## Lessons 1 and 2

- Change between rectangular and polar coordinates
- Change between rectangular, cylindrical and spherical coordinates
- Equations of spheres and balls
- Add, subtract and scalar multiply vectors
- Find length of a vector



## Lessons 3 and 4

- Find dot products and cross products of vectors
- Find angle between vectors
- Find vector and scalar projection of one vector on another
- Geometric interpretation of scalar triple product



## Lessons 5 and 6

- Find vector, parametric and symmetric equations of lines
- Differentiate and Integrate vector valued functions
- Find Position, velocity and acceleration given one of these and initial conditions
- Find tangent line to a curve
- Two and three dimensional motion subject to gravitational field



## Lessons 7 and 8

- Find arc length in rectangular or polar form
- Find $\mathbf{T}$
- Find $\kappa$
- $\mathbf{N}$
- Find tangential and normal components of acceleration

Given $\mathbf{r}(t)$

| To Find | Compute |
|---|---|
| $\mathbf{v}$ | $\mathbf{r}'$ |
| speed | $\lvert\mathbf{r}'\rvert$ |
| $\mathbf{a}$ | $\mathbf{r}''$ |
| $\mathbf{T}$ | $\dfrac{\mathbf{r}'}{\lvert\mathbf{r}'\rvert}$ |
| $a_{\mathbf{T}}$ | $\dfrac{\mathbf{r}'\cdot\mathbf{r}''}{\lvert\mathbf{r}'\rvert} = \dfrac{d^2s}{dt^2}$ |

| To Find | Compute |
|---|---|
| $a_{\mathbf{N}}\mathbf{N}$ | $\mathbf{a} - a_{\mathbf{T}}\mathbf{T}$ |
| $a_{\mathbf{N}}$ $= \left(\frac{ds}{dt}\right)^2 \kappa$ | $\lvert a_{\mathbf{N}}\mathbf{N}\rvert =$ $= \dfrac{\lvert\mathbf{r}'\times\mathbf{r}''\rvert}{\lvert\mathbf{r}'\rvert}$ |
| $\mathbf{N} = \frac{1}{\kappa}\frac{d\mathbf{T}}{ds}$ | $a_{\mathbf{N}}\mathbf{N}/a_{\mathbf{N}}$ |
| $\kappa = \dfrac{\lvert\mathbf{r}'\times\mathbf{r}''\rvert}{\lvert\mathbf{r}'\rvert}$ | $a_{\mathbf{N}}/\lvert\mathbf{r}'\rvert^2$ |
| $\kappa = \left\lvert\frac{d\mathbf{T}}{ds}\right\rvert$ | $\frac{\lvert x'y''-y'x''\rvert}{\lvert(x')^2+(y')^2\rvert^{(3/2)}}$ |
| $= \left\lvert\frac{d\phi}{ds}\right\rvert$ | $\frac{\lvert f''\rvert}{\lvert 1+(f')^2\rvert^{(3/2)}}$ |



## Lessons 9 and 10

- Find equations of planes
- Find angle between planes
- Find distance from point to plane and between two parallel planes
- Find traces of surfaces
- Find level curves and contour curves



## Lessons 11 and 12

- Find limits of functions of two or three variables
- Determine when limits do not exist
- Determine points of continuity
- Find partial derivatives