Circular Motion and Gravitation:

Circular motion is the movement of an object in a circle with a changing Velocity (it has a constant speed but constant change in direction).

The technical term for this form of acceleration is centripetal acceleration (a_c), and the term for the force that makes this acceleration possible is centripetal force (F_c).Centripetal means “center seeking”.

Universal gravitation states that any two masses attract one another with a force that is inversely proportional to the distance. This is also known as Newton’s law of gravitation.

Objectives:

- To explain and calculate the centripetal acceleration of an object moving in a circle at constant speed.
- To solve problems involving centripetal force.
- To calculate the speed, period, frequency and distance traveled for an object in a circle at a constant speed.
- To state and apply Newton’s law of gravitation.
- To know when another type of force is causing circular motion.

Circular Motion and Gravitation Formulas:

$$a_c = \frac{v^2}{r}$$

$$F_c = ma_c$$

$$F = \frac{Gm_1 m_2}{r^2}$$

not on formula sheet

$$v = \frac{2\pi r}{t}$$

Concepts to Watch Out For:

- There is no such thing as Centrifugal force, it does NOT exist.
- As objects get closer together, the force of attraction increases exponentially.
- Force of attraction is directly proportional to the mass of the objects.
- It is important to measure from the center of objects when solving for gravitational force .This is important for measuring large masses, like planets, but less important when you are dealing with small masses. Small masses are considered to be “point masses”.
- Remember that when an object it traveling around a circle it travels a distance of 2πr after each complete revolution.
- The time needed to complete one revolution is period, T.
- The force and acceleration is directed towards the center of the circle for objects traveling in a circle
- The tangential velocity or speed is tangent to the circle for objects traveling in a circle

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
Circles and Gravitation
NOTES:

Notice. . .

A scientific or graphing calculator, a centimeter ruler, a protractor, and a copy of the *2002 Edition Reference Tables for Physical Setting/Physics*, which you may need to answer some questions in this examination, must be available for your use while taking this examination.

The use of any communications device is strictly prohibited when taking this examination. If you use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Part A

Answer all questions in this part.

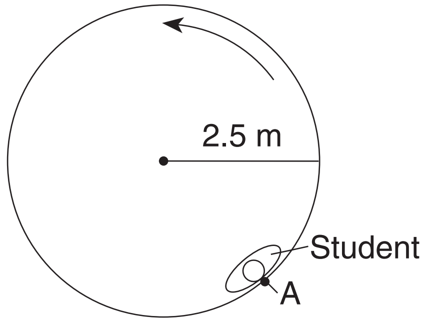
Directions (1–11): For *each* statement or question, write on the separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question.

1 A satellite weighs 200 newtons on the surface of Earth. What is its weight at a distance of one Earth radius above the surface of Earth?

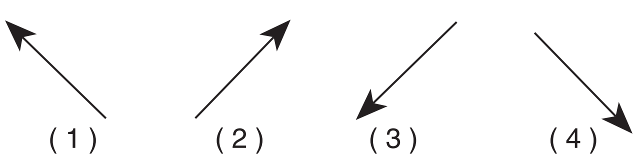
(1) 50 N
(2) 100 N
(3) 400 N
(4) 800 N

Base your answers to questions 2 and 3 on the information and diagram below.

The diagram shows the top view of a 65-kilogram student at point *A* on an amusement park ride. The ride spins the student in a horizontal circle of radius 2.5 meters, at a constant speed of 8.6 meters per second. The floor is lowered and the student remains against the wall without falling to the floor.



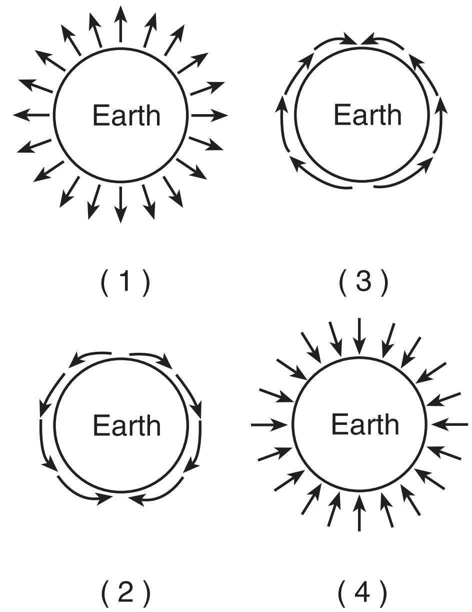
2 Which vector best represents the direction of the centripetal acceleration of the student at point *A*?



