Down to Earth
KS3

Teacher Guide

Distance between the comet and the fly-by spacecraft

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Distance between the comet and the fly-by spacecraft

In this activity the students calculate how far away the fly-by spacecraft will be when the collision occurs. This is actually one in a whole series of questions that can only be accurately answered by using geometry.

Objectives

Students will:

- Use geometry
- Use Pythagoras' theorem

to make some simple calculations about the distance of the fly-by spacecraft to the comet when impact occurs.

Resources required

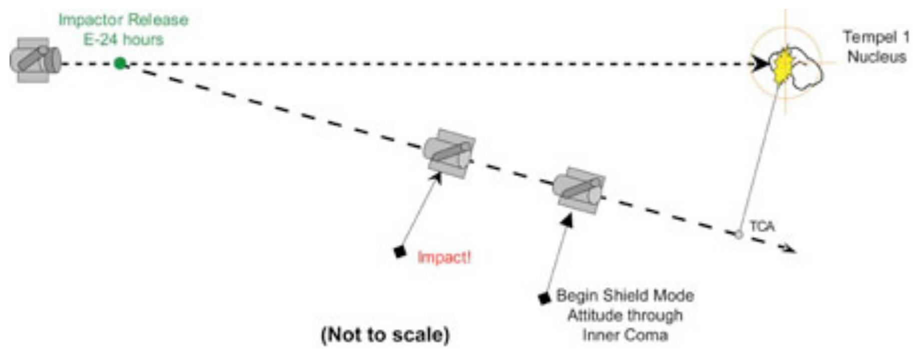
Pens and paper

Teaching activities

Introduction

The comet will be hit by an impacting spacecraft in order to produce a crater, but there will also be another spacecraft some distance away which will observe the event and record the information.

Describe the following situation to the class:



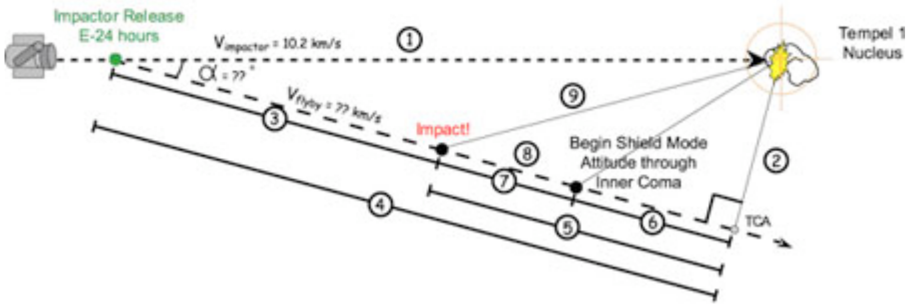
From the diagram above, it can be seen that the impactor and flyby spacecraft separate from each other 24 hours before the impact will occur. The impactor then proceeds into the path of the comet. It should be pointed out that it won't really fly in a straight line as depicted, but will probably follow a slightly more parabolic curve. That's one of the simplifications we'll make in this problem. The impactor will be traveling at a relative speed of 10.2 kilometers per second (km/sec).

The flyby spacecraft heads off at an angle to the path of the impactor. That angle will be approximately 0.033°. The flyby spacecraft will be traveling at a relative speed of 7.6 km/sec in that new direction.

After the impact, the flyby spacecraft continues in its path, taking pictures and recording information until it gets too close to the comet, and has to go into "shield mode" to protect its sensitive instruments from the dust particles in the comet's coma. The minimum safe distance from the comet is 750 km, and the flyby will actually get closer than that.

With this information the students should answer the following questions with simple conversions and geometry. Do the questions in order.

