AST 120 Activity 23
Galileo's Study of Neutral Motions

Name	Full	Partial	None

1. Recall that Aristotle divided motions into two types: violent and natural. Natural motions were those that took an object to its proper place in the universe. In the sublunary sphere these motions are either straight down (for earth or water) or straight up (for air or fire). Violent motions were those that forced objects to move in a way that was opposed to their nature (ie lifting a rock). Aristotle thought that natural motion would occur spontaneously, but violent motion required an active force to create and sustain the motion. Now consider a sphere spinning above the Earth's surface (like a spinning globe perhaps). Some parts of the globe may be moving toward the center of the Earth, while some parts may be moving away. Would you classify this motion as violent or natural (or both, or neither)? Defend your answer.

2. Medieval scholars who considered this situation described it as a combination of violent and natural motions, but Galileo thought it represented a third type of motion which he termed *neutral*. He thought this neutral motion could be produced by the slightest force and would sustain itself as long as it was not interfered with in some way. Explain how Galileo might have used this idea to defend the idea that Earth rotates about a fixed axis.

3. Galileo began to look for neutral motions elsewhere. Let's return to the inclined plane simulation to explore his through process. Run the `InclinedPlane` program. For simplicity let's turn off air resistance by unchecking the Air Resistance box (Galileo, of course, couldn't turn off air resistance - but he was at least aware of it). When the ball rolls down the inclined plane it ______________.

   (a) slows down
   (b) speeds up
   (c) maintains a constant speed
   (d) does not move

4. Pause the simulation, change the angle of incline to -10°, change the initial speed to 4 m/s, click Initialize (Clear Plots if you have looked at the plots) and then hit Play. As the ball rolls up the hill it ______________.
   (a) slows down
   (b) speeds up
   (c) maintains a constant speed
   (d) does not move
5. What do you think will happen if the ball rolls on a level plane? Don't try this with the simulation yet, just say what you THINK will happen.
6. Now Pause the simulation, set the angle to 0°, set the initial speed to 1 m/s, Initialize and click Play. As the ball rolls along the level plane it ______________.
   (a) slows down
   (b) speeds up
   (c) maintains a constant speed
   (d) does not move
7. Would the ball keep rolling forever, as long as the plane didn't end? If not, why not?
8. Now repeat the last experiment, but this time check the Air Resistance box first. Also click the Show Speed Plot button to display a plot of the ball's speed versus time. Run the simulation with a level plane. As the ball rolls along the level plane it ______________.
   (a) slows down
   (b) speeds up
   (c) maintains a constant speed
   (d) does not move
9. In a REAL experiment (as opposed to a computer simulation), would the ball keep rolling forever as long as the plane didn't end? Explain why or why not.

10. Galileo decided that horizontal motion was a neutral motion, like the spinning sphere mentioned above. If the motion of an object carried it closer to the center of Earth then it would be a natural motion and the object would speed up (as we found for falling objects in the last Activity). If the motion carried the object away from the center of the Earth then the object would slow down and eventually stop unless something continued to push it upward. But if the object moved horizontally, maintaining a constant distance from the center of the Earth, then it would neither slow down nor speed up. Suppose a ball rolls forever in this kind of neutral motion. Describe the shape of the ball's path.

11. Galileo claims that horizontal motion *appears* to be motion in a straight line, as long as we conduct our experiments over short distances. Explain why this should be so.

12. We have now discussed the two most important physical principles deduced by Galileo (he found lots of other important things too, but none so important as these two). First, all objects fall downward with the same constant acceleration. Second, an object moving horizontally will maintain a constant speed. One of Galileo's great practical triumphs was to put these two ideas together to explain projectile motion, a phenomenon which he studied experimentally. To see how this works run the `ProjectileMotionGalileoNewton` program. The simulation shows the motion of a projectile, depicted by a magneta disk. The simulation also shows the motion of an object, depicted by the blue disk, that moves horizontally at a constant velocity equal to the initial horizontal velocity of the projectile. Finally, the simulation shows the motion of an object, depicted by a red disk, that moves vertically with a constant acceleration. The initial vertical velocity of the red disk is equal to the initial vertical velocity of the projectile. You can adjust the initial height, launch angle, and initial speed of the projectile. You can also examine graphs of the motion if you like. Play around with the simulation until you have a pretty good idea of what is going on. Describe the shape of the projectile's path. (Hint: it is a shape you have almost certainly seen before, perhaps in a high school math class.)

13. Describe the *horizontal* motion of the projectile. Is this uniform motion (with constant speed), or is it motion with uniform (constant) acceleration? How can you tell?

14. Describe the *vertical* motion of the projectile. Is this uniform motion (with constant speed), or is it motion with uniform (constant) acceleration? How can you tell?

15. To see if you really understand this stuff, let's ask two more questions. These questions are anachronistic in that they involve technology not available in Galileo's time. But Galileo could have posed similar questions (and did). Here's the first: suppose you fire a bullet from a rifle aimed horizontally and *at the exact same time* you drop another bullet from the same height above ground. Ignore air resistance, the curvature of Earth's surface, and the Earth's rotation. Which bullet will hit the ground first?

    (a) the bullet fired from the gun

    (b) the dropped bullet

    (c) they will both hit the ground at the same time

    (d) neither bullet will ever hit the ground

16. Here's the second question: a UN aid plane is delivering a crate of first aid supplies to a refugee camp. The plane is flying in a straight line at a constant speed. Aid workers drop the crate out of the plane's cargo door (which we will assume is on the belly of the plane). Ignore air resistance, the curvature of Earth's surface, and the Earth's rotation. When the crate hits the ground it will be ______________.

    (a) behind the plane

    (b) directly underneath the plane

    (c) in front of the plane

    (d) directly above the plane

17. One of the arguments that had been made against the idea of a rotating Earth was that if the Earth was rotating we should feel a constant strong wind blowing from the East. Birds should be unable to fly Eastward since they could not keep up with the moving surface of the Earth. Balls dropped from towers should land far to the West of the tower's base rather than at the foot of the tower. But none of these things is observed. Pick one of these phenomena and explain, using Galileo's principle of inertia, why we should not expect to see that phenomenon even on a rotating Earth.