

Student #: _____

Student Name: _____

AP PHYSICS 1: CIRCULAR MOTION AND GRAVITY

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

Note: To simplify calculations, you may use $g = 10 \text{ m/s}^2$ in all problems.

- Two satellites of equal mass orbit a planet. Satellite B orbits at twice the orbital radius of Satellite A. Which of the following statements is true?
 - The gravitational force on Satellite A is four times less than that on Satellite B.
 - The gravitational force on Satellite A is two times less than that on Satellite B.
 - The gravitational force on the satellites is equal.
 - The gravitational force on Satellite A is two times greater than that on Satellite B.
 - The gravitational force on Satellite A is four times greater than that on Satellite B.
- A 70 kg astronaut floats at a distance of 10 m from a 50 000 kg spacecraft. What is the force of attraction between the astronaut and spacecraft?
 - $2.4 \times 10^{-6} \text{ N}$
 - $2.4 \times 10^{-5} \text{ N}$
 - Zero; there is no gravity in space.
 - $2.4 \times 10^5 \text{ N}$
 - $2.4 \times 10^6 \text{ N}$
- The centripetal acceleration on 1000 kg car in a turn is $1 \times 10^5 \text{ m/s}^2$. The radius of the turn is 10 m. What is the car's speed?
 - $1 \times 10^1 \text{ m/s}$
 - $1 \times 10^2 \text{ m/s}$
 - $1 \times 10^3 \text{ m/s}$
 - $1 \times 10^4 \text{ m/s}$
 - $1 \times 10^5 \text{ m/s}$
- A proposed "space elevator" can lift a 1000 kg payload to an orbit of 150 km above the Earth's surface. The radius of the Earth is $6.4 \times 10^6 \text{ m}$, and the Earth's mass is $6.0 \times 10^{24} \text{ kg}$. What is the gravitational potential energy of the payload when it reaches orbit?
 - $1.0 \times 10^3 \text{ J}$
 - $2.7 \times 10^6 \text{ J}$
 - $6.1 \times 10^{10} \text{ J}$
 - $2.7 \times 10^{12} \text{ J}$
 - $1.0 \times 10^{15} \text{ J}$
- A satellite orbits the Earth at a distance of 200 km. If the mass of the Earth is $6.0 \times 10^{24} \text{ kg}$ and the Earth's radius is $6.4 \times 10^6 \text{ m}$, what is the satellite's speed?
 - $1.0 \times 10^3 \text{ m/s}$
 - $3.5 \times 10^3 \text{ m/s}$
 - $7.8 \times 10^3 \text{ m/s}$
 - $5 \times 10^6 \text{ m/s}$
 - $6.1 \times 10^7 \text{ m/s}$
- Mars orbits the Sun at a distance of $2.3 \times 10^{11} \text{ m}$. The mass of the Sun is $2.0 \times 10^{30} \text{ kg}$, and the mass of Mars is $6.4 \times 10^{23} \text{ kg}$. Approximately what is the gravitational force that the Sun exerts on Mars?
 - $1.6 \times 10^{20} \text{ N}$
 - $1.6 \times 10^{21} \text{ N}$
 - $3.7 \times 10^{21} \text{ N}$
 - $3.7 \times 10^{32} \text{ N}$
 - $3.7 \times 10^{42} \text{ N}$

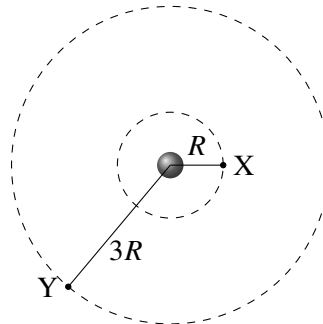
7. When climbing from sea level to the top of Mount Everest, a hiker changes elevation by 8848 m. By what percentage will the gravitational field of the Earth change during the climb? (The Earth's mass is 6.0×10^{24} kg, and its radius is 6.4×10^6 m.)
- (A) It will increase by approximately 0.3 %.
- (B) It will decrease by approximately 0.3 %.
- (C) It will increase by approximately 12 %.
- (D) It will decrease by approximately 12 %.
- (E) The gravitational field strength will not change.

