Student #: ____________________ Student Name: ____________________

AP PHYSICS C CLASS 12: UNIVERSAL GRAVITATION

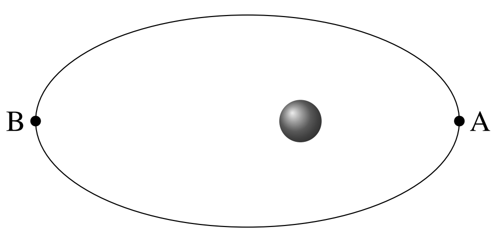
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

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

1. The Earth is at an average distance of 1 AU from the Sun and has an orbital period of 1 year. Jupiter orbits the Sun at approximately 5 AU. About how long is the orbital period of Jupiter?
   (A) 1 year
   (B) 2 years
   (C) 5 years
   (D) 11 years
   (E) 125 years

2. A satellite orbits the Earth at a distance of 200 km in a circular path. If the mass of the Earth is 6.0×10^{24} kg and the Earth's radius is 6.4×10^6 m, what is the satellite's speed?
   (A) 1.0×10^3 m/s
   (B) 3.5×10^3 m/s
   (C) 7.8×10^3 m/s
   (D) 5×10^6 m/s
   (E) 6.1×10^7 m/s

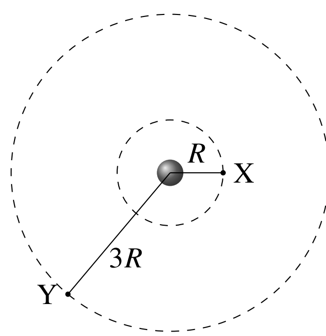
3. A satellite orbits the Earth in an elliptical orbit, with point A being close to the Earth and point B farther away. As the satellite moves from point A to point B, which of the following is true of the angular momentum and kinetic energy of the satellite?



	Angular momentum	Kinetic energy
(A)	Increases	Remains constant
(B)	Remains constant	Increases
(C)	Decreases	Remains constant
(D)	Remains constant	Decreases
(E)	Remains constant	Remains constant

4. 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) $\frac{R}{4}$
   (B) $\frac{R}{2}$
   (C) R
   (D) $2R$
   (E) $4R$

5. 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) $a_X = a_Y$

6. 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) $\frac{GM}{4\pi^2 R}$

7. A moon orbits a large planet in an elliptical orbit, with its closest approach at a distance a, and its farthest distance b. The speed of the moon at point b is v. The speed at point a is

   (A) $\frac{av}{b}$
   (B) $\frac{bv}{a}$
   (C) $\frac{(a+b)v}{b}$
   (D) $\frac{(b-a)v}{b}$
   (E) $\frac{2bv}{a}$

8. A satellite orbits the Earth in an elliptical orbit. Which of the following statements is true?

   (A) The angular velocity of the satellite increases as it travels farther from the Earth.
   (B) The acceleration of the satellite increases as it travels closer to the Earth.
   (C) The angular momentum of the satellite increases as it travels closer to the Earth.
   (D) The potential energy of the satellite is equal to its kinetic energy at all points in the orbit.
   (E) The speed of the satellite must remain constant for it to remain in orbit around the Earth.

9. A satellite of mass m travels in an elliptical orbit around a planet of mass M. The satellite has a speed v when it is closest to the planet at a distance r. Work is done by the engines of the satellite to change its orbit to a circular orbit when it is at this distance r. Which of the following statements is true of the transition from an elliptical orbit to a circular orbit?

   (A) The work done by the satellite engines to change the orbit is equal to the change in kinetic energy of the satellite.
   (B) The work done by the satellite engines to change the orbit is equal to the change in potential energy of the satellite.
   (C) The work done by the satellite engines to change the orbit is equal to the change in angular momentum of the satellite.
   (D) The work done by the satellite engines to change the orbit is equal to the change in speed of the satellite.
   (E) The work done by the satellite engines to change the orbit is equal to the change in orbital radius of the satellite.

10. A satellite of mass m orbits the Earth with a potential energy U and a kinetic energy K. Which of the following statements would have to be true for the satellite to escape the Earth's gravity completely?

   (A) The kinetic energy of the satellite would have to be equal to the potential energy between the Earth and the satellite.
   (B) The potential energy between the Earth and the satellite would have to be greater than the kinetic energy of the satellite.
   (C) The total energy of the satellite would have to be greater than the kinetic energy of the satellite.
   (D) The kinetic energy of the satellite would have to be greater than the potential energy of the satellite.
   (E) The total energy of the satellite would have to be equal to the potential energy of the satellite.

AP PHYSICS C CLASS 12: UNIVERSAL GRAVITATION
SECTION II
3 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.

11. In March 1999 the Mars Global Surveyor (GS) entered its final orbit about Mars, sending data back to Earth. Assume a circular orbit with a period of 1.18×10^2 min $= 7.08 \times 10^3$ s and orbital speed of 3.40×10^3 m/s. The mass of the GS is 930 kg and the radius of Mars is 3.43×10^6 m.

    (a) Calculate the radius of the GS orbit.

    (b) Calculate the mass of Mars.

    (c) Calculate the total mechanical energy of the GS in this orbit.

