**Activity 1: Horizontal Motion**

Open the Kinematics applet on the “Open Educational Resources @ SG” website: <http://tinyurl.com/driving-car>



The simulation has three sections:

* A top panel that shows a car that can move horizontally along the x-axis. Playing the simulation allows time to elapse in the simulation, and the car moves according to whatever rules are set for it—either by a pre-set function or values you can set yourself.
* A middle panel that can show plots of displacement, velocity, and acceleration versus time. As time elapses, the simulation makes plots in the second panel. By default, only the displacement versus time (*x-t*) graph is plotted.
* A bottom section where you can adjust settings in the simulation. You can use the check-boxes next “v=” and “a=” to show velocity versus time and acceleration versus time (the *v-t* and *a-t* graphs).

You can select some pre-set motions using the drop-down menu at the bottom left of the figure. You can **play** (►) the simulation by clicking the appropriate button (click again to pause). You can also **store data** (▼) from a plot by pushing the appropriate button, allowing you to compare multiple plots.

**Investigate**

Try it now … choose the pre-set for “uniform motion = 1” and click Play. Then you can watch the car move and see the *x-t* graph as it is plotted.

1. Describe what the *x-t* graph tells you about the motion of the car.

Choose a **different pre-set** option; watch the car’s motion and look at the *x-t* graph.

Write down which pre-set you chose: \_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. How did the car’s motion and the *x-t* graph differ from “uniform motion = 1”?

*v-t* Graph

Now show the *v-t* graph, by clicking the checkbox next to “v =” at the bottom of the simulation (see the circled part of figure).



Try the pre-set simulation for “uniform motion = 1” again, and compare that with another present, such as “uniform motion = 2”.

1. What do the *v-t* graphs tell you about the motion of the car in these situations?

**Model**

Adjust on your own! Change the setting to “user defined,” and then adjust the values for *x* and for *v* — either by using the slider or by typing a number into the textboxes.

This changes the initial values of *x* and *v* (which can be denoted as *x0* or *v0*, or as *s* and *u*). Try several different starting values for *x* and for *v*, and compare using the **store data** (▼) feature.

1. Write down some **rules** for the relationship between *x* and *v*. We’ll give you an example:

“*x* doesn’t change if *v* is always 0”

**Apply**

The picture shows x-t graphs for two cars. Try to re-create these motions using the simulation!



*Equations for speed = 0:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Equations for uniform motion:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

**ConcepTests 1 & 2!**

**Activity 2: Vertical Motion**

Open another applet on the “Open Educational Resources @ SG” website: <http://tinyurl.com/falling-ball>



Just like for horizontal motion, this simulation has three parts:

* The left panel shows a ball that can be thrown up or dropped down.
* The right panel contains plots of the ball’s motion. By default it plots vertical displacement over time (*y-t* graph): time is plotted horizontally and the ball’s vertical displacement is plotted vertically. Again, you can use the checkboxes to show the vertical velocity or acceleration versus time.
* At the bottom you have controls for the simulation.

The applet again comes with pre-set motions, and the buttons operate the same as before.

**Investigate**

Try it now … choose the pre-set function for “free fall” and click Play. Then you can watch the ball move and see the *y-t* graph as it is plotted.

1. Describe what the *y-t* graph tells you about the motion of the ball.

Choose a **different pre-set** option; watch the ball’s motion and look at the *y-t* graph.

Write down which pre-set you chose: \_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. How did the ball’s motion and the *y-t* graph differ from “free fall”?

**Model**

Adjust on your own! Put in your own values in the simulation. Change the setting to “user defined,” and then you can adjust the value for *y*, *vy* (y-velocity), or *ay* (y-acceleration).

Try several different starting values for *y* and for *vy*, and one or two variations for *ay*. Remember you can **store data** (▼button) from each run to make comparison easier.

1. Write down some rules for the relationships among *y*, and *vy*, and *ay*. Here’s an example:

“y changes if v is always 0”

**Apply**

Here are plots for two balls, E and F. Try to re-create these with the simulation.



How is vertical motion different from horizontal motion?

***Conclusions for vertical motion:***

*Displacement:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Velocity:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

**ConcepTests 3 & 4!**

**Activity 3: Projectile Motion**

**ConcepTests 5!**

Open yet another applet on the “Open Educational Resources @ SG” website: <http://tinyurl.com/two-cannons>



The simulation shows two objects that are thrown at each other while experiencing gravity. The gravity is simulated by acceleration in the vertical direction: *ay* = -9.81 m/s2. This is the acceleration due to gravity on Earth. It is again possible to change many of the settings, such as the initial velocity of the left projectile (*v*1), the velocity of the right projectile (*v*2) and the angle with respect to the horizontal at which the left projectile is shot (*θ*1).

