Lab Guide
Density Lab

I. Objectives

After completing this simulation, the student will be able to:
1. Determine the volume of an object by water displacement
2. Determine the mass of an object on balance
3. Decide if an object will float in a fluid if the densities are known
4. Find the force of gravity on an object
5. Find the buoyant force on an object

II. User Interface and Simulation Features

In this simulation, you can measure the masses and volumes of several “hunks” of different materials. The volume is measured by dragging the object into a graduated cylinder that is partially filled with water, and observing the increase in volume, which shown on a digital display. The mass is measured by placing the object on a balance. There is also a digital display of the mass of the object. You can also see if each object will float in a container of a liquid. You can vary the density of the fluid using a slider bar. You can place more than one object in the scale or in the container of water, but only one object at a time in the graduated cylinder.

III. Questions

In each case when you start a simulation for the following questions, reset the values using the icon in the control panel at the left side of the screen. Each question assumes that you have done this. Then set only the values indicated in the question.

<u>a. Introductory Level</u>

1. Select the brick-red cube of material. Place it on the balance. What is its mass in grams? Convert this mass to kilograms. Now place the cube in the graduated cylinder. What is its volume in mL? Convert this volume to liters. Divide the mass in grams by the volume in mL. This is the density of the object. What is the density of this cube? Determine the density of the cube in $\mathrm{g/mL}$. Now determine the density in $\mathrm{kg/L}$. What do you notice about these two density values?

2. What is the mass of the banana? What is the volume of the banana? Calculate the density of the banana.

3. Measure the mass of the green “pill” in grams. What is this value in kilograms? What is its volume in mL? Calculate the density of the green “pill.” What would be the mass of one liter of this material?

4. What is the mass in kg of the blue-and-white variegated object? What is the magnitude of the force of gravity, $F_g = mg$, on this object in newtons? Place the object in the container of water

(density of $1.0\,\mathrm{g/mL}$). Does this object float in water? What is the magnitude of the buoyant force on this object when it is in equilibrium in the water?

5. Which is denser, the marble pyramid or the red “pill”? What is the ratio of the density of the marble pyramid to the red “pill”? Which of these will float in water?

<u>b. Intermediate Level</u>

6. What is the density of the blue disk with the triangular cutout? Does it float in water? Is it more likely wood, metal, or a plastic?

7. What is the density of the yellow cylinder? Will it float in water? Suppose the liquid in the container was bromoform (density of $2.9\,\mathrm{g/mL}$). Will the yellow cylinder float in bromoform? Try it.

8. Will the blue hunk of pipe (shaped like the letter S) float in water? Set the density of the liquid in the container to that of tetrachloromethane, $1.60\,\mathrm{g/mL}$. Will the pipe float in tetrachloromethane?

9. What is the least dense object provided in the simulation? What is its density? Will it float in water? Will it float in methanol (density of $0.8\,\mathrm{g/mL}$). What would the density of the liquid in the container need to be for this object to sink?

<u>c. Advanced Level</u>

10. Will the green “pill” float in liquid gallium (density of $5.9\,\mathrm{g/mL}$)? Can you cause the green “pill” to float at all under any circumstances? Why or why not?

11. Suppose that you have no scale to measure mass and no graduated cylinder to measure volume. You do, however, have quite a number of containers of liquid of different known densities, ranging from $0.6\,\mathrm{g/mL}$ to $2.7\,\mathrm{g/mL}$. How would you list the hunks of material in order of increasing density? Try it.

Lab Guide
U Tube

I. Objectives

After completing this simulation, the student will be able to:
1. Describe balancing pressures in a U-tube with different fluids
2. Explain the effect of gas pressure in the headspace of a U-tube
3. Show a relationship between fluid column height and pressure
4. Show a relationship between column height and force of gravity.

II. User Interface and Simulation Features

In this simulation you are provided with a U-tube with a fixed amount of blue fluid in it. You can choose the density of the blue fluid within a range. You can also have a red fluid on one side of the tube and a green fluid on the other side. For these two fluids, you can choose both the density and the height of the column. You can measure the surface pressure difference across the two arms of the tube. These settings are made by means of slider bars. There is a stylized dial gauge to show the surface pressure difference ΔP between the arms. This acts as a center-zero gauge with the pointer in the direction of the higher pressure. Each fluid interface shows the total column height measured from the bottom of the tube and the pressure at that point. A graph plots pressure versus column height for both arms, with the gas in the headspace graphed in black.

