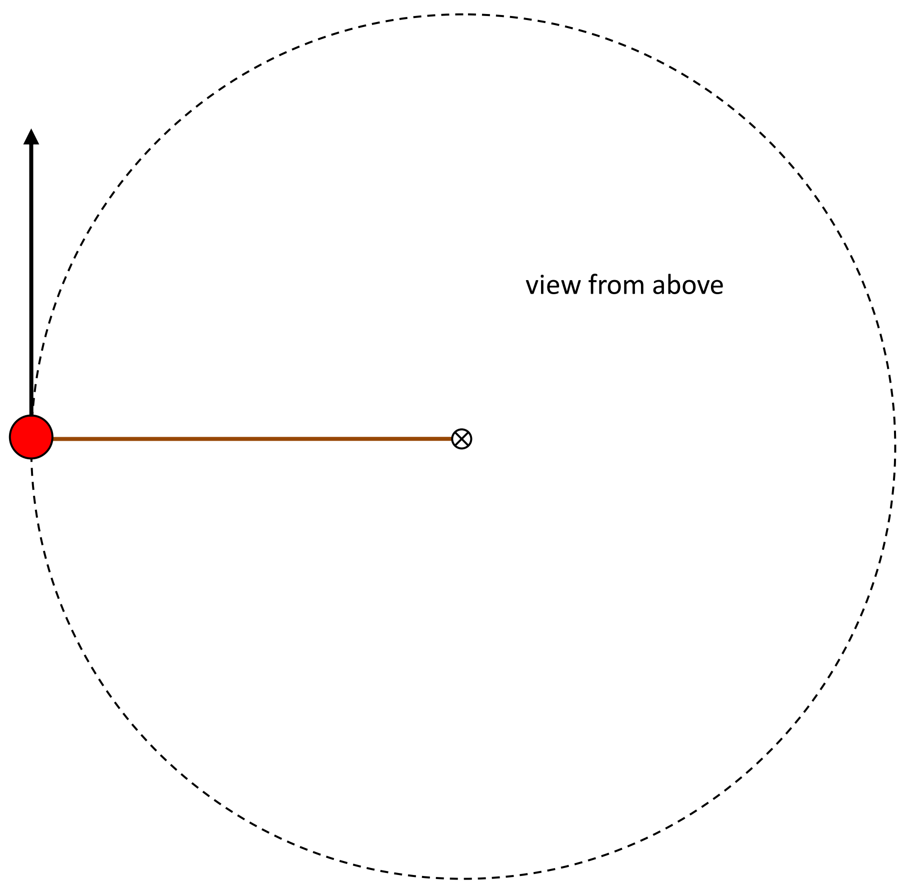
Teacher notes
Topic C

It's hard to believe but it's true!

If event C causes event E, and C and E happen at different points in space, E must happen **later** than C. The time delay is determined by the distance separating C and E and the speed at which information is being transmitted from C to E. In most cases, the information transmitted is in the form of a wave. My favorite example discussed in the textbook is the following: if the Sun were to magically disappear, how much later would we plunge into darkness and how much later would the earth leave its circular orbit? It turns out that the time delay for both is the same and equal to the distance to the Sun divided by the speed of light, $\frac{1.5\times10^{11}}{3\times10^{8}} = 500\text{ s} = 8.3\text{ min}$. This is obvious for light. It is also true for gravitational effects since disturbances in a gravitational field are disturbances in the geometry of space-time and Einstein showed that these also travel at the speed of light.

But we now want to discuss this idea in a more down to earth context. A ball is attached to a string and moves with constant speed along a horizontal circle as shown in the figure.



The question is:

The string is cut at the position shown. What is the path of the ball immediately afterwards?

This has been asked on IB exams many times. The accepted answer is that the ball will move in the direction of the velocity at the instant the string is cut, i.e. tangentially to the circle. But will it?

You realize of course the analogy between this situation and the Sun-earth case discussed earlier. The problem is the same. There must be a delay because the information "the string is cut" cannot be transferred to the mass in zero time. It will be transferred in terms of a wave that will travel through the string and arrive at the position of the mass in a time determined by the length of the string and the speed of the wave.

During this time, the mass still feels the tension in the string and therefore continues to move along the circular path, even though the string is cut!

