Problem Set 1

Motion in one dimension

PHYS-101(en)

1. Units

a. A snail crawls at a speed of 5.00 m/hr. Express this speed in miles/fortnight. Note that a mile corresponds to 1609.31 meters and a "fortnight" lasts 14 days.

b. The density of water is 1 g/cm^3. Express this density in kg/m^3, g/dm^3 and kg/mm^3.

c. The speed of light is 3.0×10^8 m/s. How many km does light travel in 365.24 days?

2. Uncertainty and significant figures

a. State the number of significant figures:

1. 0.00001
2. 10.002
3. 200
4. 2.0×10^3
5. 0.02×11.235
6. $z = xy + y^2$, where $x = 1.2 \pm 0.2$ cm and $y = 2.5 \pm 0.8$ cm

b. A ball is dropped from a given height 5 different times. The recorded times are:

0.23 s, 0.35 s, 0.44 s, 0.33 s, 0.38 s

Calculate the result of this experiment and its estimated error, i.e., the standard error.

3. The train

A regional train follows a straight trajectory. For 1 minute it accelerates at constant acceleration from 0 to 72 km/hr, then it maintains its velocity for 5 minutes, and then, during 2 minutes, it slows down at constant acceleration and comes to a stop. Plot (with numerical values) the position, velocity and acceleration as a function of time.

4. The tortoise and the hare

The tortoise and the hare are racing a distance L along a straight track. The tortoise and hare start with constant velocities, $v_t = C_t$ and $v_h = C_h$ respectively. The hare is not taking this race seriously, so $C_h < C_t$. Once the tortoise arrives at a bridge a distance $L' < L$ from the start, the hare realizes it could lose and accelerates with a constant acceleration a. They tie, both reaching the distance L at the same moment. Sketch a rough plot of the positions of the tortoise and hare as a function of time.

5. The jumping salmon

a. The problem of rectilinear motion under constant acceleration a is given by

$$\ddot{x} = a.$$

Show by integration that the solution is

$$x(t) = \frac{1}{2}at^2 + v_0 t + x_0.$$

Interpret the constants v_0 and x_0. (Remember that $\dot{x}$ is the first derivative of the x with respect to time, i.e. dx/dt, and $\ddot{x}$ is the second derivative of x with respect to time, i.e. d^2x/dt^2.)

b. A salmon jumps vertically out of a lake with an initial velocity of v_0 in the upwards direction. The salmon is subject to a constant acceleration equal to $-g$ due to gravity. Show graphically the vertical position and velocity of the salmon as a function of time.

c. What is the maximum height of the salmon? How long does the fish stay in the air? Assume that $v_0 = 3$ m/s and $g = 10$ m/s^2.

6. Elevator

A person is standing in an elevator. Initially the elevator is at rest. The elevator then begins to ascend to the sixth floor, which is a distance h above the starting point. The elevator undergoes an unknown constant acceleration a for a time t_1. Then the elevator moves at a constant velocity for a time interval $\Delta t_2 = 4t_1$. Finally, the elevator brakes with a deceleration of the same magnitude as the initial acceleration for a time interval $\Delta t_3 = t_1$ in order to come to a stop at the sixth floor. Assume the gravitational constant is given as g. Find the magnitude of the acceleration a.

a. Sketch the position, velocity, and acceleration as a function of time.

b. Briefly explain how you intend to model this problem and write down your strategy before solving it.

c. Use numbers from your everyday experience to estimate the height h and the time t_1 and check if your answer makes sense.