8. Four planets, A through D, orbit the same star. The relative masses and distances from the star for each planet are shown in the table. For example, Planet A has twice the mass of Planet B, and Planet D has three times the orbital radius of Planet A. Which planet has the highest gravitational attraction to the star?

Planet	Relative mass	Relative distance
A	$2m$	r
B	m	$0.1r$
C	$0.5m$	$2r$
D	$4m$	$3r$

- (A) Planet A
- (B) Planet B
- (C) Planet C
- (D) Planet D
- (E) All have the same gravitational attraction to the star.
9. A satellite orbits the Earth at a distance that is four times the radius of the Earth. If the acceleration due to gravity near the surface of the Earth is g , the acceleration of the satellite is most nearly
- (A) zero
- (B) $g/2$
- (C) $g/4$
- (D) $g/8$
- (E) $g/16$

10. The mass of a planet is $1/4$ that of Earth and its radius is half of Earth's radius. The acceleration due to gravity on this planet is most nearly
- (A) 2 m/s^2
- (B) 4 m/s^2
- (C) 5 m/s^2
- (D) 10 m/s^2
- (E) 20 m/s^2
11. Two planets of mass M and $9M$ are in the same solar system. The radius of the planet of mass M is R . In order for the acceleration due to gravity to be the same for each planet, the radius of the planet of mass $9M$ would have to be
- (A) $R/2$
- (B) R
- (C) $2R$
- (D) $3R$
- (E) $9R$
12. Two planets, X and Y, orbit a star. Planet X orbits at a radius R , and Planet Y orbits at a radius $3R$. Which of the following best represents the relationship between the acceleration a_X of Planet X and the acceleration a_Y of Planet Y?

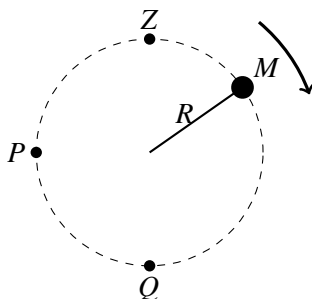


- (A) $a_X = 9a_Y$
- (B) $9a_X = a_Y$
- (C) $a_X = 3a_Y$
- (D) $3a_X = a_Y$
- (E) $a_X = a_Y$
13. A satellite is in a stable circular orbit around the Earth at a radius R and speed v . At what radius would the satellite travel in a stable orbit with a speed $2v$?
- (A) $14 R$
- (B) $12 R$
- (C) R
- (D) $2R$
- (E) $4R$

14. The Earth and the moon apply a gravitational force to each other. Which of the following statements is true?
- (A) The Earth applies a greater force on the moon than the moon exerts on the Earth.
 - (B) The Earth applies a smaller force on the moon than the moon exerts on the Earth.
 - (C) The Earth applies a force on the moon, but the moon does not exert a force on the Earth.
 - (D) The Earth does not apply a force on the moon, but the moon exerts a force on the Earth.
 - (E) The force the Earth applies to the moon is equal and opposite to the force the moon applies to the Earth.
15. Two masses exert a gravitational force F on each other. If one of the masses is doubled, and the distance between the masses is tripled, the new force between them is
- (A) $6F$
 - (B) $2F/3$
 - (C) $2F/9$
 - (D) $3F/2$
 - (E) $4F/9$
16. A planet orbits at a radius R around a star of mass M . The period of orbit of the planet is
- (A) $\sqrt{\frac{4\pi^2 R^2}{GM}}$
 - (B) $\frac{4\pi^2 R^3}{GM}$
 - (C) $\sqrt{\frac{4\pi^2 R^3}{GM}}$
 - (D) $\sqrt{\frac{4\pi^2 R}{GM}}$
 - (E) $\frac{GM}{4\pi^2 R}$
17. Consider a two-star system shown above, which consists of two stars of mass m rotating in a circle of radius r about their center of mass. What is the total energy of the two-star system?
- (A) $-Gm^2/2r$
 - (B) $Gm^2/2r$
 - (C) $Gm^2/4r$
 - (D) $3Gm^2/4r$
 - (E) $-Gm^2/4r$
18. If a planet has twice the radius of Earth and half of Earth's density, what is the acceleration due to gravity on the surface of the planet (in terms of the gravitational acceleration g on the surface of Earth)?
- (A) $4g$
 - (B) $2g$
 - (C) g
 - (D) $g/2$
 - (E) $g/4$

AP PHYSICS 1: CIRCULAR MOTION AND GRAVITY
SECTION II
5 Questions

Directions: Answer all questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should show your work. Credit also depends on demonstrating that you know which physical principles would be appropriate to apply in a particular situation. Therefore, you should clearly indicate which part of a question your work is for.



