

Formulas PHYS 121- exam1

Units: SI system: kg (kilogram), m (meter), s (second), C (coulomb); \mathcal{A} (ampere)=C/s. 1 mm = 10^{-3} m, 1 cm = 10^{-2} m, 1 km = 10^3 m; 1 N (newton)=kg·m/s², 1 J (joule)=N · m = kg · m²/s², 1 W (watt)=J/s; prefixes: m (milli) 10^{-3} , μ (micro) 10^{-6} , n (nano) 10^{-9} , p(pico) 10^{-12} , k (kilo) 10^3 , M (mega) 10^6 .

Constants: $g = 9.8 \text{ m/s}^2$, $k_e = 9 * 10^9 \text{ N m}^2/\text{C}^2 = 1/(4\pi\epsilon_0)$, $\epsilon_0 = 8.85 * 10^{-12} \text{ C}^2/(\text{N m}^2)$. $e = -1.6 * 10^{-19} \text{ C}$, $m_e = 9.11 * 10^{-31} \text{ kg}$, $m_p \simeq m_n = 1.67 * 10^{-27} \text{ kg}$

Volumes. Cylinder: $\pi R^2 h$, sphere: $\frac{4}{3}\pi R^3$, cone: $\frac{1}{3}\pi R^2 h$. **Areas:** Sphere: $4\pi R^2$

Quadratic equation. $ax^2 + bx + c = 0$, $x = \left(-b \pm \sqrt{b^2 - 4ac} \right) / (2a)$

Derivatives/integrals. $\frac{d}{dt}t^n = nt^{n-1}$, $\int r^n dr = \frac{1}{n+1}r^{n+1}$

Vectors. If $\vec{c} = \vec{a} + \vec{b}$, then $c_x = a_x + b_x$, $c_y = a_y + b_y$, $c_z = a_z + b_z$ and $c = \sqrt{c_x^2 + c_y^2 + c_z^2}$. Dot product: $\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z = ab \cos \alpha$. Cross product: $\hat{i} \times \hat{j} = \hat{k}$, $\hat{j} \times \hat{k} = \hat{i}$, $\hat{k} \times \hat{i} = \hat{j}$.

Coulombs Law: $F = k_e \frac{q_1 q_2}{r^2}$, r -distance between charges; in vector form $\vec{F} = k_e \frac{q_1 q_2}{r^2} \hat{r}$, $\hat{r} = \vec{r}/r$ - unit vector from charge q_1 to q_2 , $k_e = 9 * 10^9 \dots$ Superposition: if charge q_1 acts on q_0 with \vec{F}_{01} , charge q_2 acts on q_0 with \vec{F}_{02} , etc., then $\vec{F}_{\text{net on } q_0} = \vec{F}_{01} + \vec{F}_{02} + \dots$

Electric field. Definition: $\vec{E} = \vec{F}_0/q_0$ (charge q_0 is a "probe"). Field from a charge q : $E = k_e \frac{q}{r^2}$, r -distance between charge and observation point; in vector form $\vec{E} = k_e \frac{q}{r^2} \hat{r}$, $\hat{r} = \vec{r}/r$ - unit vector from charge q to the observation point, $k_e = 9 * 10^9 \dots$ Superposition: consider charges q_1, q_2 , etc. and the observation point. If q_1 creates field \vec{E}_1 at the observation point, q_2 creates field \vec{E}_2 , etc., then $\vec{E} = \vec{E}_1 + \vec{E}_2 + \dots$

Force on a charge placed in external field \vec{E} : $\vec{F} = q\vec{E}$.

Gauss Law. Elementary flux (definition): $\Delta\Phi = \vec{E} \cdot \Delta\vec{A}$. Flux through a closed surface: $\oint \vec{E} \cdot d\vec{A} = q_{\text{enc}}/\epsilon_0$. Field $E(r)$ from a uniformly charged spherical shell with radius R and charge Q : $E(r < R) = 0$, $E(r > R) = k_e Q/r^2$. Field $E(r)$ from a uniformly charged infinite line with linear charge density λ : $E(r) = \lambda/(2\pi\epsilon_0 r)$. Field E from a uniformly charged infinite non-conducting plane with surface charge density σ : $E = \sigma/(2\epsilon_0)$.

Conductors. Inside the body of a conductor: $\vec{E} = 0$, no charge. Extra charge - goes to outer surface. Field near the surface of a conductor, *outside*, is $E = \sigma/\epsilon_0$. Inner surfaces (surfaces of cavities) - uncharged, unless charge inside cavities.

From Phys 111:

Kinematics: $v = dx/dt$, $a = dv/dt = d^2x/dt^2$. Constant a : $v - v_0 = at$, $x - x_0 = \frac{v_0 + v}{2}t = v_0 t + \frac{1}{2}at^2 = \frac{v^2 - v_0^2}{2a}$.

Circular motion with constant speed: $\omega = v/R$, $a_c = v^2/R = \omega^2 R$, towards center.

The three Laws of motion: (1) If $\vec{F}_{\text{net}} = 0$ then $\vec{v} = \text{const}$; (2) $\vec{F}_{\text{net}} = m\vec{a}$; (3) $\vec{F}_{21} = -\vec{F}_{12}$

Specific forces. Gravity: $m\vec{g}$ (down). Normal \vec{N} - perpendicular to surface; tension T - constant along the string.

Centripetal motion: $F_{\text{net}} = mv^2/R$; direction of \vec{F}_{net} - towards center of revolution.

Work and power. Constant force $W = \vec{F} \cdot (\vec{r}_2 - \vec{r}_1) = F_x \Delta x + F_y \Delta y + F_z \Delta z$ (or, $W = F \Delta r \cos \alpha$); general: $W_{AB} = \int_A^B \vec{F} \cdot d\vec{r}$. Power:

$P = W/\Delta t = \vec{F} \cdot \vec{v}$. Work by specific forces: gravity: $W_g = -mg\Delta y$ (and Δx does not matter); normal: $W_N = 0$.

Kinetic energy and work-energy theorem: $K = \frac{1}{2}mv^2$, $\Delta K = W$ where W is the *net* work (i.e. work by all forces).

Potential energy. For conservative forces (with path-independent work) introduce $U(\vec{r})$ so that $W_{AB} = U_A - U_B = -\Delta U$. For specific forces: gravity: $U_g = mgh$. If *only* conservative forces, then energy conservation: $K + U = \text{const}$.