AP PHYSICS 1 & C: SIMPLE HARMONIC MOTION & UNIVERSAL GRAVITATION
(Classes 7 & 8)

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 $g = 10\,\mathrm{m/s^2}$ in all problems.

1. A simple pendulum has a mass m, length L, and period T. If the pendulum mass is replaced by a mass of $2m$, the period will be
   (a) doubled
   (b) halved
   (c) quartered
   (d) quadrupled
   (e) unchanged

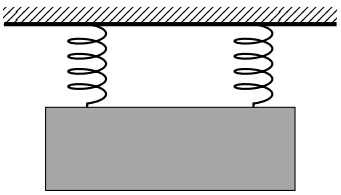
2. A mass oscillates on the end of a spring that obeys Hooke's law. Which of the following statements is true?
   (a) The amplitude of oscillation is equal to the potential energy of the spring.
   (b) The kinetic energy of the oscillating mass is constant.
   (c) Maximum potential energy occurs when the mass reaches the equilibrium position.
   (d) The potential energy of the spring at the amplitude is equal to the kinetic energy at the equilibrium position.
   (e) The kinetic energy of the spring at the amplitude is equal to the potential energy at the equilibrium position.

3. A superball is dropped from a height of 5.0 m above a floor. The ball bounces off the floor in a perfectly elastic collision so that it rises to the same height with each bounce. The motion of the ball can be described as
   (a) harmonic motion with a period of 2 s
   (b) harmonic motion with a period of 1 s
   (c) harmonic motion with a period of $1/2$ s
   (d) motion with a constant velocity
   (e) motion with a constant momentum

4. An object oscillates in simple harmonic motion along the x-axis according to the equation $x = 6\cos(4t)$. The period of oscillation of the object is
   (a) $1/4$ s
   (b) 4 s
   (c) π/4 s
   (d) π/2 s
   (e) 4π s

5. A mass m oscillates on the end of a string of length L. The frequency of the pendulum is f. How would you increase the frequency of the pendulum to $2f$?
   (a) Increase the length of the pendulum to $4L$
   (b) Decrease the length of the pendulum to $1/4L$
   (c) Increase the length of the pendulum to $2L$
   (d) Decrease the length of the pendulum to $1/2L$
   (e) Decrease the mass of the pendulum to $1/2m$

6. A mass hangs from two parallel springs, each with the same spring constant k. Compared to the period T of the same mass oscillating on one of the springs, the period of oscillation of the mass with both springs connected to it is



   (a) $T/4$
   (b) $T/2$
   (c) T (unchanged)
   (d) $2T$
   (e) $4T$

GO ON TO THE NEXT PAGE.

7. Which of the following is generally true for an object in simple harmonic motion on a spring of constant k?
   (a) The greater the spring constant k, the greater the amplitude of the motion.
   (b) The greater the spring constant k, the greater the period of the motion.
   (c) The greater the spring constant k, the greater the frequency of the motion.
   (d) The lower the spring constant k, the greater the frequency of the motion.
   (e) The lower the spring constant k, the greater the kinetic energy of the motion.

Questions 8 to 10

A harmonic oscillator follows the equation $\frac{d^2x}{dt^2} = -4x$. The spring constant k is 4 N/m.

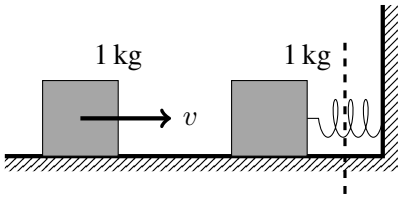
8. The angular frequency ω of the harmonic motion is
   (a) zero
   (b) 2 rad/s
   (c) 4 rad/s
   (d) 8 rad/s
   (e) 16 rad/s

9. The mass m oscillating on the spring is
   (a) 1 kg
   (b) 2 kg
   (c) 4 kg
   (d) 8 kg
   (e) 16 kg

10. The period T of oscillation is
   (a) zero
   (b) $\pi/4$s
   (c) $\pi/2$s
   (d) π s
   (e) 2π s

11. A pendulum of length L has a period of 2 s on Earth. A planetary explorer takes the same pendulum of length L to another planet where its period is 1 s. The gravitational acceleration on the surface of this planet is most nearly
   (a) $8g$
   (b) $4g$
   (c) $2g$
   (d) $12g$
   (e) $14g$

