) Acceleration due to gravity: $g = 9.80\,\mathrm{m/s^2}$.

   (d) Time of flight, horizontal range, and maximum height in projectile motion:

$$T = \frac{2v_0\sin\theta_0}{g}, \qquad R = \frac{v_0^2\sin 2\theta_0}{g}, \qquad H = \frac{v_0^2\sin^2\theta_0}{2g}. \tag{5}$$

   (e) Relative velocity: $\vec{\mathbf{v}}_{AB} = \vec{\mathbf{v}}_{AG} - \vec{\mathbf{v}}_{BG}$.

3. Forces:

   (a) Newton's law:

$$\vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2 + \vec{\mathbf{F}}_3 + \ldots = m\vec{\mathbf{a}}. \tag{6}$$

   (b) Gravitational force:

$$F_G = \frac{Gm_1m_2}{R^2}, \qquad G = 6.67\times10^{-11}\,\mathrm{N\,m^2/kg^2}. \tag{7}$$

   (c) Force due to friction:

$$F_f \le \mu_s N, \quad \text{(static)}, \tag{8a}$$
$$F_f = \mu_k N, \quad \text{(kinetic)}. \tag{8b}$$

   (d) Force due to a spring:

$$F = -kx. \tag{8c}$$

   (e) Circular motion:

$$v = \omega r, \qquad \omega = 2\pi f, \qquad f = \frac{1}{T}, \tag{9}$$
$$a_c = \frac{v^2}{r} = \omega^2 r = 4\pi^2 f^2 r = \frac{4\pi^2}{T^2}r \tag{10}$$

4. Work and energy:

   (a) Kinetic energy:

$$K = \frac{1}{2}mv^2 \tag{11}$$

   (b) Work done by a force:

$$W = Fd\cos\theta \tag{12}$$

   (c) Work-kinetic energy theorem:

$$W_1 + W_2 + \ldots = \Delta K \tag{13}$$

   (d) Potential energy due to gravity:

$$U_g = mgh \tag{14}$$

   (e) Potential energy due to spring:

$$U_s = \frac{1}{2}kx^2 \tag{15}$$

   (f) Mechanical energy:

$$E_{\text{mech}} = K + U_g + U_s \tag{16}$$

5. Linear momentum:

$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}, \qquad \vec{\mathbf{p}}_f - \vec{\mathbf{p}}_i = \vec{\mathbf{F}}\Delta t. \tag{17}$$

   (a) Conservation of linear momentum:

$$m_1\vec{\mathbf{v}}_{1i} + m_2\vec{\mathbf{v}}_{2i} + \ldots = m_1\vec{\mathbf{v}}_{1f} + m_2\vec{\mathbf{v}}_{2f} + \ldots. \tag{18}$$

   (b) Elastic collision in 1-D:

$$v_{1i} + v_{1f} = v_{2i} + v_{2f}. \tag{19}$$

   (c) Center of mass:

$$X_{\text{cm}} = \frac{m_1x_1 + m_2x_2 + \ldots}{m_1 + m_2 + \ldots}. \tag{20}$$

6. Rotational dynamics:

   (a) Kinematic equations:

   i. Constant angular speed ($\alpha = 0$): $\Delta\theta = \omega\Delta t$.

   ii. Constant angular acceleration:

$$\omega_f = \omega_i + \alpha\,\Delta t, \qquad \Delta\theta = \omega_i\Delta t + \frac{1}{2}\alpha\,\Delta t^2, \tag{21}$$
$$\omega_f^2 = \omega_i^2 + 2\,\alpha\,\Delta\theta, \qquad \Delta\theta = \omega_f\Delta t - \frac{1}{2}\alpha\,\Delta t^2, \qquad \frac{\Delta\theta}{\Delta t} = \frac{\omega_i + \omega_f}{2}. \tag{22}$$

   (b) Rotational inertia (moment of inertia) of a point mass:

$$I = MR^2. \tag{23}$$

   (c) Torque:

$$\tau = RF\sin\theta. \tag{24}$$

   (d) Rotational kinetic energy:

$$K_{\text{rot}} = \frac{1}{2}I\omega^2. \tag{25}$$

   (e) Angular momentum:

$$L = I\omega. \tag{26}$$

7. Fluid dynamics:

   (a) Denisty-mass relation:

$$m = \rho V. \tag{27}$$

   Density of water = 10^3 kg/m^3.

   (b) Pressure:

$$P = \frac{F}{A}. \tag{28}$$

   (c) Pressure in a static fluid:

$$P_2 = P_1 + \rho hg. \tag{29}$$

   1 atm = 1.01×10^5 N/m^2.

   (d) Buoyant force:

$$B = m_{\text{dis}}g, \tag{30}$$

   where $m_{\text{dis}} = \rho_{\text{dis}}V_{\text{dis}}$ is the mass of the displaced liquid.

   (e) Continuity equation:

$$A_1v_1 = A_2v_2. \tag{31}$$

   (f) Bernoulli's equation:

$$P + \rho hg + \frac{1}{2}\rho v^2 = \text{const} \tag{32}$$

8. Waves and oscillations:

$$T = \frac{1}{f} = \frac{2\pi}{\omega}, \qquad \lambda = \frac{2\pi}{k}, \qquad v = \lambda f. \tag{33}$$

   (a) Simple pendulum:

$$T = 2\pi\sqrt{\frac{L}{g}}. \tag{34}$$

   (b) Mass-spring system:

$$T = 2\pi\sqrt{\frac{m}{k}}. \tag{35}$$

   (c) Speed of a wave on a string:

$$v = \sqrt{\frac{F_T}{\mu}}. \tag{36}$$

9. Sound waves:

   (a) Speed of sound in air:

$$v = 331 + 0.6T, \tag{37}$$

   measured in m/s, where T is the temperature in °C. $v = 343$ m/s at 20°C.

   (b) Resonance in strings and tubes:

$$L = n\frac{\lambda}{2}, \qquad L = (2n-1)\frac{\lambda}{4}, \qquad n = 1, 2, 3, \ldots \tag{38}$$

   (c) Intensity in decibels:

$$\beta = 10\log\left(\frac{I}{I_0}\right), \qquad I_0 = 10^{-12}\frac{\mathrm{W}}{\mathrm{m^2}}, \qquad I = \frac{\text{Power}}{\text{Area}}, \tag{39}$$

   measured in decibels.

   (d) Doppler effect:

$$f' = f\,\frac{v_0 \pm v_D}{v_0 \pm v_S}. \tag{40}$$