Past-paper walk-through

Newton's First Law ▪ 2.4

eXercise

Questions in this set

- 2018 Q1

Reading the mark scheme

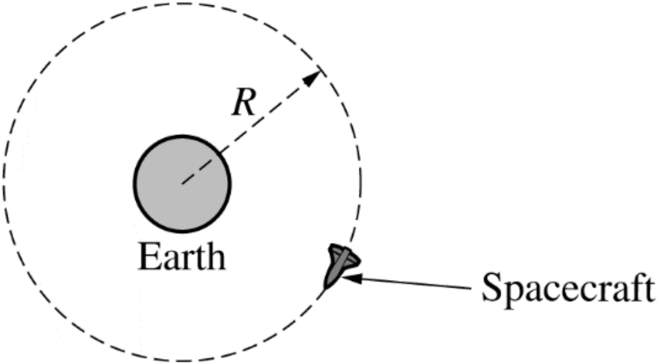
- B1 a mark that stands on its own – the point is either made or not.
- M1 a *method* mark: the right approach, even if the number is wrong.
- A1 an *answer* mark, and it usually needs its M mark first.
- C1 a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 1

2018 ▪ Q1

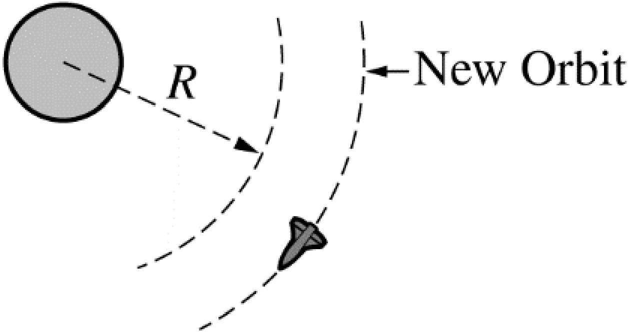
A spacecraft of mass m is in a clockwise circular orbit of radius R around Earth, as shown in the figure above. The mass of Earth is M_E.
[Figure: Earth (a solid grey circle, labeled "Earth") at the center, with a dashed circular orbit of radius R around it; a spacecraft icon sits on the orbit path, labeled "Spacecraft", indicating clockwise motion. Note: Figure not drawn to scale.]
(a) In the figure below, draw and label the forces (not components) that act on the spacecraft. Each force must be represented by a distinct arrow starting on, and pointing away from, the spacecraft.
[Figure: Earth shown at upper left with the spacecraft positioned on a dashed arc representing part of its orbit, provided blank for the student to draw and label force arrows. Note: Figure not drawn to scale.]

Question 1



Note: Figure not drawn to scale.

Question 1



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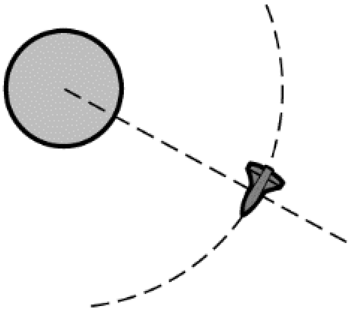
Question 1



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Question 1

2018 ▪ Q1

A spacecraft of mass m is in a clockwise circular orbit of radius R around Earth, as shown in the figure above. The mass of Earth is M_E.

[Figure: Earth (a solid grey circle, labeled "Earth") at the center, with a dashed circular orbit of radius R around it; a spacecraft icon sits on the orbit path, labeled "Spacecraft", indicating clockwise motion. Note: Figure not drawn to scale.]

(b)(i) Derive an equation for the orbital period T of the spacecraft in terms of m, M_E, R, and physical constants, as appropriate. If you need to draw anything other than what you have shown in part (a) to assist in your solution, use the space below. Do NOT add anything to the figure in part (a).

(b)(ii) A second spacecraft of mass $2m$ is placed in a circular orbit with the same radius R. Is the orbital period of the second spacecraft greater than, less than, or equal to the orbital period of the first spacecraft?

Question 1

_____ Greater than _____ Less than _____ Equal to

Briefly explain your reasoning.

Question 1

2018 ▪ Q1

A spacecraft of mass m is in a clockwise circular orbit of radius R around Earth, as shown in the figure above. The mass of Earth is M_E.

[Figure: Earth (a solid grey circle, labeled "Earth") at the center, with a dashed circular orbit of radius R around it; a spacecraft icon sits on the orbit path, labeled "Spacecraft", indicating clockwise motion. Note: Figure not drawn to scale.]

(c) The first spacecraft is moved into a new circular orbit that has a radius greater than R, as shown in the figure below.

[Figure: Earth with the original dashed orbit of radius R shown alongside a larger, concentric dashed orbit labeled "New Orbit"; the spacecraft is shown on this larger new orbit. Note: Figure not drawn to scale.]

Is the speed of the spacecraft in the new orbit greater than, less than, or equal to the original speed?

Question 1

_____ Greater than _____ Less than _____ Equal to
Briefly explain your reasoning.

Solution 1

(a)

Mark scheme

- Only one force acts on the orbiting spacecraft: the gravitational force from Earth. Draw a single arrow starting on the spacecraft and pointing directly toward Earth's center, labeled F_g (gravity). No other forces (e.g. a forward 'motion' force) should be drawn. Scoring (2 points, 1 each): (1) an arrow directed toward Earth's center; (2) a correct label on that arrow identifying it as the gravitational force, with the arrow pointing toward Earth's center. Note: a maximum of 1 point can be earned if extraneous (incorrect) forces are also present.

Solution 1

(b)(i) Mark scheme

- Apply Newton's second law, setting the gravitational force equal to the centripetal force: $F_g = ma = \frac{mv^2}{R}$, so $\frac{GmM_E}{R^2} = \frac{mv^2}{R}$. Relate speed to period via the orbit's circumference: $v = \frac{2\pi R}{T}$. Combine and solve for T: $T = \sqrt{\frac{4\pi^2 R^3}{GM_E}}$ (equivalently $T^2 = \frac{4\pi^2 R^3}{GM_E}$, an acceptable final form). Scoring (3 points, 1 each): (1) using (or implying) Newton's second law and equating the centripetal force to the gravitational force, $\frac{GmM_E}{R^2} = \frac{mv^2}{R}$; (2) explicitly or implicitly determining

Solution 1

$v = \dfrac{2\pi R}{T}$; (3) a correct final answer algebraically equivalent to $T = \sqrt{4\pi^2 R^3/(GM_E)}$.

Solution 1

(b)(ii) Mark scheme

- Correct answer: 'Equal to.' The orbital period does not depend on the spacecraft's mass – from part (b)(i), $T = \sqrt{4\pi^2 R^3/(GM_E)}$ contains no dependence on m (mass cancels out of Newton's second law), so doubling the mass to $2m$ leaves the period unchanged for the same orbital radius R. Scoring (1 point): for a correct explanation that the period does not depend on the spacecraft's mass (or depends only on Earth's mass and the orbital radius), OR an explanation consistent with the (possibly incorrect) equation derived in part (b)(i). The explanation must be consistent with whichever box is checked.

Solution 1

(c)

Mark scheme

- Correct answer: 'Less than.' From the derivation in part (b)(i), $v = \sqrt{GM_E/R}$, so orbital speed decreases as the orbital radius R increases; a spacecraft in a larger orbit therefore moves slower than in the original orbit. Scoring (1 point): for a correct explanation of why speed decreases with increasing orbital radius (e.g., citing the part (b)(i) derivation step showing $v \propto 1/\sqrt{R}$). Note: if the wrong option is selected, the explanation is not graded.