III. Questions

In each case when you start a simulation for the following questions, reset the values using the icon in the control panel at the left side of the screen. Each question assumes that you have done this. Then set only the values indicated in the question.

<u>a. Introductory Level</u>

1. Set the depth of both the green and red fluids to zero. Is the blue fluid at the same level in both arms? Why not? Set the surface pressure difference to zero. Did the level of the blue fluid equalize between the arms?

2. Set the surface pressure difference to zero. Look at the heights of the red and green fluids. Which fluid is higher? What is the pressure at the top of the red fluid? What is the pressure at the top of the green fluid? Why do both columns not have the same pressure at the same colored fluid height? Which fluid has a greater density, the red or the green fluid?

3. Adjust the surface pressure difference so that the red and green fluids are at the same height above the bottom of the U-tube. What value is the surface pressure difference? Does the left or right arm of the tube experience the higher surface pressure? Look at the black vertical lines on the graph. Does the right line show a pressure of about $0.2\ \mathrm{kPa}$ higher than the left line?

4. Set the depths of the red and green fluids to zero. Assume that the blue fluid is water with the default density of $1.0\,\mathrm{g/mL}$. How high can you get the water to rise in one arm of the tube?

What is the difference in height between the arms? What did you have to do to accomplish this? Divide the surface pressure difference by the difference in height of the water columns. What is this ratio?

5. Set the depths of the red and green fluids to zero. By adjusting the surface pressure difference, move the height of the water column in the left arm exactly $6.00\ \mathrm{cm}$. How far did the height of the water column in the right arm move? What does this tell you about the diameters and cross-sectional areas of the two arms?

b. Intermediate Level

6. Set the surface pressure difference to zero. Can you find a height of green fluid that will cause the total fluid height in each arm to be the same? What is the height of green fluid? In this situation, how much pressure is exerted at the bottom of the column of the red fluid?

7. Set the surface pressure difference to zero. Find the height of green fluid that will cause the total fluid height in each arm to be the same. What is the pressure difference between the bottom of the red fluid and the bottom of the green fluid? How much higher is the blue fluid in the aright arm than in the left? Is are the difference in height and pressure difference consistent with the ratio you calculated in Item 4?

c. Advanced Level

8. Why do we not mention the column height of the blue fluid? Does the total column height matter or not? What quantity relating to the columns of blue fluid does matter in our calculations?

9. Take a closer look at the ratio we calculated in Item 4. Can we use this ratio and the density of water to calculate the force of gravity on a certain mass of water? What is the force of gravity on $1.00\ \mathrm{kg}$ of blue fluid (water). Show how you might do this.

Lab Guide
Buoyancy Lab

I. Objectives

After completing this simulation, the student will be able to:
1. Calculate buoyant force on an object in a fluid
2. Calculate the total force on an object in a fluid, neglecting viscosity and friction
3. Describe how a moving object behaves as it touches the surface of a fluid from above or below
4. Predict whether an object of known density will float in a liquid of known density
5. Apply the principle of buoyancy to the physical world.

II. User Interface and Simulation Features

This simulation consists of a block of matter and a pail of liquid. You can change the density of the liquid. You can change the mass and volume of the block. You can click on the block to drag it to a desired starting location. A histogram shows the gravitational force, the buoyant force and the total force on the block at any moment. A digital display give the gravitational force and the buoyant force to two decimal places.

III. Questions

In each case when you start a simulation for the following questions, reset the values using the icon in the control panel at the left side of the screen. Each question assumes that you have done this. Then set only the values indicated in the question.

<u>a. Introductory Level</u>

1. Observe the values for gravitational force and buoyant force. What are they? Which direction does each point? What is the vector sum of these forces (magnitude and direction)? Will the object float? Run the simulation to verify your answer. What happens?

2. Let's do the same thing for a $10.0\ \mathrm{cm}^3$ block of iron (density of $7.8\,\mathrm{g}/\mathrm{cm}^3$). Set the volume and the mass of the block. Keep the density of the liquid in the pail to that of water. What is the total, or net force on the block? After the block is submerged, do any of the forces in the histogram change?

3. Set the object mass to $20\ \mathrm{g}$. Run the simulation. Does it float? Stop the simulation. Drag the block so that it is as far above the water as possible. Run the simulation again.
Is the motion of the block different? How? Is the equilibrium position the same?