3 The magnitude of the centripetal force acting on the student at point *A* is approximately

(1) 1.2×10^4 N
(2) 1.9×10^3 N
(3) 2.2×10^2 N
(4) 3.0×10^1 N

4 Which diagram best represents the gravitational field lines surrounding Earth?



5 The magnitude of the centripetal force acting on an object traveling in a horizontal, circular path will *decrease* if the

(1) radius of the path is increased
(2) mass of the object is increased
(3) direction of motion of the object is reversed
(4) speed of the object is increased

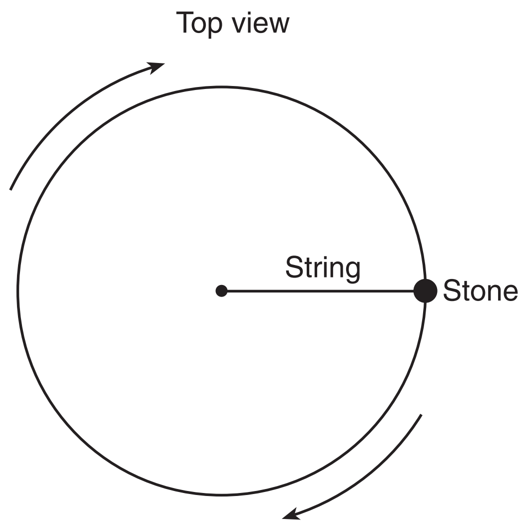
6 The centripetal force acting on the space shuttle as it orbits Earth is equal to the shuttle's

(1) inertia
(2) momentum
(3) velocity
(4) weight

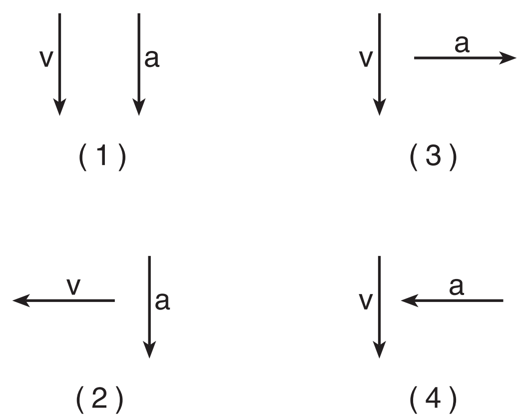
7 An unbalanced force of 40. newtons keeps a 5.0-kilogram object traveling in a circle of radius 2.0 meters. What is the speed of the object?

(1) 8.0 m/s
(2) 2.0 m/s
(3) 16 m/s
(4) 4.0 m/s

8 A stone on the end of a string is whirled clockwise at constant speed in a horizontal circle as shown in the diagram below.



Which pair of arrows best represents the directions of the stone's velocity, *v*, and acceleration, *a*, at the position shown?



9 At a certain location, a gravitational force with a magnitude of 350 newtons acts on a 70.-kilogram astronaut. What is the magnitude of the gravitational field strength at this location?

(1) 0.20 kg/N
(2) 5.0 N/kg
(3) 9.8 m/s^2
(4) 25 000 N•kg

10 The Hubble telescope's orbit is 5.6×10^5 meters above Earth's surface. The telescope has a mass of 1.1×10^4 kilograms. Earth exerts a gravitational force of 9.1×10^4 newtons on the telescope. The magnitude of Earth's gravitational field strength at this location is

(1) 1.5×10^{-20} N/kg
(2) 0.12 N/kg
(3) 8.3 N/kg
(4) 9.8 N/kg

11 A 2.0-kilogram mass is located 3.0 meters above the surface of Earth. What is the magnitude of Earth's gravitational field strength at this location?

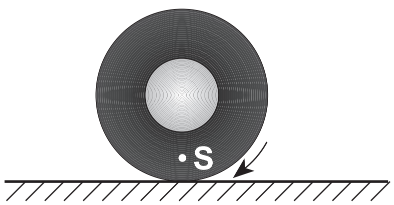
(1) 4.9 N/kg
(2) 2.0 N/kg
(3) 9.8 N/kg
(4) 20. N/kg

Part B–1

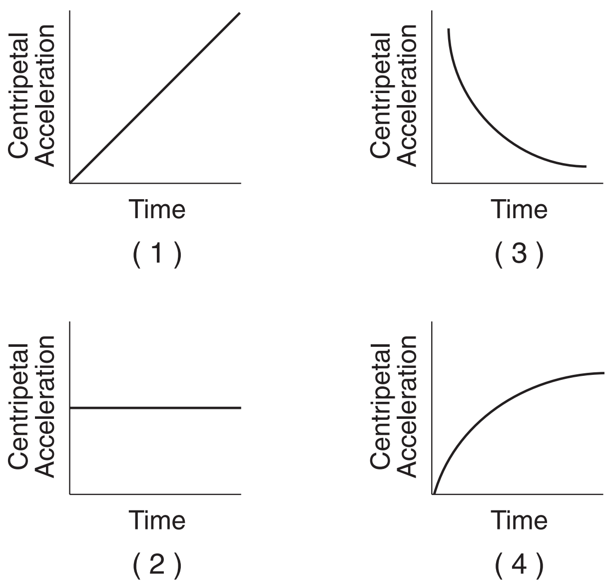
Answer all questions in this part.

Directions (12-17): For *each* statement or question, write on the separate answer sheet the *number* of the word or expression that, of those given, best completes the statement or answers the question.

12 In the diagram below, *S* is a point on a car tire rotating at a constant rate.



Which graph best represents the magnitude of the centripetal acceleration of point *S* as a function of time?



