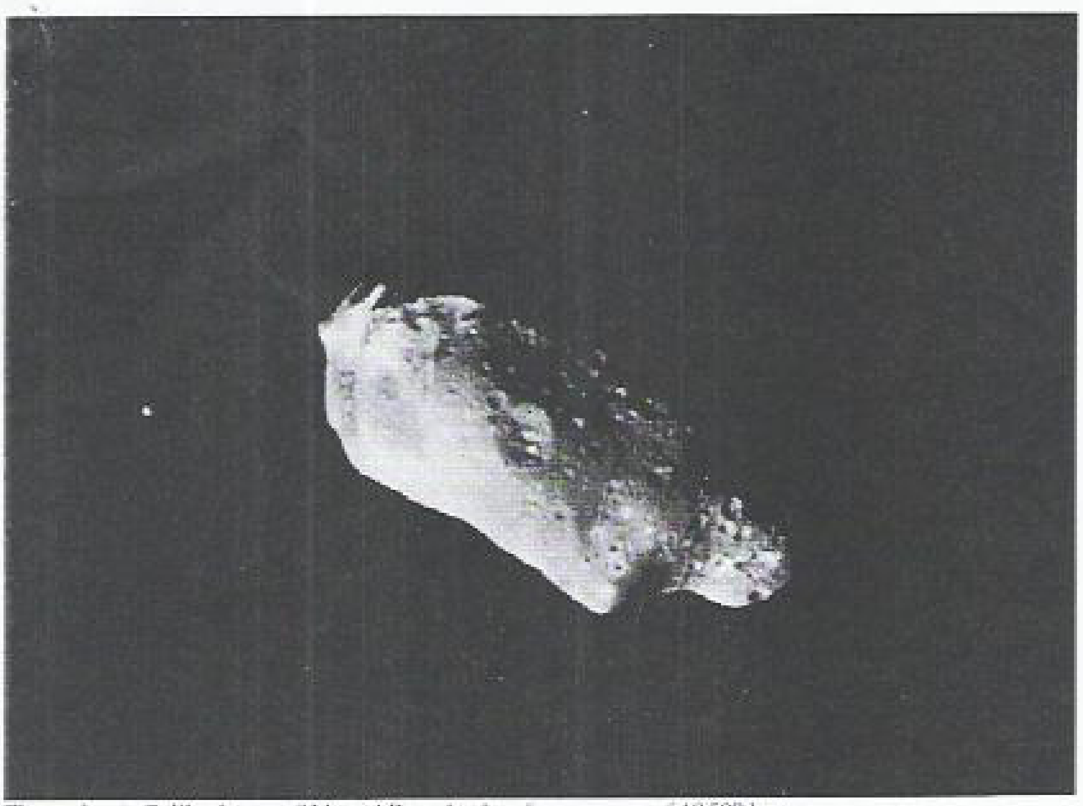

Figure 1 A *Galileo* image of Ida and Dactyl, taken from a range of 10 500 km.

Step one was getting a reliable volume estimate. Based on its light curve, telescopic astronomers already knew that Ida rotates in just under 4.63 hours and is quite elongated. So *Galileo* scientists had the spacecraft record 150 snapshots of the craggy, 55-km long body over a span of 5.7 hours, more than a full rotation's worth. Peter Thomas (Cornell University) and other members of the imaging team then used these views in a painstaking reconstruction of Ida's shape. Thomas feels that the resulting volume, 16 100 km^3, is accurate to about 10 percent.

Deducing Dactyl's orbit proved more challenging. Situated about 100 km from Ida and moving in the same retrograde direction as Ida's rotation, the little satellite appears in 47 *Galileo* images. But the flyby path ended up very nearly in Ida's equatorial plane – a big plus for imaging the asteroid but a handicap for watching the motion of its satellite, whose orbit is inclined only 8`°.

The perspective was so poor, in fact, that a whole range of orbits can fit the observations. At one extreme Dactyl might be just barely within Ida's gravitational grip; its very eccentric orbit would measure roughly 80 by 8 000 km, and *Galileo*'s visit would have coincided with the once-per-year occasion when the two bodies are close together. This scenario requires that Ida have a relatively low mass. At the other extreme, a nearly circular 82-by-95-km orbit implies a third more mass for Ida; in this case, Dactyl completes a revolution every 27 hours. The moonlet's circuit shrinks further as its parent becomes heftier. However, computer simulations show that still-tighter orbits probably don't work. In most cases they become unstable if the nearest point to Ida's center is under 70 km, and Dactyl either crash-lands or escapes to interplanetary space.

Taken together, these factors dictate that Ida have a density somewhere between 2.2 and 2.9 grams per cubic centimeter.

(a) (3 marks) According to the extract from *Sky and Telescope*, Kepler's third law could be used to determine Ida's mass, if we know the size and period of Dactyl's orbit around it. Drawing on what you know of Kepler's third law from page 13 of Book 2, discuss whether or not that is a reasonable statement. (*Two or three sentences*)

(b) (*3 marks*) If Ida were observed from a viewpoint in space a long distance north of the ecliptic plane, explain whether its rotation would appear clockwise or anticlockwise. (*Two or three sentences*)

(c) (*2 marks*) Explain how Ida's light curve, observed from Earth, would have enabled Ida's rotation period to be deduced. (*One or two sentences*)

(d) The extract states that a range of orbits can fit the Galileo observations. Figure 2 shows some of the possible orbits. The one that is drawn closest to Ida has an orbital period of 61 700 s (just over 17 hours). Whether or not you believe the computer simulations referred to in the penultimate paragraph of the extract, it should be fairly obvious to you that no orbit passing much closer to Ida would be possible without hitting it. By calculating the mass Ida must have if this orbit *does* represent the actual orbit of Dactyl, you will have calculated the maximum possible mass for Ida.

(i) (*9 marks*) Use the method of ITQ 1.2 (page 14 of Book 2) to calculate this maximum possible mass for Ida. State any assumptions that you make. Express your result to two significant figures. (e.g. if your value works out to 4.567×10^n kg, you should quote it as 4.6×10^n kg. Similarly 9.03×10^n kg should be quoted as 9.0×10^n kg.) *Show your working, making it clear what you are doing in each step.*