

**QUIZ 5**  
**FORMULA SHEET**  
**Quiz Date: Friday, March 4, 2005**

For motion in one dimension:

$$v_{\text{av}} = \frac{\Delta x}{\Delta t} \quad \text{Average velocity;}$$

$$v = \frac{dx}{dt} \quad \text{Instantaneous velocity;}$$

For motion in three dimensions:

$$\vec{v} = \frac{d\vec{r}}{dt}; \quad \vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}; \quad \vec{r}(t_1) = \vec{r}_0 + \int_0^{t_1} \vec{v} dt; \quad \vec{v}(t_1) = \vec{v}_0 + \int_0^{t_1} \vec{a} dt .$$

For *constant* acceleration  $\vec{a}$ , if  $\vec{r} = \vec{r}_0$  and  $\vec{v} = \vec{v}_0$  at time  $t = 0$ , then

$$\vec{v}(t) = \vec{v}_0 + \vec{a}t$$

$$\vec{r}(t) = \vec{r}_0 + \vec{v}_0t + \frac{1}{2}\vec{a}t^2 .$$

For one-dimensional motion with constant acceleration  $a$ :

$$v^2 = v_0^2 + 2a(x - x_0) .$$

For circular motion at constant speed  $v$ :

$$a = \frac{v^2}{r} ,$$

where  $r$  is the radius of the circle, and the acceleration is directed towards the center of the circle.

If an object has position  $\vec{r}$  and velocity  $\vec{v}$ , its position and velocity relative to an observer with position  $\vec{r}_0$  and velocity  $\vec{v}_0$  are given respectively by

$$\vec{r}' = \vec{r} - \vec{r}_0 , \quad \vec{v}' = \vec{v} - \vec{v}_0 .$$

Average velocity and acceleration are given by

$$\vec{v}_{\text{average}} = \frac{\Delta\vec{r}}{\Delta t} , \quad \vec{a}_{\text{average}} = \frac{\Delta\vec{v}}{\Delta t} .$$

### Mass, Acceleration, and Force:

$$\vec{\mathbf{F}} = m\vec{\mathbf{a}} \quad (\text{Newton's second law});$$

$$\vec{\mathbf{F}} = -\frac{GMm}{r^2}\hat{\mathbf{r}} \quad (\text{the gravitational force between two particles});$$

$$\vec{\mathbf{F}} = \frac{1}{4\pi\epsilon_0} \frac{Qq}{r^2}\hat{\mathbf{r}} \quad (\text{the electrostatic force between two particles});$$

$$F_x = -kx \quad (\text{Hooke's law});$$

where  $\hat{\mathbf{r}}$  is a unit vector pointing from the particle which is the source of the force, toward the particle on which the force is acting.

### Friction:

$$|\vec{\mathbf{F}}_k| = \mu_k |\vec{\mathbf{N}}| \quad (\text{kinetic friction});$$

$$|\vec{\mathbf{F}}_s| \leq \mu_s |\vec{\mathbf{N}}| \quad (\text{static friction}).$$

### Kinetic Energy and Work:

1 Dimension	3 Dimensions	Description
$W \equiv F\Delta x$	$W \equiv \vec{\mathbf{F}} \cdot \Delta\vec{\mathbf{r}}$	Work done by a constant force $\vec{\mathbf{F}}$
$W \equiv \int F(x) dx$	$W \equiv \int_{\vec{\mathbf{r}}_1}^{\vec{\mathbf{r}}_2} \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$	Work done by a varying force $\vec{\mathbf{F}}$

$$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = |\vec{\mathbf{a}}||\vec{\mathbf{b}}| \cos \theta \quad (\text{scalar (or dot) product of two vectors});$$

$$= a_x b_x + a_y b_y + a_z b_z$$

$$E_k = \frac{1}{2}mv^2 \quad (\text{kinetic energy of a particle});$$

$$W = E_{k,f} - E_{k,i} \quad (\text{work-energy theorem});$$

$$W = \frac{1}{2}kx^2 \quad (\text{work to compress a spring});$$

$$W = mgh \quad (\text{work to lift a body near the surface of the Earth}).$$