**Investigate**

Try it now … reset the applet to its original settings (the button between Store Data and FullScreen) and click Play.

1. Describe what you observe.

Change the location or initial velocity of one or both of the projectiles (*v*1 and *v*2).

First you can drag the “cannons” to different positions. Then, using your mouse or finger, you can drag to adjust the length of the initial velocity.

Write down which velocities you chose: \_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. How did the motion vary from the initial case, where both velocities were 10 m/s?

Change the initial angle for the left projectiles (*θ*1).

Write down which angle you chose: \_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. How did the motion vary from the initial case, with *θ*1 = 0?
2. Leave the angle to the value that you chose. Can you adjust the velocities such that the two projectiles will still hit each other?

Change the setting to “The Monkey and the Hunter” and press Play.

1. What do you observe?

Now adjust the settings to make them more “real”. The hunter is probably aiming up at the monkey, who is hanging in a tree. Make sure the monkey starts with zero velocity, unless you want the monkey to jump at the hunter.

1. What do you observe?

Now watch the video <http://www.tinyurl.com/monkey-and-gun>

What happens is this. Note that if there were no gravity, the hunter would definitely hit the monkey: the monkey would not fall and the bullet, being aimed straight at the monkey, would go towards the monkey in a straight line.

However, now we “switch on” gravity. This causes a downward acceleration of 9.81 m/s2, the gravitational acceleration. Since this downward acceleration is the same for both the monkey and the bullet, the monkey and the bullet “fall” the same distance.

The monkey was falling straight down: it was following the motion of Activity 2. But the bullet was different! It was moving horizontally and vertically at the same time. Luckily, we can analyse the horizontal and vertical motion completely separately. All we need to know is the initial speed and the initial angle with respect to horizontal.



We here have the example of an initial speed *v* and angle *θ*. The horizontal initial speed is given by ***v* cos *θ***. There is no acceleration in the horizontal direction, so the horizontal motion follows Activity 1.

The vertical initial speed is given by ***v* sin *θ***. There is a uniform acceleration in the vertical direction due to gravity, so the vertical motion follows Activity 2.

***Conclusions for projectile motion:***

*Horizontal displacement:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Horizontal velocity:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Vertical displacement:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Vertical velocity:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

*Time of flight:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*

**ConcepTest 6!**

**MODEL**

1. A car starts at the original position (*x* = 0 m), travels forward slowly and steadily for 5 seconds, stops for 2 seconds, and then travels backward steadily about twice as fast for 3 seconds. Draw *position versus time* and *velocity versus time* graphs to illustrate its travel.
2. A car starts at the original position (*x* = 0 m), travels backward slowly and steadily for 5 seconds, stops for 2 seconds, and then travels forward steadily about twice as fast for 3 seconds. Draw *position versus time* and *velocity versus time* graphs to illustrate its travel.

**ANALYZE**

1. Consider two cars, a 1,700 kg BMW and a 1,500 kg Mercedes-Benz. The BMW is speeding along at 120 km/h and the Mercedes-Benz is going half the speed at 60 km/h. If the two cars brake to a stop with the same constant acceleration,
2. is the amount of time required to come to a stop influenced by their initial velocity? Explain your answer using diagrams, equations, or any explanatory rules/principles.
3. is the distance travelled prior to stopping influenced by their initial velocity? Explain your answer using diagrams, equations, or any explanatory rules/principles.

**EVALUATE**

Explain your answer to each of the questions below using diagrams, equations, or any explanatory rules/principles.

1. A sky diver jumps out of a hovering helicopter. A few seconds afterwards another sky diver jumps out and they both fall along the same vertical line. Ignore air resistance so that both sky divers fall with the same acceleration.
2. Does the difference in their speeds stay the same throughout the fall?
3. Does the vertical distance between them stay the same throughout the fall?
4. A tennis ball thrown from the top of a building is given an initial velocity of 20 m/s straight upward. The building is 50 m high, and the ball just misses the edge of the roof on its way down. Using *t* = 0 as the time the ball leaves the thrower’s hand, determine
5. the time at which the ball reaches its maximum height
6. the maximum height
7. the time at which the ball returns to the height from which it was thrown
8. the velocity of the ball at this instant
9. the velocity and position of the ball at *t* = 5 s