1. A ball of mass M is attached to a string of length R and negligible mass. The ball moves clockwise in a vertical circle, as shown above. When the ball is at point P , the string is horizontal. Point Q is at the bottom of the circle and point Z is at the top of the circle. Air resistance is negligible. Express all algebraic answers in terms of the given quantities and fundamental constants.

- (a) On the figures below, draw and label all the forces exerted on the ball when it is at points P and Q , respectively.



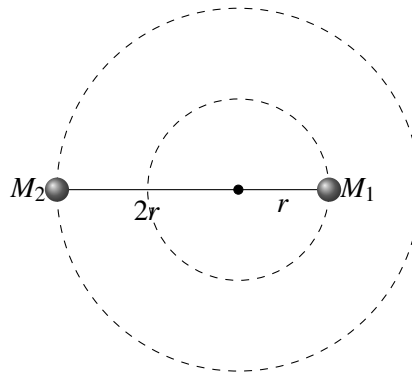
- (b) Derive an expression for v_{\min} , the minimum speed the ball can have at point Z without leaving the circular path.
- (c) The maximum tension the string can have without breaking is T_{\max} . Derive an expression for v_{\min} , the maximum speed the ball can have at point Q without breaking the string.
- (d) Suppose that the string breaks at the instant the ball is at point P . Describe the motion of the ball immediately after the string breaks.

2. Two stars of equal mass M are orbiting each other in a circular path. Show that the orbital period is given by:

$$T^2 = \frac{2\pi^2 d^3}{GM}$$

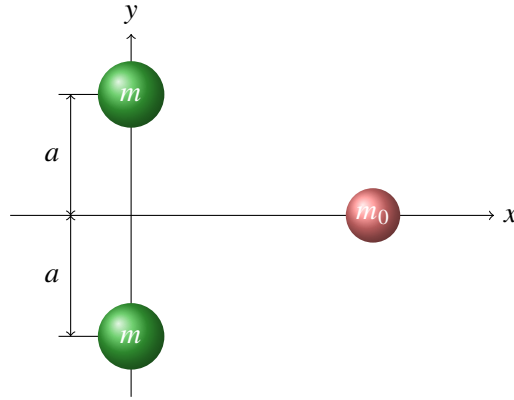
where d is the distance between the stars.

3. Two stars of unequal mass orbit each other about their common center of mass as shown. The star of mass M_1 orbits in a circle of radius r , and the star of mass M_2 orbits in a circle of radius $2r$.



- (a) Determine the ratio of masses M_1/M_2 .
- (b) Determine the ratio of the acceleration a_1 of M_1 to the acceleration a_2 of M_2 .
- (c) Determine the ratio of the period T_1 of M_1 to the period T_2 of M_2 .

4. Two point particles of mass m are on the y axis at $y = a$ and $y = -a$, as shown in the figure below.



- (a) Derive the expression for the gravitational force exerted by these two particles on a third particle of mass m_0 located on the x axis at a distance x away from the origin.
- (b) What is the gravitational field \mathbf{g} on the x -axis due to the two particles?
- (c) Show that g_x (the x component of \mathbf{g}) due to the two particles on the y axis is approximately $-\frac{2Gm}{x^2}$ when x is much greater than a .
- (d) Show that the maximum value of $|g_x|$ occurs at the point $x = \frac{\pm a}{\sqrt{2}}$.

5. Five equal masses M are equally spaced on the arc of a semicircle of radius R as shown in the figure below. A mass m is located at the center of curvature of the arc. If M is 3 kg, m is 21 kg, and R is 10 cm, what is the force on m due to the five masses?

