

Orbits, escape speed and gravitational energy

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

Model answers use the sample data in the table. If you use another data set, expect a straight line through the origin and a mass of the right order of magnitude. State the units of the gradient and quote the mass to three significant figures at most.

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

Question 1 Unit conversion

$T = 7.15 \times 86\,400 = 6.18 \times 10^5 \text{ s}$, so $T^2 = 3.82 \times 10^{11} \text{ s}^2$ (38.2 in the table's units). $r^3 = (1.070 \times 10^9)^3 = 1.225 \times 10^{27} \text{ m}^3$. **$T^2 = 3.82 \times 10^{11} \text{ s}^2$, $r^3 = 1.23 \times 10^{27} \text{ m}^3$.**

Question 2 Shape of the graph

The points lie on a straight line through the origin, so **T^2 is proportional to r^3** , as Kepler's third law states for orbits around one central body.

Question 3 Gradient

Gradient = $(2.079 \times 10^{12} - 2.34 \times 10^{10}) / (6.676 \times 10^{27} - 7.5 \times 10^{25}) = 2.056 \times 10^{12} / 6.60 \times 10^{27} = \mathbf{3.11 \times 10^{-16} \text{ s}^2/\text{m}^3}$.

Question 4 Mass of the planet

Gradient = $4\pi^2/(GM)$, so $M = 4\pi^2 / (G \times \text{gradient}) = 39.48 / (6.67 \times 10^{-11} \times 3.11 \times 10^{-16}) = \mathbf{1.90 \times 10^{27} \text{ kg}}$.

Question 5 Logarithmic test

$\ln(16.69/1.77) = 2.244$ and $\ln(18.83/4.22) = 1.496$. The gradient is $2.244 / 1.496 = \mathbf{1.50}$, so $T \propto r^{(3/2)}$.

Question 6 Uncertainty

The period uncertainty is about 0.3 %. $M \propto r^3/T^2$, so the uncertainty in M is about $3 \times (\text{radius error}) + 2 \times 0.3 \%$. With radius errors near 0.1 %, **M is uncertain by about 1 %**.

Question 7 Assumptions

The orbits are assumed circular, and the moons' masses are assumed negligible compared with the planet. If the orbits are slightly elliptical, the mean radius gives a small bias. **Both**

effects are small here.