

# Physics 2311 Mechanics

## Equation list for Exam I

### Chapter 1 Measurement

Density.  $\rho \equiv M/Vol$

Dimensions for base units: L, M, T

### Chapter 2 Motion in 1-D

Definitions

Displacement.  $\Delta \mathbf{x} = \mathbf{x}_f - \mathbf{x}_i$

Average velocity.  $\vec{v}_{avg} = \frac{\Delta \mathbf{x}}{\Delta t}$

Average speed.  $v_{avg} = \frac{s}{\Delta t}$  ( $s$  is a path length)

Instantaneous velocity.  $\vec{v}_{inst} = \frac{d\mathbf{x}}{dt}$

Instantaneous speed.  $v = |\vec{v}_{inst}|$

Average acceleration.  $\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t}$

Instantaneous acceleration.  $\vec{a}_{inst} = \frac{d\vec{v}}{dt}$

Equations of Motion for Particle Under Constant Acceleration

Final velocity  $v_{xf} = v_{xi} + a_x t$

Average Velocity  $v_{x,avg} = \frac{v_{xi} + v_{xf}}{2}$

Position as function of time:  $x_f = x_i + v_{x,avg} t$

Position as function of time:  $x_f = x_i + v_{xi} t + \frac{1}{2} a_x t^2$

Velocity change related to position change:  $v_f^2 - v_i^2 = 2a(x_f - x_i)$

### Chapter 3 Vectors

Components of a vector given in polar coordinates,  $(r, \theta)$ :  $x = r \cos \theta$ ,  $y = r \sin \theta$ .

Polar coordinates of a vector given in rectangular coords.  $(x, y)$ :

$$r = \sqrt{x^2 + y^2} \quad \text{and} \quad \theta = \tan^{-1}\left(\frac{y}{x}\right)$$

## Chapter 4 Motion in Two Dimensions

Definitions ... (Most of these are very similar to the Ch. 2 equations)

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

Displacement:  $\Delta\vec{r} = \vec{r}_f - \vec{r}_i$

Average velocity:  $\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t}$  . Instantaneous velocity:  $\vec{v}_{inst} = \frac{d\vec{r}}{dt}$

Average acceleration:  $\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t}$  . Instantaneous acceleration:  $\vec{a}_{inst} = \frac{d\vec{v}}{dt}$

For the special case of uniform acceleration ... (very similar to Ch. 2 equations)

Final velocity  $\vec{v}_f = \vec{v}_i + \vec{a}t$

Average Velocity  $\vec{v}_{avg} = \frac{\vec{v}_i + \vec{v}_f}{2}$

Position as function of time:  $\vec{r}_f = \vec{r}_i + \vec{v}_{avg}t$

Position as function of time:  $\vec{r}_f = \vec{r}_i + \vec{v}_i t + \frac{1}{2}\vec{a}t^2$

Velocity change related to position change:  $\vec{v}_f \cdot \vec{v}_f - \vec{v}_i \cdot \vec{v}_i = 2\vec{a} \cdot (\vec{r}_f - \vec{r}_i)$

Projectile Motion ...

Time to reach max height:  $t_{max} = \frac{v_i \sin \theta_i}{g}$  ( $v_i$  is the magnitude of the initial velocity)

Maximum height:  $h_{max} = \frac{v_i^2 \sin^2 \theta}{2g}$

Range:  $R = \frac{v_i^2 \sin 2\theta}{g}$

Uniform circular motion ...

Centripetal acceleration:  $a_c = \frac{v^2}{r}$

Period of circular motion:  $T = \frac{2\pi r}{v}$

Non-uniform circular motion ...

Total acceleration:  $\vec{a} = \vec{a}_r + \vec{a}_t$  (radial + tangential)

where  $a_r = -a_c = \frac{-v^2}{r}$  and  $a_t = \left| \frac{dv}{dt} \right|$

Relative motion ...

A position of the point P is observed by person A is  $\vec{r}_{PA}$  . If person B moves with velocity  $\vec{v}_{BA}$  as seen by person A. Then  $\vec{r}_{PB} = \vec{r}_{PA} - \vec{v}_{BA}t$  gives the position of P as seen by person B.

The velocities of point P observed by A and B are then given by:  $\vec{v}_{PB} = \vec{v}_{PA} - \vec{v}_{BA}$

## Chapter 5 The Laws of Motion

Newton's 1st: when observed from an inertial frame of reference, an object will maintain a constant velocity unless acted upon by some net force.

Newton's 2nd:  $\vec{a} = \frac{\vec{F}_{net}}{m}$

Newton's 3rd:  $\vec{F}_{12} = -\vec{F}_{21}$

Gravitational Force (near Earth's surface).  $\vec{F}_g = m\vec{g}$

Kinetic Friction  $f_k = \mu_k N$

Static Friction  $f_s = F_{app}$  if  $F_{app} \leq f_{s,max}$  where  $f_{s,max} = \mu_s N$

## Chapter 6 Circular Motion and Other Applications of Newton's Laws

For an object in uniform circular motion,  $\Sigma \vec{F} = m\vec{a}_c = \vec{F}_c$

Centripetal force:  $\vec{F}_c = m \frac{v^2}{r} (-\hat{r})$

Tension in a pendulum string (non-uniform circular motion):  $T = mg \cos \theta + m \frac{v^2}{r}$