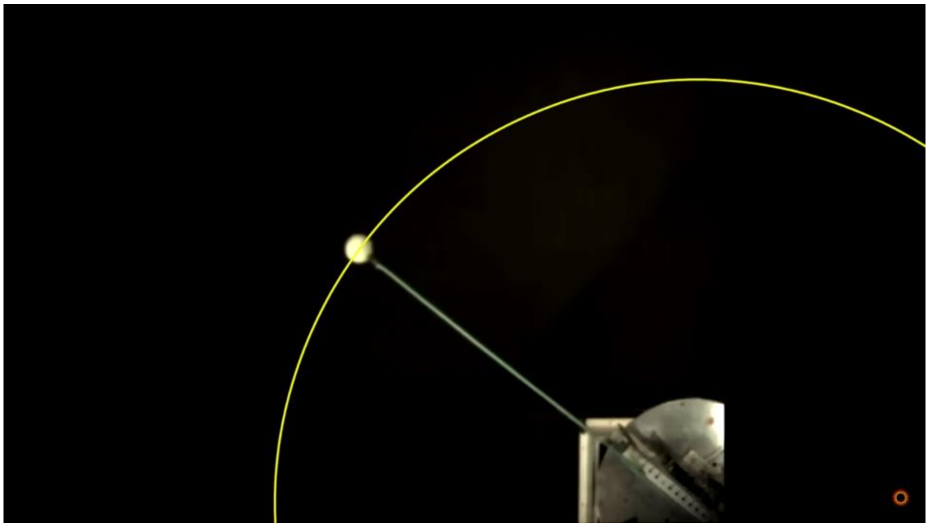
How long does this take? For an ordinary string of any reasonable length the time delay is less than 1 ms and so essentially impossible to see with the naked eye. We need to find a way to make the speed of the wave smaller. One way is to replace the string with a spring. The speed of the wave in the spring is substantially smaller.

You will find a very beautiful set of experiments and demonstrations on this in a video by David Jackson in his All-things Physics series at

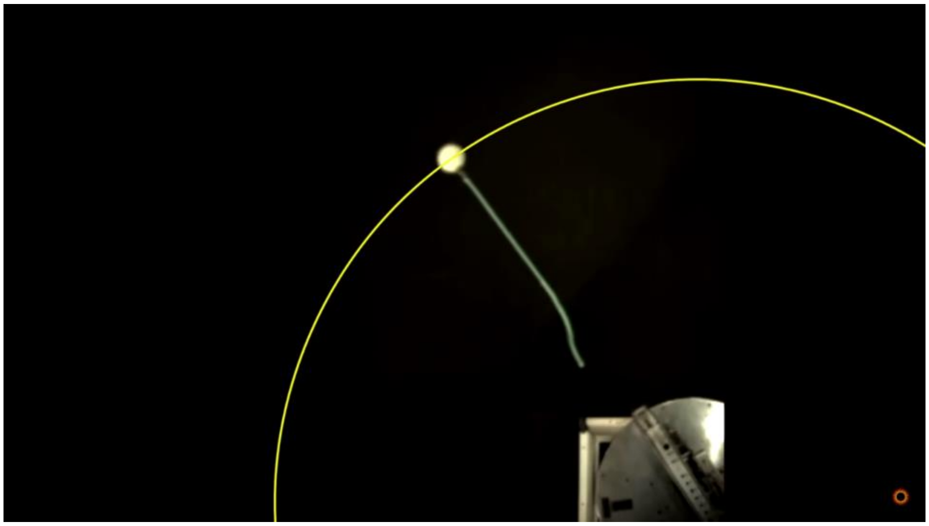
https://www.youtube.com/watch?v=AL2Chc6p_Kk

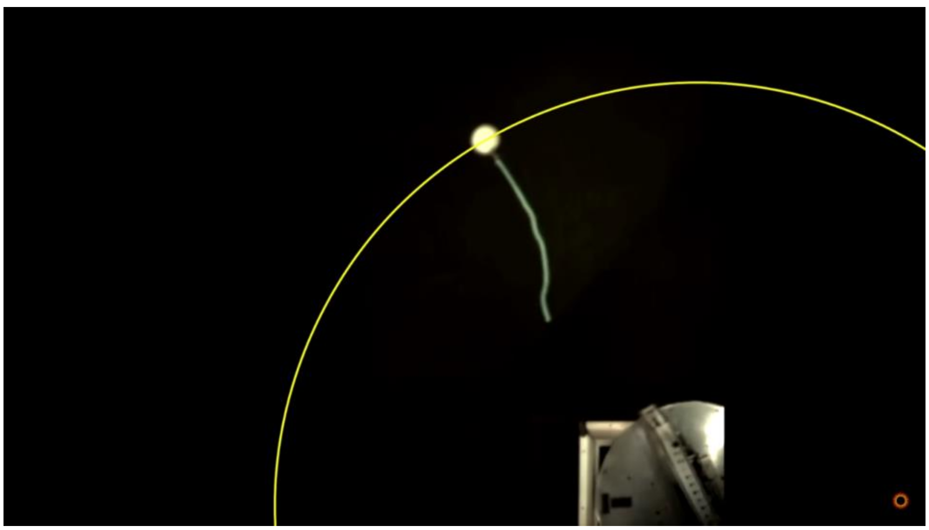
It has convincing evidence that the ball does not initially move tangentially to the circle but follows the circle instead!

Here are four screenshots of the ball. In the first the string is about to be released.



In the next 2, the string is released but the ball is still on the circular path!





Eventually the ball leaves the circular path.