NJIT Physics 111 Formula Sheet

Chapter 1:Vectors and Mathematics Formulas

Vector magnitude: $|\vec{A}| = \sqrt{A_x^2 + A_y^2}$ or $\sqrt{A_x^2 + A_y^2 + A_z^2}$

Vector direction: $\tan\theta = \frac{A_y}{A_x}$

Dot Product: $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z = |\vec{A}||\vec{B}|\cos\theta$

Cross Product: $\hat{\imath} \times \hat{\jmath} = \hat{k} \quad \hat{\jmath} \times \hat{k} = \hat{\imath} \quad \hat{k} \times \hat{\imath} = \hat{\jmath}$

$\hat{\imath} \times \hat{\imath} = \hat{\jmath} \times \hat{\jmath} = \hat{k} \times \hat{k} = 0$

$\vec{A} \times \vec{B} = (A_y B_z - A_z B_y)\,\hat{\imath} + (A_z B_x - A_x B_z)\,\hat{\jmath}$
$+(A_x B_y - A_y B_x)\,\hat{k}$

$|\vec{A} \times \vec{B}| = |\vec{A}||\vec{B}|\sin\theta$

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

Derivatives, Integrals: $\frac{d}{dt}t^n = nt^{n-1}$ and $\int t^n\,dt = \frac{1}{n+1}t^{n+1}$

Circumference: $C = 2\pi r$

Sphere area, volume: $A = 4\pi r^2$, $V = \frac{4}{3}\pi r^3$

Chapter 2: One-Dimensional Motion

Displacement: $\Delta x = x_f - x_0$

Constant velocity: $x_f = x_0 + vt$ or $\Delta x = vt$

Kinematics: $v_f = v_0 + at$

$\Delta x = v_0 t + \frac{1}{2}at^2$

$v_f^2 = v_0^2 + 2a\Delta x$

$v_f + v_0 = 2\Delta x/t$

Velocity: $v_{\text{avg}} = (x_f - x_0)/(t_f - t_0)$, $v(t) = dx/dt$

Acceleration: $a_{\text{avg}} = (v_f - v_0)/(t_f - t_0)$, $a(t) = dv/dt$

Acceleration due to gravity: $g = 9.8\ \text{m/s}^2$

Chapter 3: Two- and Three-Dimensional Motion

Position vector: $\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$

Average velocity $\vec{v}_{\text{avg}} = (\vec{r}_f - \vec{r}_0)/(t_f - t_0)$

Instantaneous velocity: $\vec{v}(t) = d\vec{r}/dt$

Average acceleration: $\vec{a}_{\text{avg}} = (\vec{v}_f - \vec{v}_0)/(t_f - t_0)$

Instantaneous acceleration: $\vec{a}(t) = d\vec{v}/dt$

Radial acceleration: $a_{\text{rad}} = v^2/r = 4\pi^2 r/T^2$

Chapter 4: Newton's Laws of Motion

First Law: $\vec{F}_{\text{net}} = 0 \longleftrightarrow \vec{v} = \text{constant}$

Second Law: $\vec{F}_{\text{net}} = m\vec{a}$

Third Law: $\vec{F}_{12} = -\vec{F}_{21}$

Chapter 5: Applying Newton's Laws

Kinetic and static friction: $f_k = \mu_k F_N$ and $f_s \le \mu_s F_N$

Normal force: $F_N = mg$ on horizontal surface,
$F_N = mg\cos\theta$ on incline

Chapter 6: Work and Kinetic Energy

Work done by a constant force: $W = \vec{F} \cdot \vec{s} = Fs\cos\theta$

Kinetic energy: $K = \frac{1}{2}mv^2$

Work-energy theorem: $W_{\text{tot}} = K_2 - K_1 = \Delta K$

Work by a non-constant force: $W_{a\to b} = \int_a^b \vec{F} \cdot d\vec{r}$

Power: $P = \Delta W/\Delta t$ or dW/dt

$P = \vec{F} \cdot \vec{v}$

Chapter 7: Potential Energy and Energy Conservation

Hooke's Law: $F_x = kx$

Work done by a spring: $W = \frac{1}{2}k(x_0^2 - x_f^2)$

Work done by gravity: $W = -mg\Delta y$

Gravitational potential energy: $U_g = mgh$

Elastic potential energy: $U_E = \frac{1}{2}kx^2$

Conservation: $(K + U_g + U_E)_0 + W_{\text{other}} = (K + U_g + U_E)_f$

Force and Potential Energy: $F_x = -dU(x)/dx$

Conservative forces: $W_{\text{ab}} = U_{\text{a}} - U_{\text{b}} = -\Delta U$

Chapter 8: Momentum, Impulse, and Collisions

Momentum: $\vec{p} = m\vec{v}$

Force and momentum: $\vec{F} = \Delta\vec{p}/\Delta t$ or $d\vec{p}/dt$

Impulse: $\vec{J} = \Delta\vec{p} = m\Delta\vec{v} = \vec{F}_{\text{avg}}\Delta t$