12. A block of mass 1.0 kg is sliding on a frictionless horizontal surface with a speed of 4.0 m/s when it collides inelastically with another 1.0 kg block attached to a spring. The spring compresses a distance of 0.5 m after the collision. The force constant k of the spring is

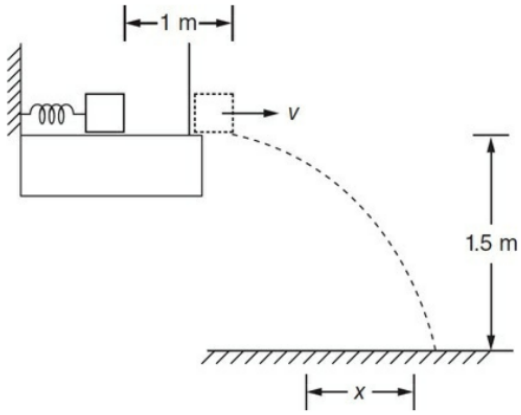


   (a) 2 N/m
   (b) 4 N/m
   (c) 8 N/m
   (d) 16 N/m
   (e) 32 N/m

13. A satellite orbits the Earth at a distance of 100 km. The mass of the satellite is 100 kg, while the mass of the Earth is approximately 6.0×10^{24} kg. The radius of the Earth is approximately 6.4×10^6 m. What is the approximate force of gravity acting on the satellite?
   (a) 4×10^4 N
   (b) 6.2×10^6 N
   (c) 4×10^8 N
   (d) 6.2×10^9 N
   (e) 4×10^{14} N

GO ON TO THE NEXT PAGE.

14. A block of mass 0.5 kg rests up against a compressed spring of force constant 5 N/m. The spring is released, and the block travels a distance of 1.0 m when the block leaves the spring at the edge of the horizontal frictionless table, and is projected to the floor. The table is 1.5 m high. The horizontal distance from the table the block lands on the floor is



(a) 1.2 m
(b) 1.7 m
(c) 2.1 m
(d) 2.8 m
(e) 3.4 m

15. 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?

(a) The gravitational force on Satellite A is four times less than that on Satellite B.
(b) The gravitational force on Satellite A is two times less than that on Satellite B.
(c) The gravitational force on the satellites is equal.
(d) The gravitational force on Satellite A is two times greater than that on Satellite B.
(e) The gravitational force on Satellite A is four times greater than that on Satellite B.

16. A 70-kg astronaut floats at a distance of 10 m from a 50000-kg spacecraft. What is the force of attraction between the astronaut and spacecraft?

(a) 2.4×10^{-6} N
(b) 2.4×10^{-5} N
(c) Zero; there is no gravity in space.
(d) 2.4×10^{5} N
(e) 2.4×10^{6} N

17. The centripetal acceleration on 1000 kg car in a turn is 1×10^{5} m/s^2. The radius of the turn is 10 m. What is the car's speed?

(a) 1×10^{1} m/s
(b) 1×10^{2} m/s
(c) 1×10^{3} m/s
(d) 1×10^{4} m/s
(e) 1×10^{5} m/s

18. 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 6.4×10^{6} m, and the Earth's mass is 6×10^{24} kg. What is the gravitational potential energy of the payload when it reaches orbit?

(a) 1.0×10^{3} J
(b) 2.7×10^{6} J
(c) 6.1×10^{10} J
(d) 2.7×10^{12} J
(e) 1.0×10^{15} J

19. 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

GO ON TO THE NEXT PAGE.

20. A satellite orbits the Earth at a distance of 200 km. 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) 1×10^{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

21. Mars orbits the Sun at a distance of 2.3×10^{11} m. The mass of the Sun is 2×10^{30} kg, and the mass of Mars is 6.4×10^{23} kg. Approximately what is the gravitational force that the Sun exerts on Mars?

(a) 1.6×10^{20} N
(b) 1.6×10^{21} N
(c) 3.7×10^{21} N
(d) 3.7×10^{32} N
(e) 3.7×10^{42} N

22. 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.