    (d) If the GS was to be placed in a lower circular orbit (closer to the surface of Mars), would the new orbital period of the GS be greater than or less than the given period? Justify your answer.

    ____ Greater than ____ Less than

    (e) In fact, the orbit the GS entered was slightly elliptical with its closest approach to Mars at 3.71×10^5 m above the surface and its furthest distance at 4.36×10^5 m above the surface. If the speed of the GS at closest approach is 3.40×10^3 m/s, calculate the speed at the furthest point of the orbit.

12. A student is given the set of orbital data for some of the moons of Saturn shown below and is asked to use the data to determine the mass M_S of Saturn. Assume the orbits of these moons are circular.

Orbital Period, T (seconds)	Orbital Radius, R (meters)		
8.14×10^4	1.85×10^8		
1.18×10^5	2.38×10^8		
1.63×10^5	2.95×10^8		
2.37×10^5	3.77×10^8		

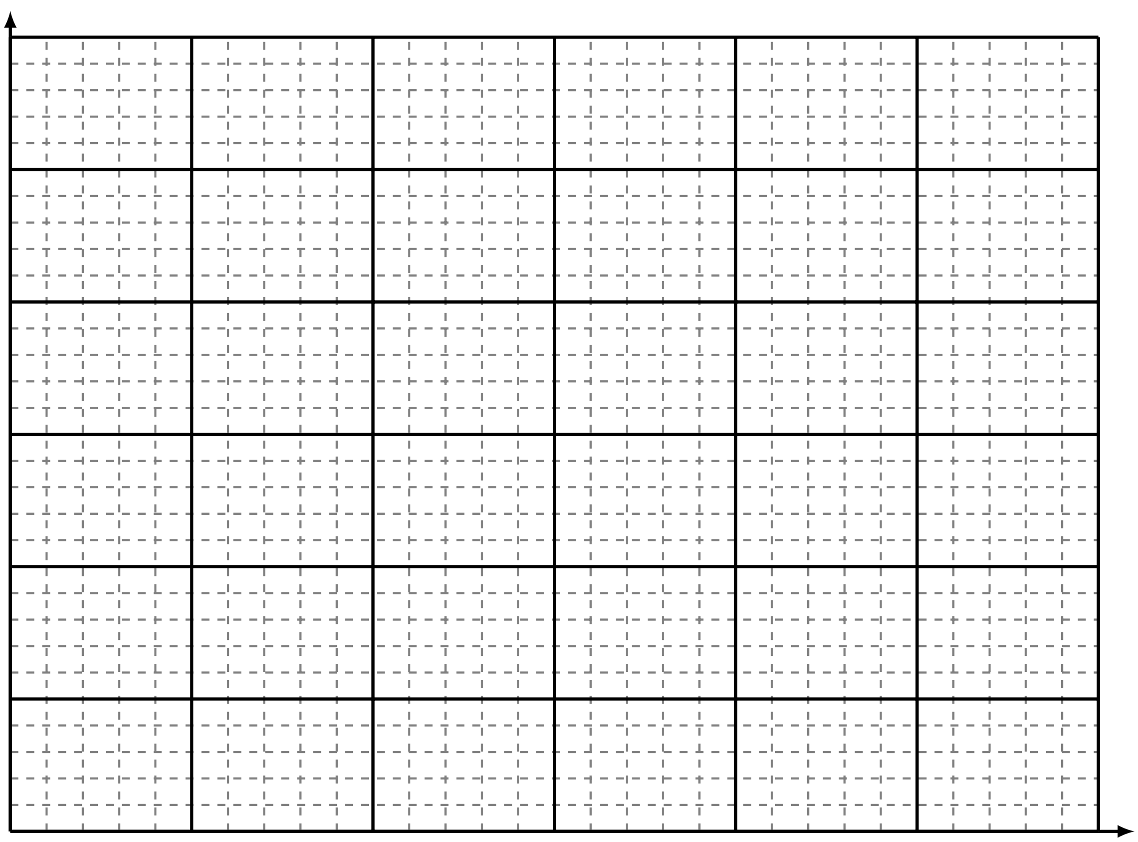
(a) Write an algebraic expression for the gravitational force between Saturn and one of its moons.

(b) Use your expression from part (a) and the assumption of circular orbits to derive an equation for the orbital period T of a moon as a function of its orbital radius R.

(c) Which quantities should be graphed to yield a straight line whose slope could be used to determine Saturn's mass?

(d) Complete the data table by calculating the two quantities to be graphed. Label the top of each column, including units.

(e) Plot the graph on the axes below. Label the axes with the variables used and appropriate numbers to indicate the scale.



(f) Using the graph, calculate a value for the mass of Saturn.

13. **THIS IS A CHALLENGE PROBLEM THAT IS MORE DIFFICULT THAN AP EXAMS:** Spacecraft that study the Sun are often placed at the "L1 Lagrange Point", located sunward of Earth on the Sun–Earth line. L1 is the point where Earth's and Sun's gravity together produce an orbital period of one year, so that a spacecraft at L1 stays fixed relative to Earth as both planet and spacecraft orbit the Sun. This placement ensures an uninterrupted view of the sun, without being periodically eclipsed by Earth as would occur in Earth orbit. Find L1's location relative to Earth. (Hint: This problem calls for numerical methods for solving high-order polynomial equation.)