$\vec{J} = \int_{t_1}^{t_2} \vec{F}(t)\,dt$

Conservation: $m_A\vec{v}_A + m_B\vec{v}_B + \ldots = m_A\vec{v}_A{}' + m_B\vec{v}_B{}' + \ldots$
($\vec{v}_A{}'$, $\vec{v}_B{}'$ are post-collision velocities)

Completely inelastic collision: $m_A\vec{v}_A + m_B\vec{v}_B = (m_A + m_B)\vec{v}_f$

1-D Elastic collisions: $v_A + v_A' = v_B + v_B'$

Center of mass: $\vec{r}_{\text{CM}} = (m_1\vec{r}_1 + m_2\vec{r}_2 + \ldots)/(m_1 + m_2 + \ldots)$

Chapter 9: Rotation of Rigid Bodies

Angular displacement: $\Delta\theta = \theta_f - \theta_0$

Constant velocity: $\theta_f = \theta_0 + \omega t$ or $\Delta\theta = \omega t$

Kinematics: $\omega_f = \omega_0 + \alpha t$

$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega_f^2 = \omega_0^2 + 2\alpha\Delta\theta$

$\omega_f + \omega_0 = 2\Delta\theta/t$

Velocity: $\omega_{\text{avg}} = (\theta_f - \theta_0)/(t_f - t_0)$, $\omega(t) = d\theta/dt$

Acceleration: $\alpha_{\text{avg}} = (\omega_f - \omega_0)/(t_f - t_0)$, $\alpha(t) = d\omega/dt$

Angular $\rightarrow$ tangential: $\Delta s = r\Delta\theta$, $v_{\tan} = r\omega$, $a_{\tan} = r\alpha$

Radial acceleration: $a_{\text{rad}} = r\omega^2$

Rotational kinetic energy: $K_{\text{rot}} = \frac{1}{2}I\omega^2$

CM Moment of Inertia: Point mass, mr^2. Disk, $\frac{1}{2}mR^2$. Ring, mR^2.
Spherical shell, $\frac{2}{3}mR^2$. Sphere, $\frac{2}{5}mR^2$.
Rod (about center), $\frac{1}{12}mL^2$

Parallel axis theorem: $I = I_{\text{CM}} + md^2$

Chapter 10: Dynamics of Rotational Motion

Torque (magnitude):	$\tau = rF\sin\theta$
Torque (vector):	$\vec{\tau} = \vec{r} \times \vec{F}$
Newton's 2nd Law:	$\tau_{\text{net}} = I\alpha$
Translation/rotation:	$K = \frac{1}{2}mv_{\text{cm}}^2 + \frac{1}{2}I_{\text{cm}}\omega^2$
No-slip condition:	$v_{\text{cm}} = R\omega$
Work done by constant torque:	$W = \tau\Delta\theta$
Work-energy theorem:	$W_{\text{tot}} = \frac{1}{2}I\omega_f^2 - \frac{1}{2}I\omega_0^2$
Angular momentum:	$\vec{L} = \vec{r} \times \vec{p}$ (particle)
	$\vec{L} = I\vec{\omega}$ (rigid body rotating about axis)
Conservation of angular momentum:	$I_A\omega_A + I_B\omega_B = I'_A\omega'_A + I'_B\omega'_B$
	(primes indicate 'final')

Chapter 11: Static Equilibrium

Static equilibrium conditions:	$\vec{F}_{\text{net}} = 0$
	$\vec{\tau}_{\text{net}} = 0$ about any point

Chapter 12: Fluid Mechanics

Density:	$\rho = m/V$ or $m = \rho V$
Density of water:	$\rho_{\text{H}_2\text{O}} = 1000 \text{ kg/m}^3$
Pressure:	$P = F/A$
Atmospheric pressure:	$P_{\text{atm}} = 1.01 \times 10^5$ Pa
Fluid pressure:	$P = P_0 + \rho g h$
Absolute pressure	$P_{\text{abs}} = P_g + P_{\text{atm}}$
Buoyant force:	$F_B = \rho_f g V_{\text{obj}}$
Volume flow rate:	$dV/dt = Av$
Continuity equation:	$A_1v_1 = A_2v_2$ (incompressible fluid)
Bernoulli Equation:	$P + \rho g h + \frac{1}{2}\rho v^2 = \text{constant}$

Chapter 13: Gravitation

Gravitational constant:	$G = 6.67 \times 10^{-11}$ N·m^2/kg^2
Mass of the Earth:	$M_E = 5.97 \times 10^{24}$ kg
Radius of the Earth:	$R_E = 6.38 \times 10^6$ m
Force of gravity:	$F_G = GMm/r^2$
Local acceleration due to gravity:	$g = GM_E/R_E^2$
Gravitational potential energy:	$U = -GMm/r$
Orbits:	$v = 2\pi r/T$
	$v^2 = GM/r$
	$T^2 = 4\pi^2 r^3/(GM)$ (Kepler's Law)
	$T^2/r^3 = \text{constant} = 4\pi^2/(GM)$
Escape velocity from surface:	$v_{\text{esc}} = \sqrt{2GM/R}$, R = planet radius

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