4. Set the object mass to $20\ \mathrm{g}$. Drag the block to the bottom of the pail. Run the simulation. Watch the histogram. When do the buoyant force and the total force start to change?

b. Intermediate Level

5. Can you find a volume for which the default mass of $70\ \text{g}$ will just float? Remember Newton's first law of motion! Increase the volume of the object by $5\ \text{cm}^3$ at a time. Run the simulation after each change. What is the necessary volume? What is the ratio of mass to volume? What is the density of the liquid in the pail?

6. Decrease the mass of the object by $5\ \text{g}$ at a time. Run the simulation after each change. Can you find a mass for which the default volume of $50\ \text{cm}^3$ will just float? What is the necessary mass? What is the density of the liquid in the pail?

7. Will aluminum (density = $2.70\,\text{g}/\text{cm}^3$) float in water? Try it. What is the buoyant force on $8\ \text{g}$ of aluminum? For the purposes of this simulation, a volume of $3\ \text{cm}^3$ is close enough. What buoyant force would be necessary to cause this sample of aluminum to float? Would liquid gallium (density = $5.9\,\text{g}/\text{cm}^3$) provide sufficient buoyant force? Try it. How great is the buoyant force if the block of aluminum is completely submerged?

c. Advanced Level

8. When an object floats, but does not start in its equilibrium position, why does it bob up and down upon reaching the surface? Remember Newton's first law.

9. Make an iceberg! Ice has a density of $0.9167\,\text{g}/\text{cm}^3$ under natural conditions when it is in equilibrium with water at $0\ ^\circ\text{C}$. Seawater has a density slightly greater than fresh water, but for our purposes we will use the density of fresh water. Create a $100\ \text{cm}^3$ berg and set the mass to the appropriate value. What is the value of the mass? Drag the iceberg above the water so that it will be part of its parent glacier. Start the simulation, calving the iceberg into the water. How does the direction of the total force change over a period of about a minute?

Lab Guide
Bernoulli's Equation

I. Objectives

After completing this simulation, the student will be able to:
1. Describe the effect of a change in velocity on pressure in a pipe flowing full
2. Describe the effect of a change in cross-sectional area on fluid velocity
3. Describe the effect of head height on pressure
4. Connect Bernoulli's equation to the law of conservation of energy.

II. User Interface and Simulation Features

In this simulation you are presented with two connected sections of pipe through which water flows, a left section and a right section. The pipe is full and water is considered incompressible. The water enters under an applied pressure and velocity that you can vary. You can vary the cross-sectional area of each pipe using the "handle" on the top of the section of pipe. You can vary the height of the pipe above and below an arbitrary zero level, or datum, near the vertical center of the screen, by using the rectangular "handle" in the middle of the pipe. Two histograms show pressure and velocity, one for the left pipe and one for the right pipe. There is a digital display of pressure, velocity, and area. Some rounding takes place in the digital display, and the values may not appear exactly as calculated. Friction in the fluid (viscosity) and friction with the walls of the pipe ("pressure drop") are both ignored in Bernoulli's equation for an ideal liquid.

III. Questions

In each case when you start a simulation for the following questions, reset the values using the icon in the control panel at the left side of the screen. Each question assumes that you have done this. Then set only the values indicated in the question.

<u>a. Introductory Level</u>

1. Run the simulation. What is the relationship between the values for the left pipe compared to the respective values for the right pipe?

2. Increase and decrease the velocity through its full range for the left pipe. Does the velocity in the right pipe change?

3. Increase and decrease the applied pressure through its full range for the left pipe. Does the pressure in the right pipe change?

4. Using the handle on the left pipe, move the center of the pipe from its default vertical position of $0.05\ \mathrm{m}$ to a position of $-0.05\ \mathrm{m}$. How far did you displace the pipe? Did you displace the pipe in the positive or negative direction? How much higher is the right section of pipe now than the left section? Look at the second term in the Bernoulli equation, $\rho g h$. If you substitute m/V for ρ, what is the meaning of the expression in the numerator? What happens to this value as the water flow from the left pipe to the right pipe?

b. Intermediate Level

5. Using the handle on the left pipe, move the center of the pipe from its default vertical position of $0.05\ \mathrm{m}$ to a position of $-0.05\ \mathrm{m}$ .again as you did in Item 4. What would be the change in gravitational potential energy for every kilogram of water moving from the left section of pipe to the right section of pipe? Did any other value change? Which value? What was the amount of the change? Using the fact that a cubic meter of water has a mass of $1000\ \mathrm{kg}$, relate the change in gravitational potential energy to the change in pressure. Was net energy per unit mass gained or lost?

