

University Physics I Equation Sheet and Homework and Test Instructions

It is imperative that your work be *neat* and *clear*. To receive full credit for a problem, your work must convincingly demonstrate that you understand the physics behind that problem. This means not only providing the correct answer but also showing how you obtained your answer. There should always be a symbolic expression for any formula. The symbolic equation is what you should manipulate, then, substitute in your numbers, with units. Report final answers with correct units and vector expressions. There should be enough English to give the reader some idea of what you are doing without looking at the math, and the diagrams need to be big enough (and neat enough) that they can be clearly read.

Equations for the first test:

Vectors have magnitude and direction. Many of the quantities below are vectors, such as position, velocity and acceleration. In one dimension, the sign is enough to denote direction, so explicit vector notation is not always used below. In more dimensions, the following notation is recommended.

$$\vec{r} = r\hat{r} \quad \text{where} \quad r = |\vec{r}| \equiv \text{length of } \vec{r} \quad \text{and} \quad \hat{r} = \frac{\vec{r}}{r} \equiv \text{direction of } \vec{r}$$

Uniformly accelerated motion:

$$x(t) = x_0 + v_{0x}t + \frac{1}{2}at^2 \quad \Delta x = v_{0x}\Delta t + \frac{1}{2}a_x\Delta t^2 \quad \Delta x = x_f - x_i = x(t) - x_0$$

$$v_x(t) = v_{0x} + a_x t \quad v_f^2 = v_i^2 + 2\vec{a} \cdot \Delta \vec{r} \quad a_g = g \sin \theta$$

$$v_{x,av} = \frac{\Delta x}{\Delta t} \quad v(t) = \frac{dx}{dt}$$

$$\vec{a}_{av} = \frac{\Delta \vec{v}}{\Delta t} \quad a_x(t) = \frac{dv_x}{dt} = \frac{d^2x}{dt^2}$$

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

Our first conservation law, Conservation of Linear Momentum (for a closed system): $\Delta p_{sys} = 0$

Our first energy we can calculate, kinetic energy for a particle: $K = \frac{1}{2}mv^2$

Coefficient of Restitution:

$$e = -\frac{v_{rel,f}}{v_{rel,i}} = -\frac{(v_{2,f} - v_{1,f})}{(v_{2,i} - v_{1,i})}$$

New equations for the second test:

Our second conservation law, Conservation of Energy (for a closed system):

$$\Sigma E = K_f + U_f + E_{diss} = K_i + U_i + E_{source} = \text{constant}$$

Another way to say this is, if nothing is transferred across the system boundary, $E_{sys,f} = E_{sys,i}$, so: $\Delta E_{sys} = 0$

Relative Reference Frames: $t' = t \quad v' = v - V \quad x' = x - Vt \quad p' = m'v' \quad m' = m$

Finding kinetic energy for a system of n particles:

$$K_{sys} = \sum_{j=1}^n K_j \quad K_{sys} = \frac{1}{2}Mv_{cm}^2 + \frac{1}{2}\mu v_{rel}^2, \quad \Delta K_{sys} = \frac{1}{2}\mu v_{rel,i}^2(e^2 - 1) \quad \mu = \frac{m_1 \cdot m_2 \cdot \dots}{m_1 + m_2 + \dots}$$

Forces are always vectors, and are used when something is crossing a system boundary.

Notation: $\vec{F}_{by,on}^{type}$ For particles: $\Sigma \vec{F} = \vec{F}_{net} = \frac{\Delta \vec{p}}{\Delta t}$ (really $\frac{d\vec{p}}{dt}$) $\Sigma \vec{F} = m\vec{a} \quad \Delta \vec{p} = I = \int_{t_i}^{t_f} \vec{F} dt$

For systems: $\vec{F}_{ext} = \frac{\Delta \vec{p}_{sys}}{\Delta t}$

New equations for the third test:

Dot Product (3-D):

$$\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z = AB \cos \theta$$

Magnitude of Cross Product:

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

Springs:

Hooke's Law: $F_{spr} = -k(x - x_0)$ Spring Potential Energy: $|\Delta U_{spr}| = \left| \int_{x_0}^x -F_{spr} dx \right| = \frac{1}{2}k(x - x_0)^2$

System acted upon by an external force (and therefore not closed):

$$K_f + U_f + E_{diss} = K_i + U_i + E_{source} + W \quad \Delta E = W \quad \text{For a constant force: } W = \vec{F}_{ext} \cdot \Delta \vec{x}$$

Power:

$$P = \frac{dE}{dt} \quad \text{For constant force: } P_{av} = \frac{\Delta E}{\Delta t} = \frac{F \Delta x}{\Delta t} = F_{ext} v_{ave}$$

Frictional Forces:

$$F_{12}^k = \mu_k F_{12}^n \quad F_{12}^s \leq \mu_s F_{12}^n$$

Angular Momentum:

$$\vec{L} = I\vec{\omega} \quad \text{and} \quad L = I\omega \quad \text{For a particle, } \vec{L} = \vec{r} \times \vec{p} \quad \text{and} \quad L = rp \sin \theta \quad (\text{if } \vec{r} \perp \vec{p}, \text{ then } |L| = |rp|)$$

Rotational Inertia: $I_{disk} = I_{cylinder} = \frac{1}{2}MR^2 \quad I_{hoop} = I_{particle} = MR^2$

Our third conservation law, Conservation of Angular Momentum (closed system):

$$\Delta L = 0$$

Rotational Kinetic Energy: $K_{rot} = \frac{1}{2}I\omega^2$

Torque:

$$\vec{\tau} = \vec{r} \times \vec{F} = I\vec{\alpha} \quad \left(\text{where } \vec{\alpha} = \frac{d\vec{\omega}}{dt} \right) \quad \tau_{ave} = \frac{\Delta L}{\Delta t} \quad \text{If } \vec{r} \perp \vec{F}, \text{ then } \tau = rF = I\alpha$$

Centripetal Acceleration (constant central force): $a_c = \frac{v^2}{r}$

Condition for rolling motion: $v_{cm} = R\omega$ if accelerating, $a_{cm} = R\alpha$

New equations for the fourth test:

Gravity:

$$\vec{F}_{12}^g = -\frac{Gm_1m_2}{(r_{12})^2}\hat{r} \quad U = -\frac{Gm_1m_2}{r_{12}} \quad E_{tot} = K + U = -\frac{Gm_1m_2}{2a} = \text{constant} \quad G = 6.673 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}$$

Periodic Motion:

$$f = \frac{1}{T} \quad \omega = 2\pi f \quad x(t) = A \sin(\omega_0 t + \phi_0) \quad a = \frac{d^2x}{dt^2} = -\omega_0^2 x \quad E_{tot}(t) = \frac{1}{2}m\omega^2 x_{max}^2$$

Damped oscillations:

$$x(t) = Ae^{-\frac{bt}{2m}} \sin(\omega_d t + \phi_0) \quad \omega_d = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}} \quad E(t) = E_0 e^{-\frac{t}{\tau}} \quad \tau = \frac{m}{b} \quad Q = \frac{2\pi\tau}{T}$$

Waves:

$$c = \lambda f \quad T = \frac{1}{f} \quad \omega = 2\pi f \quad k = \frac{2\pi}{\lambda}$$