Questions



(Not to scale)

1. How far will the impactor spacecraft travel between separation and the time of impact?

This problem is a simple conversion problem. We have the time between these two events (24 hours) and the speed that the impactor spacecraft will be traveling (10.2 km/sec). Using these two pieces of information, we can calculate the distance it will travel. It is necessary to first convert the time into seconds, then multiply by the speed to get distance:

$$24\ \text{hr} \times \frac{60\ \text{min}}{1\ \text{hr}} \times \frac{60\ \text{sec}}{1\ \text{min}} \times \frac{10.2\ \text{km}}{1\ \text{sec}} = 881280\ \text{km}$$

2. What's the closest distance (TCA) the flyby spacecraft will come to the comet?

Here's the first use of geometry. We now know the total distance the impactor spacecraft will travel (881280 km), and we know the angle between the impactor spacecraft's trajectory and the flyby spacecraft's trajectory (0.033°). The distance the impactor spacecraft travels can be seen as the hypotenuse of a right triangle, with the closest distance of the flyby spacecraft being the "opposite side" to the 0.033° angle.

The sine of 0.033° will equal the length of the opposite side over the length of the hypotenuse, so:

$$\sin 0.033° = \frac{\text{TCA}}{\text{impactor distance}}$$

Rearranging this equation gives us:

TCA = impactor distance x sin 0.033° = (881280 km) x (0.000575969) = 508 km

3. How far will the flyby spacecraft travel between separation and the time of impact?

This is another conversion problem like in number 1.

$$24 \text{ hr} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{60 \text{ sec}}{1 \text{ min}} \times \frac{7.6 \text{ km}}{1 \text{ sec}} = 656640 \text{ km}$$

4. How far will the flyby spacecraft travel between separation and the point of it's closest approach (TCA)?

Here we need to use the Pythagorean theorem ($c^2 = a^2 + b^2$). The distance that the impactor space craft covers between separation and impact, the closest distance between the flyby to the to the comet (TCA) and the distance between separation and TCA make up a right triangle. Rearranging the Pythagorean theorem yields:

$$a = \sqrt{c^2 - b^2} = \sqrt{(881280)^2 - (508)^2} = 881280 \text{ km}$$

5. How far will the flyby spacecraft travel between the time of impact and the point of its closest approach (TCA)?

This is a simple subtraction. The flyby spacecraft travels 881280 km between separation and TCA (number 4) and it travels 656640 km between separation and impact. This means the distance between impact and TCA must be:

$$881280 \text{ km} - 656640 \text{ km} = 234640 \text{ km}$$

6. How far will the flyby spacecraft travel between the point where it has to enter "shield mode" and the point of its closest approach (TCA)?

Here we need the Pythagorean theorem again. This time the triangle's hypotenuse is the minimum safe distance between the comet and the flyby spacecraft (750 km), and one of the legs is the closest distance between the flyby spacecraft and the comet (508 km). The distance between the start of "shield mode" and TCA is the other leg.

$$a = \sqrt{c^2 - b^2} = \sqrt{(750)^2 - (508)^2} = 552 \text{ km}$$

7. How far will the flyby spacecraft travel between the time of impact and the point where it has to enter "shield mode"?

This is another simple subtraction. The flyby spacecraft travels 234640 km between impact and TCA (number 5) and it travels 552 km between the start of "shield mode" and TCA. This means the distance between impact and the start of "shield mode" must be:

$$234640 \text{ km} - 552 \text{ km} = 234088 \text{ km}$$

8. How much time will the impactor have to take pictures and images between the time of impact and the point where it has to enter "shield mode"?

This is another conversion problem like number 1. We know the distance the flyby spacecraft will travel between impact and the start of "shield mode", and we know how fast it will be traveling, so:

$$234088 \text{ km} \times \frac{1 \text{ sec}}{7.6 \text{ km}} \times \frac{1 \text{ min}}{60 \text{ sec}} = 513 \text{ min}$$

9. How far away from the comet will the flyby spacecraft be at the time of impact?

This final problem again requires the Pythagorean theorem. This time the answer to the problem is the hypotenuse, the distance between impact and TCA (234640 km) is one leg of the triangle, and the closest distance the flyby spacecraft comes to the comet (508 km) is the other leg.

$$c = \sqrt{a^2 + b^2} = \sqrt{(234640)^2 + (508)^2} = 234641 \text{ km}$$