1 1D Motion

1.1 Formulas

For a vector $\vec{r} = (x, y)$, $x = r\cos\theta$ and $y = r\sin\theta$

Radians versus degrees: $\theta_{\text{radians}} = \theta_{\text{degrees}}\pi/180$

Arc Length: $s = r\Delta\theta$, $r = \sqrt{r_x^2 + r_y^2}$

$\theta = a\tan(r_y/r_x) = \tan^{-1}(r_y/r_x)$.

Area of circle: πr^2

Volume of sphere: $\frac{4}{3}\pi r^3$

Surface area of sphere: $4\pi r^2$

$\log(AB) = \log A + \log B$; $\log(A/B) = \log A - \log B$

$ax^2 + bx + c = 0 \implies x = (-b \pm \sqrt{b^2 - 4ac})/2a$

Quantity and Units:

- Position, m
- Time, s
- Mass, kg
- Velocity, m/s
- Acceleration, m/s^2
- Energy, Joules = kg m^2/s^2
- Force, Newtons = kg m/s^2

Velocity: $\overline{v} = \frac{\Delta x}{\Delta t}$ $\qquad v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$

Acceleration: $a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$

Speed: Absolute value (one dimension) of velocity.

Uniform acceleration: $x = x_0 + v_0 t + \frac{1}{2}at^2$

Velocity: $v = v_0 + at$

Velocity and distance: $v^2 = v_0^2 + 2a(x - x_0)$

1.2 Bird and Runner Problem

A runner is jogging in a straight line at a steady $v_r = 5$ km/hr. When the runner is $L = 5$ km from the finish line, a bird begins flying straight from the runner to the finish line at $v_b = 10$ km/hr (2 times as fast as the runner). When the bird reaches the finish line, it turns around and flies directly back to the runner.

(a) What cumulative distance does the bird travel? Even though the bird is a dodo, assume that it occupies only one point in space (a "zero" length bird), travels in a straight line, and that it can turn without loss of speed. Answer in units of km.

(b) After this first encounter, the bird then turns around and flies from the runner back to the finish line, turns around again and flies back to the runner. The bird repeats the back and forth trips until the runner

reaches the finish line. How far does the bird travel from the beginning (including the distance traveled to the first encounter)? Answer in units of km.

1.3 Dropped Tennis Ball Problem

A tennis ball is dropped from 1.2 m above the ground. It rebounds to a height of 1 m.

(a) With what velocity does it hit the ground?

The acceleration of gravity is 9.8 m/s^2. (Let down be negative.) Answer in units of m/s.

(b) With what velocity does it leave the ground? Answer in units of m/s.

(c) If the tennis ball were in contact with the ground for 0.01 s, find the acceleration given to the tennis ball by the ground. Answer in units of m/s^2.

1.4 Reconnaissance Plane Problem

A reconnaissance plane flies 600 km away from its base at 400 m/s, then flies back to its base at 600 m/s.

What is its average speed? Answer in units of m/s.