6. Express the second term in Bernoulli's equation, ρgh, in terms of energy in joules. If PV has units of work or energy, how would you express the first term, P in terms of joules?

7. Since water is incompressible, the flow rate Q in m^3/s has to be the same throughout the two pipes. If area is expressed in units of m^2 and velocity is in $\mathrm{m/s}$, what would be an expression for Q in terms of A and v? If you doubled A, how would v change if the flow rate remained constant? Would this relationship remain the same if A were expressed in other units?

8. Set the cross-sectional area of the left pipe to $0.08\ \mathrm{cm}^2$. Set the cross-sectional area of the right pipe to $0.64\ \mathrm{cm}^2$. What is the ratio of the area on the right to the area on the left? If the flow rate must remain constant, how will the velocity on the right compare with the velocity on the left?

c. Advanced Level

9. Consider the third term in Bernoulli's equation, $\frac{1}{2}\rho v^2$. This is a familiar form. Write an expression for this term using the formula for kinetic energy. What is the physical meaning of the expression you came up with?

10. Set the area in the left pipe to $A = 0.08\ \mathrm{cm}^2$ and in the right pipe to $A = 0.76\ \mathrm{cm}^2$. Set the height of the left pipe to $-0.75\ \mathrm{m}$ and of the right pipe to zero. Set the velocity in the left pipe to $v = 0.50\,\mathrm{m/s}$ and the applied pressure in the left pipe to $50\ \mathrm{kPa}$. Consider the assumptions in Bernoulli's equation. What can you say about the energy per liter of flowing water in the left pipe compared to the energy per liter of flowing water in the right pipe?

Lab Guide
Torricelli's Law

I. Objectives

After completing this simulation, the student will be able to:
1. Analyze the dependence of horizontal velocity on depth below the liquid surface
2. Explain the path of a stream of water in terms of the motion of a particle of water.
3. Calculate the horizontal displacement of a stream of water
4. Calculate the elapsed time for a particle of water to strike the ground
5. Determine the angle at which a stream of water strikes the ground.

II. User Interface and Simulation Features

In this simulation, a tank of water has a small hole in its side. The water discharges horizontally from the hole and is immediately in projectile motion. Torricelli's law, $v = \sqrt{2gh}$ gives the initial velocity in the x-direction of a particle of water. You can calculate the trajectory of the water using the two-dimensional motion formulas. You can choose the distance between the fluid surface and the hole. You can change the acceleration due to gravity. The water stream appears as individual droplets that have some randomness to their initial velocity. It is convenient to turn the trails on using the button marked "Trails On/Off".

III. Questions

In each case when you start a simulation for the following questions, reset the values using the icon in the control panel at the left side of the screen. Each question assumes that you have done this. Then set only the values indicated in the question.

<u>a. Introductory Level</u>

1. How far below the surface of the water is the hole located?

2. Using Torricelli's law, what is the initial velocity of the water?

3. If you doubled the distance that the hole is below the surface of the water, what would happen to the magnitude of the initial horizontal velocity? Try this in the simulation. Move the hole in the tank to twice its default position below the surface. Using the equations of two-dimensional motion, what is the time it takes for a particle of water to hit the ground? How far horizontally from the point of discharge should the stream of water hit the ground? What does the simulation report?

4. Where is the hole when horizontal velocity is a maximum value? What is the maximum velocity you can obtain?

5. Calculate the maximum distance the water stream should travel horizontally in this simulation (See Item 4). What does the simulation report?

6. Consider the depth of the tank and its height above ground as shown in the simulation. Which gives you a greater horizontal displacement, a hole higher in the tank or a hole lower in the tank?

b. Intermediate Level

7. Run the simulation. Now set $g = 4\,\mathrm{m/s^2}$. After the water stream equilibrates, do you see a difference in the place where it strikes the ground? Now set $g = 15\,\mathrm{m/s^2}$. Is there a difference now? Does the acceleration of gravity have an effect on the point at which the stream of water strikes the ground?

8. Examine Torricelli's law. Now solve the free-fall equation for Δt. Substitute this expression for Δt and the horizontal velocity from Torricelli's law into $\Delta x = v_x \Delta t$. What happens to the acceleration due to gravity? Mathematically, why is the answer to Item 7 true?

c. Advanced Level

9. Create a series of trails using holes at the following distances from the surface of the water: $0.1\ \mathrm{m}$, $1\ \mathrm{m}$, $2\ \mathrm{m}$, $3\ \mathrm{m}$, $4\ \mathrm{m}$, $6\ \mathrm{m}$, $7.8\ \mathrm{m}$. These paths all seem to converge to a negative slope of about $45°$. Is there a reason for the appearance of $45°$, or is this just a coincidence and do they actually converge to some value that we can calculate?

