

# Orbits, escape speed and gravitational energy

AP Physics C (Mechanics and E&M, calculus-based) · Lab

Name: \_\_\_\_\_ Date: \_\_\_\_\_ Class: \_\_\_\_\_

Do the moons of a giant planet obey the same rule as the planets around the Sun? This lab uses a table of moon radii and periods to test  $T^2 \propto r^3$  and to turn the gradient of the graph into a measurement of the mass of a planet that nobody can put on a balance.

**Level:** AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:M Unit 7

## Aim

To test Kepler's third law with orbital data for four moons of one planet, and to use the result to find the planet's mass.

## Equipment

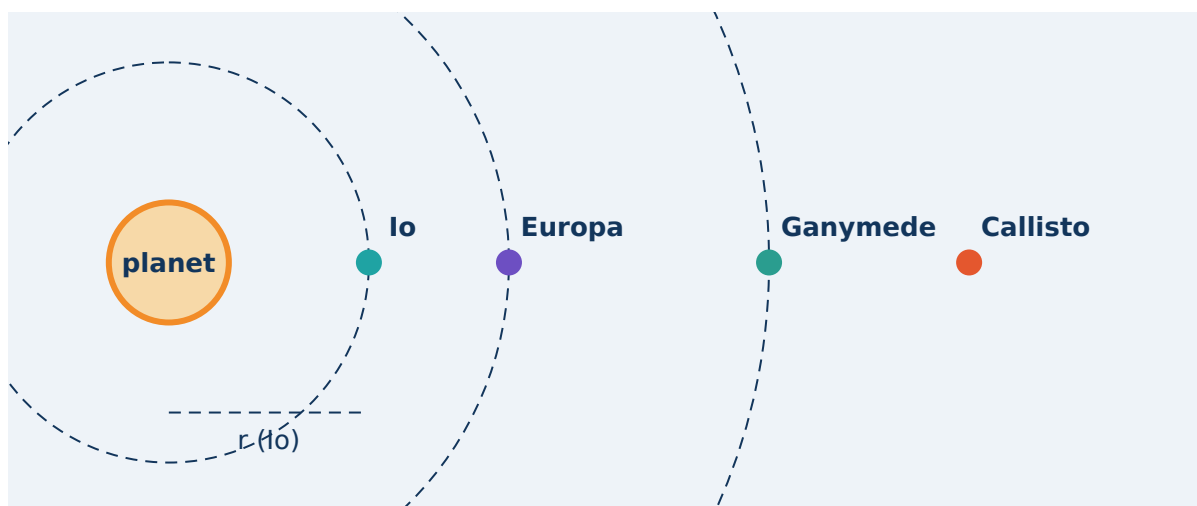
- The data table below (moon radius and period)
- Graph paper or a spreadsheet
- A calculator with a power key
- A ruler for the line of best fit

## Safety

### Safety

This is a desk-based data lab. Sit with the screen and paper at a comfortable height, take a break from the screen every 20 minutes, and keep drinks away from any computer.

## Method



Data for four moons of one planet: radius  $r$  from the planet's centre and period  $T$ .

1. Convert each period from days to seconds (1 day = 86 400 s).
2. Calculate  $T^2$  and  $r^3$  for each moon and complete the table.
3. Plot  $T^2$  on the vertical axis against  $r^3$  on the horizontal axis, with the origin included.
4. Draw the line of best fit and find its gradient using the first and last points.
5. Use the gradient to calculate the mass of the planet from gradient =  $4\pi^2/GM$ .

## Results

Sample data, with the calculated columns already filled for checking:

| Moon     | $r$ ( $10^8$ m) | $T$ (days) | $T$ ( $10^5$ s) | $T^2$ ( $10^{10}$ s <sup>2</sup> ) | $r^3$ ( $10^{26}$ m <sup>3</sup> ) |
|----------|-----------------|------------|-----------------|------------------------------------|------------------------------------|
| Io       | 4.22            | 1.77       | 1.529           | 2.34                               | 0.752                              |
| Europa   | 6.71            | 3.55       | 3.067           | 9.41                               | 3.02                               |
| Ganymede | 10.70           | 7.15       | 6.178           | 38.2                               | 12.3                               |
| Callisto | 18.83           | 16.69      | 14.42           | 208                                | 66.8                               |

## Analysis questions

### Question 1 Unit conversion

Convert the period of Ganymede to seconds and calculate  $T^2$  and  $r^3$  for it.

### Question 2 Shape of the graph

Describe the graph of  $T^2$  against  $r^3$  and state what it shows about Kepler's third law.

### Question 3 Gradient

Calculate the gradient using the Io and Callisto points, with its unit.

**Question 4 Mass of the planet**

Use the gradient to calculate the mass of the planet.

**Question 5 Logarithmic test**

Show using Io and Callisto that  $\log T$  plotted against  $\log r$  has gradient 1.5.

**Question 6 Uncertainty**

Each period is given to three significant figures. Estimate the percentage uncertainty in the planet's mass.

**Question 7 Assumptions**

State two assumptions of the method and how they could affect the result.