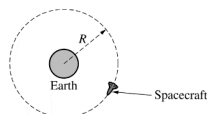


AP[®] PHYSICS 1

2018 SCORING GUIDELINES

Question 1

7 points total

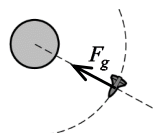
Distribution
of points

Note: Figure not drawn to scale.

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 .

- (a) LO / SP: 3.A.2.1 / 1.1; 3.B.2.1 / 1.1, 1.4
2 points

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.



Note: Figure not drawn to scale.

For an arrow directed toward Earth's center	1 point
For a correct label on the arrow representing the gravitational force, where the arrow is pointing toward Earth's center	1 point
Note: A maximum of 1 point may be earned if extraneous forces are present.	

2018 SCORING GUIDELINES

Question 1 (continued)

Distribution
of points

- (b) LO / SP: 2.B.2.1 / 2.2; 3.A.1.1 / 1.5, 2.2; 3.B.1.3 / 1.5, 2.2; 3.B.2.1 / 1.1, 1.4, 2.2, 3.C.1.2 / 2.2
4 points

- i. 3 points

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).

For using (or implying) Newton's second law and equating the centripetal force to the gravitational force: $F_g = ma = \frac{mv^2}{R} \qquad \frac{GmM_E}{R^2} = \frac{mv^2}{R}$	1 point
For explicitly or implicitly determining that the speed of the spacecraft is: $v = \frac{2\pi R}{T}$	1 point
For a correct answer algebraically equivalent to: $T = \sqrt{\frac{4\pi^2 R^3}{GM_E}}$	1 point
Note: It is acceptable to leave answer in terms of T^2 $T^2 = \frac{4\pi^2 R^3}{GM_E}$	

- ii. 1 point

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?

____ Greater than ____ Less than ____ Equal to

Briefly explain your reasoning.

Correct answer: "Equal to"	
Note: For an incorrect answer consistent with part (b)(i), the explanation is still graded for consistency with part (b)(i).	
For a correct explanation that the period of the spacecraft does not depend on the spacecraft mass (or only depends on the mass of Earth and the radius of the orbit) OR an explanation consistent with the answer from (b)(i)	1 point
Note: The explanation must be consistent with the checked answer.	

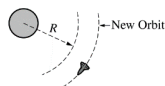
2018 SCORING GUIDELINES

Question 1 (continued)

Distribution
of points

(c) LO / SP: 2.B.1.1 / 2.2; 3.A.1.1 / 1.5, 2.2; 3.B.1.3 / 1.5, 2.2; 3.B.2.1 / 1.1, 1.4, 2.2; 3.C.1.2 / 2.2
1 point

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



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?

___ Greater than ___ Less than ___ Equal to

Briefly explain your reasoning.

Correct answer: "Less than"		
Note: If the wrong selection is made, the explanation is not graded.		
For a correct explanation of why speed decreases with increasing orbital radius		1 point
Example: Derivation step in (b)(i) shows that speed decreases with increasing R .		

2018 SCORING GUIDELINES

Question 1 (continued)

Learning Objectives (LO)

LO 2.B.1.1: The student is able to apply $F = mg$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems. [See Science Practices 2.2 and 7.2]

LO 2.B.2.1: The student is able to apply $g = GM/r^2$ to calculate the gravitational field due to an object with mass M , where the field is a vector directed toward the center of the object of mass M . [See Science Practice 2.2]

LO 3.A.1.1: The student is able to express the motion of an object using narrative, mathematical, and graphical representations. [See Science Practices 1.5, 2.1, and 2.2]

LO 3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [See Science Practice 1.1]

LO 3.B.1.3: The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [See Science Practices 1.5 and 2.2]

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, and 2.2]

LO 3.C.1.2: The student is able to use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion (for circular orbital motion only in Physics 1). [See Science Practice 2.2]