Lab Guide
Pressure and Depth

I. Objectives

After completing this simulation, the student will be able to:
1. Explain liquid pressure in terms of the force of gravity
2. Describe the additive effect of atmospheric pressure and
3. Compare the relative magnitudes of atmospheric pressure with liquid pressure.
4. Describe the effect of changing the acceleration due to gravity on pressure at depth
5. Describe the pressure and depth relationship of substances denser than water
6. Give practical examples of pressure and depth relationships.

II. User Interface and Simulation Features

This simulation involves a tank of liquid and a pressure sensor. You can vary the atmospheric pressure, density of the liquid, and the acceleration due to gravity by means of slider bars. You can drag the sensor to a desired position in the liquid. A digital display on the sensor gives values for pressure and depth. The small ball at the right side of the sensor must be inside the walls of the tank for it to take measurements. A histogram at the right of the screen shows the variation of pressure with depth.

III. Questions

In each case when you start a simulation for the following questions, reset the values using the icon in the control panel at the left side of the screen. Each question assumes that you have done this. Then set only the values indicated in the question.

<u>a. Introductory Level</u>

1. What is the pressure at the top of the liquid? What is the pressure at a depth of $10\ \mathrm{m}$ below the surface of the liquid? How much pressure was added by the liquid? What is the pressure at $100\ \mathrm{m}$ below the surface? How much of this is due to the liquid? What is the approximate increase in pressure for every meter of depth of liquid?

2. The triple point for a substance is the pressure and temperature at which the gas, liquid and solid states of matter all exist in equilibrium. Suppose the liquid in the tank has a pressure at its triple point that is higher than can be achieved in this simulation. What significance does this have for us? Set the atmospheric pressure to $10\ \mathrm{atm}$. What is the pressure at a depth of $160\ \mathrm{m}$? What part of this pressure does the liquid contribute?

3. Move the pressure sensor closer to the sides of the tank, then closer to the center of the tank. Does the pressure depend on your horizontal location?

b. Intermediate Level

4. What is the depth of the tank in meters? If you have a column of liquid with a horizontal area of 1.00m^2 and as high as the tank, what is the volume of this column?

5. The density of water is $D = 1000\ \text{kg}/\text{m}^3$. What is the mass of the column of water in Item 4? How much force does gravity exert on this mass? Over what area is this force exerted? What is the pressure at the bottom of the column in pascals? Convert this pressure to atmospheres, the unit used in this simulation.

6. The acceleration due to gravity on the mood is about $1/6$ of that on Earth. About what would the value of g_{moon} be? What is the closest value we could use in this simulation? The moon's atmosphere is nearly nonexistent. Suppose we had a tank of non-volatile liquid with density of 1.8 on the mood. What would the pressure be at a depth of $15\ \text{m}$ according to our simulation?

c. Advanced Level

7. Carbon dioxide can be a liquid at a pressure of $5.2\ \text{atm}$. In the liquid state of matter, it has a density of about $1.03\text{g}/\text{cm}^3$ If you had a tank of liquid carbon dioxide under these conditions, what would be the pressure at a depth of $30\ \text{m}$?

8. If the liquid were swirling around in circular motion inside the tank, would this change the pressure at the bottom of the tank? Why or why not?

Lab Guide
Flow Around a Wing

I. Objectives

After completing this simulation, the student will be able to:
1. Describe how the force of lift is produced
2. Discuss the relationship between the forces of lift and gravity
3. Describe the relationship between producing lift and drag
4. Describe the differing requirements of takeoff and cruising flight
5. Define “relative wind”

II. User Interface and Simulation Features

This simulation models the wing of an aircraft in a flow of air. A fan blowing on the wing symbolically produces the airflow. You can choose to turn the audio of the fan on or off. You can vary the velocity of the air by changing the speed of the fan. You can vary the angle of the wing, mass of the wing and the area of the wing by means of slider bars. The range of angle of the wing is intentionally larger than real, for emphasis. The lift, drag and gravitational force vectors are shown around the center of rotation of the wing. A histogram at the right side of the screen shows the relationships between lift, drag and gravity. There is a digital display of lift , gravity and net vertical force.

