Fall 2021

APPLIED PHYSICS - LAB

Lab-3

- Solutions to Lab-3
- Velocity vs Speed
- Accelerated bodies
- Problems

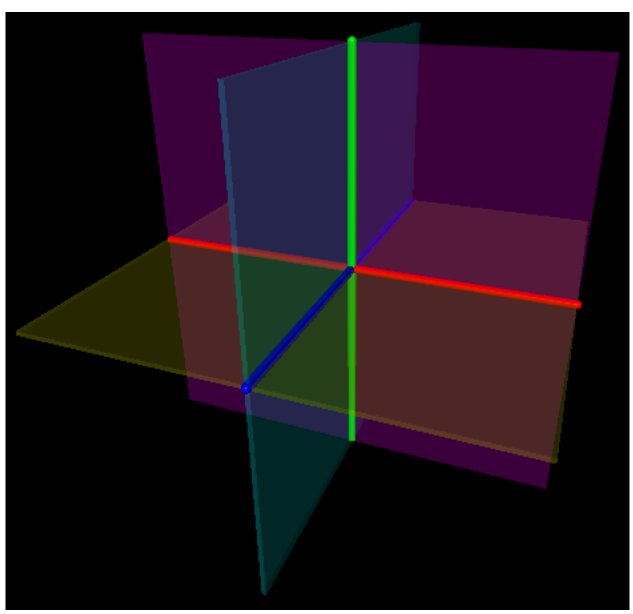
VPython documentation
VPython vector operations
Vpython basic mathematics

Solution to Lab-3:

```
GlowScript 3.1 VPython
from visual import *

x_axis = curve(pos=[vector(-5,0,0),vector(5,0,0)], color=color.red, radius=0.1)
y_axis = curve(pos=[vector(0,-5,0),vector(0,5,0)], color=color.green, radius=0.1)
z_axis = curve(pos=[vector(0,0,-5),vector(0,0,5)], color=color.blue, radius=0.1)

xy = box(pos=vector(0,0,0), size=vector(10,10,0.1), opacity=0.2, color=vector(1,0,1))
yz = box(pos=vector(0,0,0), size=vector(0.1,10,10), opacity=0.2, color=vector(0,1,1))
xz = box(pos=vector(0,0,0), size=vector(10,0.1,10), opacity=0.2, color=vector(1,1,0))
```



Velocity vs speed:

In this lab, we will learn how to understand and solve problems with implementation of all the formulas we learned in the lectures. We will first begin with calculating the average velocity and speed. To calculate these we need displacement, distance and time period. All the mathematical notations must be converted into proper variables.

$velocity_{avg} = \Delta x/\Delta t$ → `vel_avg = del_x / del_t`

$speed = \Delta d/\Delta t$ → `sp = del_d / del_t`

Where, of course, the variables `del_x = mag(x2-x1)` and `x2` and `x1` are the one dimensional final and initial positions, respectively. Hope you are clever enough to decide `del_d` and `del_t` now.

Consider the following problem: Michael Phelps, a competitive swimmer, (28 olympic medals) made a world record in Beijing Olympics 2008 for swimming 200 meters in 1 minute and 42.96 seconds.

TASK ↦ Calculate and print the average velocity and speed with proper units.

But here's the problem, the swimming race was in a 50 meters pool which means that the competitors have to go through four laps to finish the race. Following table shows the race data.

Lap #	Total distance covered	Total time taken
1	50 m	24.31 sec
2	100 m	50.29 sec
3	150 m	1 min 16.84 sec
4	200 m	1 min 42.96 sec

TASK ↦ Calculate and print the velocity and speed for all four laps.

Let us now solve another problem:

TASK ↦ **•P32** The position of a baseball relative to home plate changes from $\langle 15,8,-3\rangle$ m to $\langle 20,6,-1\rangle$ m in 0.1 s. As a vector, write the average velocity of the baseball during this time interval.

The calculation of average velocity as a vector means that we need to calculate `vel_avg_x`, `vel_avg_y` and `vel_avg_z` using proper variables and units.

Accelerated Bodies:

Read the following solved example and implement the solution in vpython.

One of the most dramatic videos on the web (but entirely fictitious) supposedly shows a man sliding along a long water slide and then being launched into the air to land in a water pool. Let's attach some reasonable numbers to such a flight to calculate the velocity with which the man would have hit the water. Figure 4-15*a* indicates the launch and landing sites and includes a superimposed coordinate system with its origin conveniently located at the launch site. From the video we take the horizontal flight distance as $D = 20.0$ m, the flight time as $t = 2.50$ s, and the launch angle as $\theta_0 = 40.0°$. Find the magnitude of the velocity at launch and at landing.