23. 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.

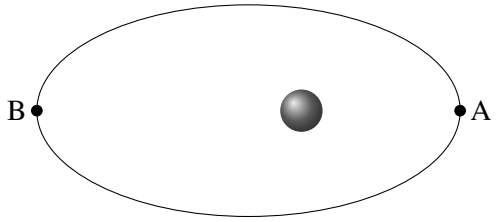
24. A satellite orbits the Earth at a distance that is four times the radius of the Earth. If the acceleration due to gravity near the surface of the Earth is g, the acceleration of the satellite is most nearly

(a) zero
(b) $g/2$
(c) $g/4$
(d) $g/8$
(e) $g/16$

25. 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

26. 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?



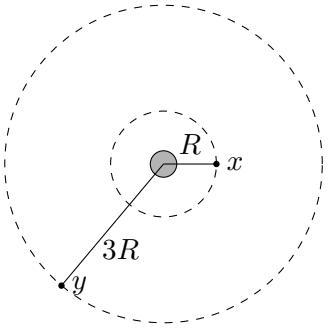
	Angular momentum	Kinetic energy
(a)	Increases	Remains constant
(b)	Remains constant	Increases
(c)	Decreases	Remains constant
(d)	Remains constant	Decreases
(e)	Remains constant	Remains constant

27. 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) $1/2\ R$
(b) R
(c) $2R$
(d) $3R$
(e) $9R$

GO ON TO THE NEXT PAGE.

28. 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) $a_X = a_Y$

29. 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) $4R$

30. 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.

31. 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) $2/3\ F$
(c) $2/9\ F$
(d) $3/2\ F$
(e) $4/9\ F$

32. A planet orbits at a radius R around a star of mass M. The period of orbit of the planet is

(a) $\sqrt{\dfrac{4\pi^2R^2}{GM}}$
(b) $\dfrac{4\pi^2R^3}{GM}$
(c) $\sqrt{\dfrac{4\pi^2R^3}{GM}}$
(d) $\sqrt{\dfrac{4\pi^2R}{GM}}$
(e) $\dfrac{GM}{4\pi^2R}$

33. 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

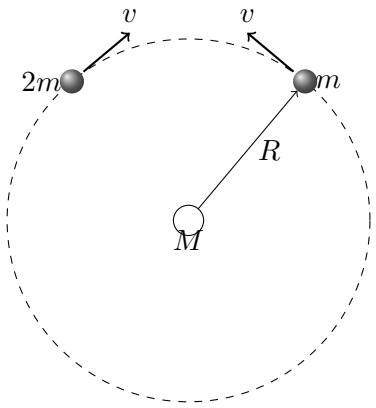
(a) $\dfrac{av}{b}$
(b) $\dfrac{bv}{a}$
(c) $\dfrac{(a+b)v}{b}$
(d) $\dfrac{(b-a)v}{b}$
(e) $\dfrac{2bv}{a}$

GO ON TO THE NEXT PAGE.

34. 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.

35. Two moons of mass m and $2m$ orbit a planet of mass M at the same radius R and speed v toward each other, as shown. The moons collide and stick together without destroying either moon. The total momentum of the moons after the collision is



    (a) mv
    (b) $2mv$
    (c) $3mv$
    (d) $6mv$
    (e) zero

36. The velocity of the two masses after the collision above is

    (a) v counterclockwise
    (b) $v/2$ counterclockwise
    (c) $v/2$ clockwise
    (d) $v/3$ counterclockwise
    (e) $v/3$ clockwise

37. 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) $-Gm^2/4r$

38. 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 & C: Simple Harmonic Motion and Universal Gravitation
Student Answer Sheet for Multiple-Choice Section

No.	Answer
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	

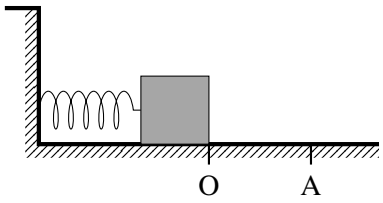
No.	Answer
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	

GO ON TO THE NEXT PAGE.