III. Questions

In each case when you start a simulation for the following questions, reset the values using the icon in the control panel at the left side of the screen. Each question assumes that you have done this. Then set only the values indicated in the question.

<u>a. Introductory Level</u>

1. When an aircraft is taking off, the pilot wants it to be an efficient slow-flying machine. The purpose is to gain altitude rapidly, sacrificing some forward speed for lift, F_L. Set the fan speed to 1. At what wing angle do you obtain maximum lift? Is this enough lift to overcome the force of gravity, F_g? Try fan speed 2. Now do you have enough lift to leave the ground? What is the maximum difference in value between F_L and F_g? At what angle?

2. In practice, a pilot uses maximum power during takeoff. Use fan speed 7. What is the maximum value for F_L? At what wing angle?

3. Once out of the traffic pattern at the airport, the pilot would like to get on to his or her destination, but must get up to the correct altitude first. Sometimes this is done with a “cruise climb” at about 100 knots (about 51m/s). First set the fan speed to 7 and the wing angle to $-45°$ to put yourself in a takeoff and departure climb. Change the angle of the wing through a range of values. What happens to the drag? Fuel is expensive, and we must reduce drag. The wing angle represents the angle the front-to-rear centerline, or chord, of the wing makes with

the direction of air past the aircraft. This mass of air rushing past the aircraft is called the "relative wind" but has little to do with what we usually refer to as wind. It is important when talking about wings and propellers. At this point, the pilot "pushes the nose over" to make a smaller angle between wing and relative wind and throttles back to a fan speed of 5. We still need a value for F_L that is about $50\ \mathrm{N}$ greater than F_g. What values can you get for lift and drag, F_{drag}, that meet this requirement? What wing angle do you have to use to do this?

4. Once the pilot has reached cruising altitude, it is time to stop climbing and concentrate on going fast! Reduce the wing angle even further so that the sum of the vertical forces is as close to zero as possible. What angle did you use? What is the value of F_L? What is the force of drag?

5. As the pilot goes from a cruise climb to cruising speed, the engine has to use less power to maintain altitude, and the pilot usually finds it necessary to reduce the throttle setting even more to keep the engine from turning too fast. Throttle back to fan speed 4 to see if you can stay at the same altitude and reduce drag even further. What are your values for wing angle, F_L, and F_{drag}?

b. Intermediate Level

6. A glider is an aircraft with no engine, a small mass and long wings with lots of surface area. Because it has no engine, it is always falling through the air. In addition to the lift produced by the wings, it must rely on the assistance of the upward vertical movement of the air in atmospheric convection currents. Air in this kind of motion is called a "thermal." Gliders are usually towed into the air by a powered aircraft, but after they are released they can sometimes stay aloft for a long time. Set the wing area to 3.0 (arbitrary units) and the wing mass to $1.7\ \mathrm{kg}$. Set the fan speed to 1. Gliders don't move very fast through the air, but they do have to move! What is the ratio of F_L/F_g? What is the value of F_{drag}? Will the glider fly at this low speed? What force opposes drag? Hint: recall inclined plane problems [Author's comment to ed.: no pun intended].

7. Suppose an aircraft were in a vertical dive. This is a serious aerobatic or military maneuver. Which direction would F_L point in this case? Which way would F_{drag} point?

c. Advanced Level

8. Suppose you were designing a military aircraft that was supposed to fly very fast. Much of the mass is going to be in the engines and the fuel. Set the fan speed to 7. Set the wing mass to $2.0\ \mathrm{kg}$ and the wing area to 1.0, What wing angle would just cause the aircraft to maintain its altitude at this speed? What is the ratio of lift to drag? Change the wing mass. Does it have an effect on the lift to drag ratio? Change the wing area. Does it change the lift? Does it change the drag? Does it change the ratio of lift to drag?

9. Can an aircraft engine overcome drag while climbing? Can it overcome drag while flying horizontally? Can it overcome drag while diving? In addition to the force of thrust on the aircraft, what other force is being added in a vertical dive? After $5.0\ \mathrm{s}$ In free fall, what would an aircraft's vertical velocity be, assuming no initial vertical component of velocity? Compare this

value to the climbing cruise speed in Item 3. Suppose a $3500\ \text{kg}$ aircraft had an engine capable of producing $10000\ \text{N}$ of thrust. If this aircraft went into a vertical dive under full power, what would its downward velocity be after $5.0\ \text{s}$? Ignore air resistance.