Chapter 1 – Concepts of Motion

This chapter introduces the ideas necessary to quantify motion. The first step in coming to grips with motion is to have a way of labeling the location of an object as it moves. The objects considered are assumed to be small enough to be considered particles. This means that the location of the object can be denoted by a single point. In one dimension, the location is defined by a series of values of x or y depending on whether the object is moving along the x or y axis. In two dimensions, each point is defined by a series of coordinate pairs x and y. Before the coordinates can be defined, you have to pick an origin and directions for the x and y axes. To finish the graphical representation of the particle’s motion, each location in the series is assigned a time. Therefore the position of the particle as it moves is represented by a series of points, (x, y, t). The same information is can be summarized by drawing a position vector from the origin to the particle. The arrow end of the position vector, \( \mathbf{r}(t) \), follows the object as it moves through space and time while the tail end is fixed at the origin.

During the time interval \( \Delta t = t_2 - t_1 \), the position vector of the object changes from \( \mathbf{r}_1 = \mathbf{r}(t_1) \) to \( \mathbf{r}_2 = \mathbf{r}(t_2) \). The object’s displacement vector during that time interval is \( \Delta \mathbf{r} = \mathbf{r}_2 - \mathbf{r}_1 \). The rate of change of the displacement vector is just the average velocity vector over that time interval, \( \mathbf{v}_{\text{average}} = \Delta \mathbf{r} / \Delta t \). If the position vector is given for 10 different times, the average velocity vector can be found for 9 intervals as the object moves from point to point, one less than the number of position vectors.

In general, the average velocity vector will change as the object moves through space and time. We will learn that a very useful quantity is the rate of change of the average velocity vector. This quantity is so important it is given a name, the average acceleration vector, \( \mathbf{a}_{\text{average}} = \Delta \mathbf{v} / \Delta t \). \( \mathbf{a}_{\text{average}} \) is the rate of change in the average velocity between neighboring positions as the object moves.

During the Indianapolis 500 auto race, the cars cover 200 laps around an oval that is 2.5 miles long. At the end of the race, the displacement vector for the winning car is zero since the car’s position vector at the end is the same as it was at the start of the race. Consequently the average velocity of the winning car is zero! On the other hand, the average speed is the ratio of the total distance covered divided by the time it took to cover that distance, typically something like 150 mph. The difference between the velocity which is a vector and the speed which is a scalar is extremely important. This
is an example that demonstrates that words with widespread common usage take on related but more nuanced meanings in a physics class. Velocity and speed are very different things and the difference needs to be kept in mind!

The chapter ends with short sections on units, significant figures, and order of magnitude estimates. Being able to change from one unit to another is essential; for example, changing 2.3 miles into meters. The relationship between miles and meters is 1 mile = 1609 meters. Therefore the ratio 1 mile divided by 1609 meters is equal to one since each represents the same distance. If the ratio is one, then the inverse ratio is also one, 1609 meters/1 mile also equals one. Any quantity can be multiplied by one without changing its value. It is surprising how useful this trick of multiplying by one can be in mathematics. Using it to convert from one unit to another is just one example of its utility. 2.3 miles (1609 meters/1 mile) = 3700 meters. Notice that the mile units cancel and also that the number of significant figures is two! Also keep in mind that you ought to expect that the number of meters in a given distance will be much larger than the number of miles in the same distance. Remembering this, will help you avoid multiplying 2.3 miles by (1 mile/1609 meters) y mistake to get 0.0014 meters in 2.3 miles!