AP PHYSICS 1 & C: SIMPLE HARMONIC MOTION & UNIVERSAL GRAVITATION
SECTION II
7 Questions

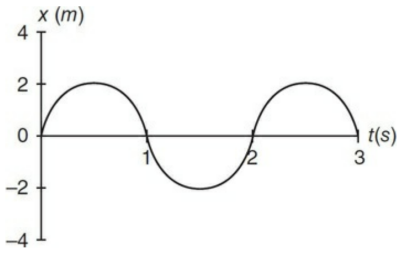
Directions: Answer all questions. The suggested time is about 10 minutes for answering each of the questions. The parts within a question may not have equal weight. All final numerical answers should include appropriate units. Credit depends on the quality of your solutions and explanations, so you should 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 mass m oscillates on an ideal spring of spring constant k on a frictionless horizontal surface. The mass is pulled aside to a distance A from its equilibrium position, and released.



   (a) In terms of the given quantities, at what distance from the equilibrium position is the potential energy of the mass equal to its kinetic energy?
   (b) In terms of the given quantities, what is the acceleration of the mass when it is at the amplitude A?

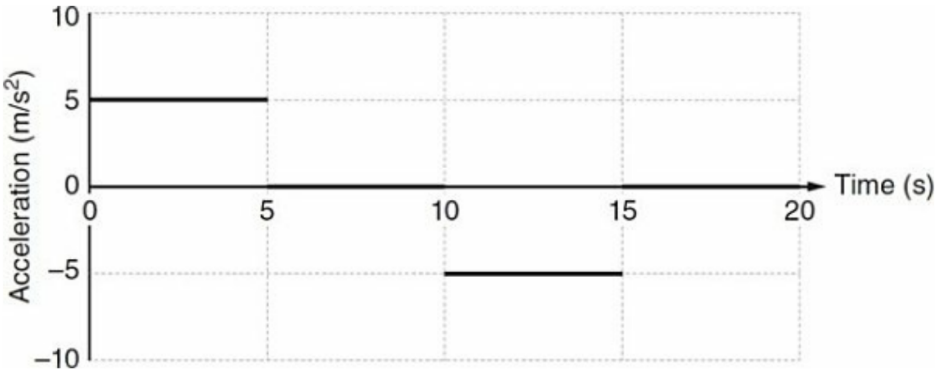
2. A mass oscillates in simple harmonic motion as shown by the position x vs. time t graph below.



   (a) What is the frequency of oscillation?
   (b) Write the equation that represents the speed of the mass as a function of time.

GO ON TO THE NEXT PAGE.

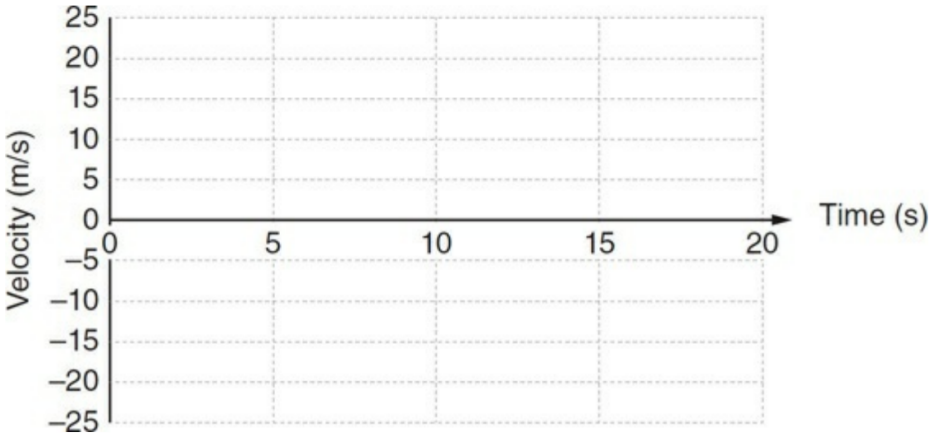
3. The acceleration vs. time graph shows the motion of an elevator during a 20-second time interval. The elevator starts from rest at time $t = 0$.



(a) Determine the instantaneous velocity of the elevator at the end of 10 s.