KEY IDEAS

(1) For projectile motion, we can apply the equations for constant acceleration along the horizontal and vertical axes *separately*. (2) Throughout the flight, the vertical acceleration is $a_y = -g = -9.8$ m/s and the horizontal acceleration is $a_x = 0$.

Calculations: In most projectile problems, the initial challenge is to figure out where to start. There is nothing wrong with trying out various equations, to see if we can somehow get to the velocities. But here is a clue. Because we are going to apply the constant-acceleration equations separately to the x and y motions, we should find the horizontal and vertical components of the velocities at launch and at landing. For each site, we can then combine the velocity components to get the velocity.

Because we know the horizontal displacement $D = 20.0$ m, let's start with the horizontal motion. Since $a_x = 0$,

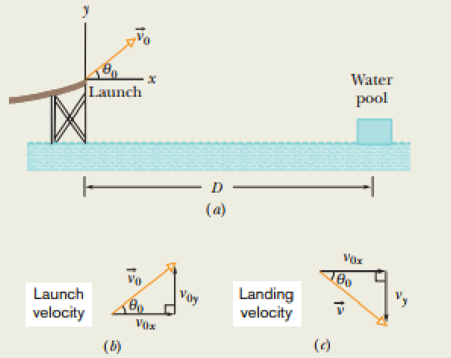


Figure 4-15 (*a*) Launch from a water slide, to land in a water pool. The velocity at (*b*) launch and (*c*) landing.

we know that the horizontal velocity component v_x is constant during the flight and thus is always equal to the horizontal component v_{0x} at launch. We can relate that component, the displacement $x - x_0$, and the flight time $t = 2.50$ s with Eq. 2-15:

$$x - x_0 = v_{0x}t + \tfrac{1}{2}a_x t^2. \tag{4-32}$$

Substituting $a_x = 0$, this becomes Eq. 4-21. With $x - x_0 = D$, we then write

$$20 \text{ m} = v_{0x}(2.50 \text{ s}) + \tfrac{1}{2}(0)(2.50 \text{ s})^2$$
$$v_{0x} = 8.00 \text{ m/s}.$$

That is a component of the launch velocity, but we need the magnitude of the full vector, as shown in Fig. 4-15*b*, where the components form the legs of a right triangle and the full vector forms the hypotenuse. We can then apply a trig definition to find the magnitude of the full velocity at launch:

$$\cos\theta_0 = \frac{v_{0x}}{v_0},$$

and so

$$v_0 = \frac{v_{0x}}{\cos\theta_0} = \frac{8.00 \text{ m/s}}{\cos 40°}$$
$$= 10.44 \text{ m/s} \approx 10.4 \text{ m/s}. \quad \text{(Answer)}$$

Now let's go after the magnitude v of the landing velocity. We already know the horizontal component, which does not change from its initial value of 8.00 m/s. To find the vertical component v_y and because we know the elapsed time $t =$ 2.50 s and the vertical acceleration $a_y = -9.8 \text{ m/s}^2$, let's rewrite Eq. 2-11 as

$$v_y = v_{0y} + a_y t$$

and then (from Fig. 4-15*b*) as

$$v_y = v_0 \sin \theta_0 + a_y t. \qquad (4\text{-}33)$$

Substituting $a_y = -g$, this becomes Eq. 4-23. We can then write

$$v_y = (10.44 \text{ m/s}) \sin (40.0°) - (9.8 \text{ m/s}^2)(2.50 \text{ s})$$
$$= -17.78 \text{ m/s}.$$

Now that we know both components of the landing velocity, we use Eq. 3-6 to find the velocity magnitude:

$$v = \sqrt{v_x^2 + v_y^2}$$
$$= \sqrt{(8.00 \text{ m/s})^2 + (-17.78 \text{ m/s})^2}$$
$$= 19.49 \text{ m/s}^2 \approx 19.5 \text{ m/s}. \qquad \text{(Answer)}$$

Solve and submit the following problems:

•25 The current world-record motorcycle jump is 77.0 m, set by Jason Renie. Assume that he left the take-off ramp at 12.0º to the horizontal and that the take-off and landing heights are the same. Neglecting air drag, determine his take-off speed.

••35 **SSM** A rifle that shoots bullets at 460 m/s is to be aimed at a target 45.7 m away. If the center of the target is level with the rifle, how high above the target must the rifle barrel be pointed so that the bullet hits dead center?