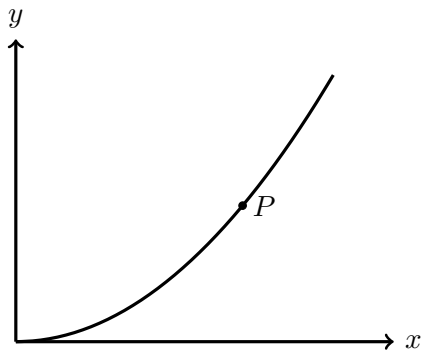
(b) Determine the displacement of the elevator after 5 s.

(c) On the axes below, sketch the graph that represents the velocity vs. time graph for the elevator for the 20-second time interval.



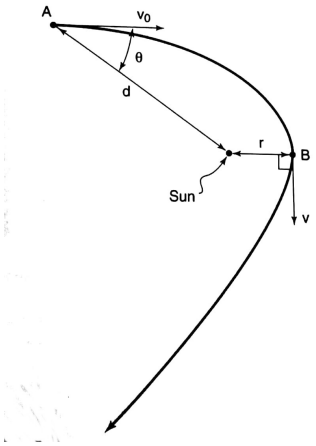
GO ON TO THE NEXT PAGE.

4. A particle follows a parabolic path with the equation $y = 2x^2$ as shown. The x-component of the particle's velocity v_x as a function of time t is 6, that is, the horizontal displacement is $x = 6t$.



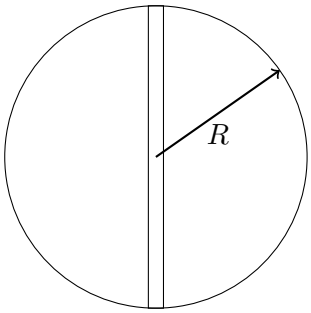
(a) Determine the y-component of the particle's velocity v_y as a function of time.
(b) On the diagram above, sketch arrows to represent the horizontal and vertical components of the particle's acceleration at point P.

5. A spacecraft moving with an initial velocity $\mathbf{v}_0$, shown below, "slingshots" around the sun in order to reverse its direction. The sun's mass is m_{sun} and you can make the assumption that the sun remains stationary.



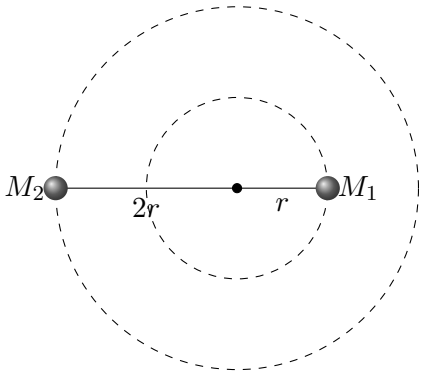
(a) What is the minimum initial speed required by the spacecraft to escape the sun's gravitational field and move in a trajectory toward infinity?
(b) What is the minimum initial speed v_o that the spacecraft must have in order to avoid falling into the sun? (Treat the sun and the spacecraft as points.)
(c) Repeat the previous questions, but now the sun has a radius R.
(d) Write down the equations required to calculate the initial angle θ in terms of v_0, d, m_{sun}, G, and r.

6. A planet of mass M, radius R, and uniform density has a small tunnel drilled through the center of the planet, as shown below. When the mass is inside the tunnel, it experiences a force of $F = (GmM/R^3)r$, whereas when the mass is outside of the planet, it experiences a gravitational force of $F = GmM/r^2$.



   (a) Setting the potential energy of the mass to be zero at the planet's center, calculate the mass's potential energy as a function of distance from the center of the planet $U(r)$, for values $r < R$. Sketch this potential function.
   (b) If the mass is dropped from R from the center of the planet, how long will it take until it returns to its original position?
   (c) If the mass is dropped from $R/2$ from the center of the planet, will it require more, or less, or the same amount of time to return to its original position compared to if it was dropped from R?
   (d) If the mass is dropped from $2R$ from the center of the planet, will it require more, or less, or the same amount of time to return to its original position compared to if it was dropped from R?

7. 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.