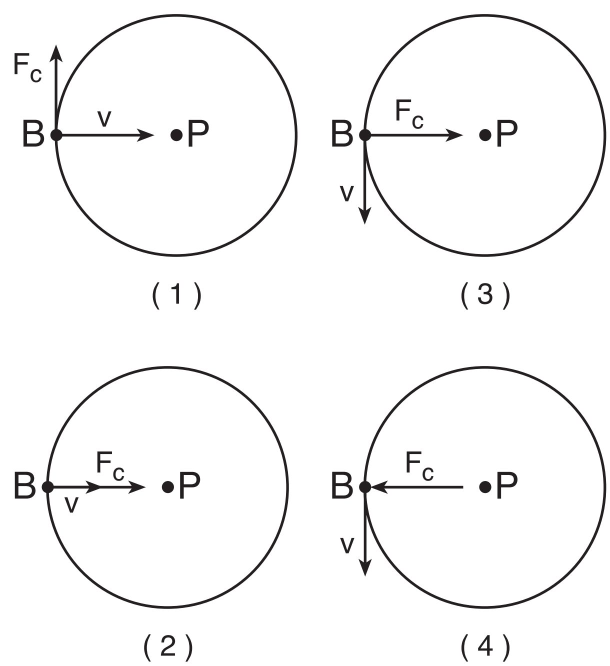
13 A student on an amusement park ride moves in a circular path with a radius of 3.5 meters once every 8.9 seconds. The student moves at an average speed of

(1) 0.39 m/s (3) 2.5 m/s
(2) 1.2 m/s (4) 4.3 m/s

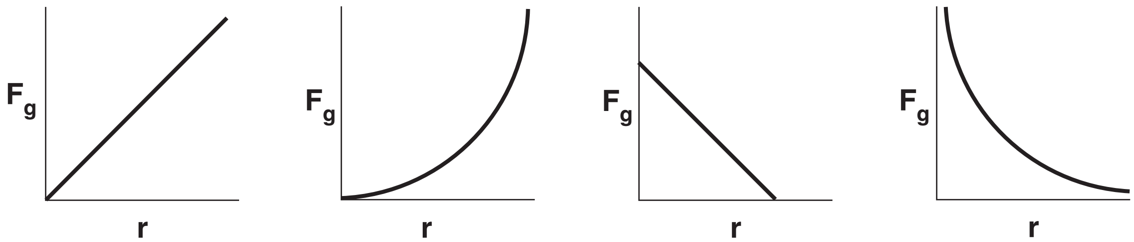
14 A 1.0×10^3-kilogram car travels at a constant speed of 20. meters per second around a horizontal circular track. The diameter of the track is 1.0×10^2 meters. The magnitude of the car's centripetal acceleration is

(1) 0.20 m/s^2 (3) 8.0 m/s^2
(2) 2.0 m/s^2 (4) 4.0 m/s^2

15 A body, *B*, is moving at constant speed in a horizontal circular path around point *P*. Which diagram shows the direction of the velocity (*v*) and the direction of the centripetal force (F_c) acting on the body?

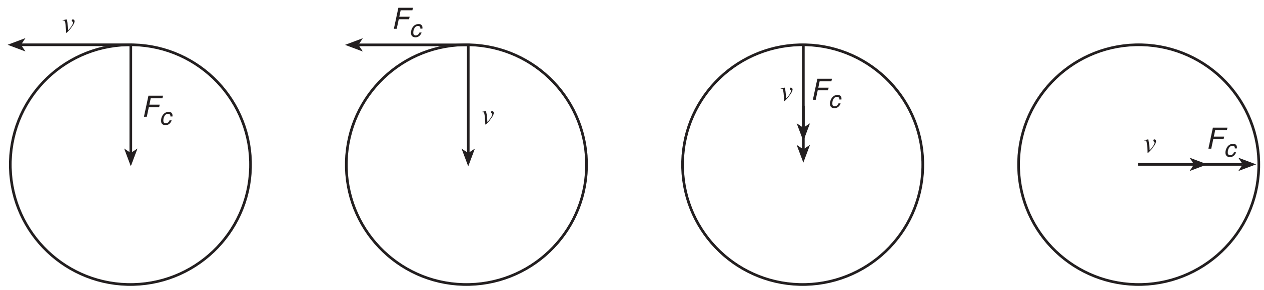


16 Which graph represents the relationship between the magnitude of the gravitational force, F_g, between two masses and the distance, r, between the centers of the masses?



(1)   (2)   (3)   (4)

17 A 1.0×10^3-kilogram car travels at a constant speed of 20. meters per second around a horizontal circular track. Which diagram correctly represents the direction of the car's velocity (v) and the direction of the centripetal force (F_c) acting on the car at one particular moment?



(1)   (2)   (3)   (4)

Part B–2

Answer all questions in this part.

Directions (18-30): Record your answers in the spaces provided in your answer booklet.

Base your answers to questions 18 through 24 on the information below.

The combined mass of a race car and its driver is 600. kilograms. Traveling at constant speed, the car completes one lap around a circular track of radius 160 meters in 36 seconds.

18-19 Calculate the speed of the car. [Show all work, including the equation and substitution with units.] [2]

20 On the diagram *on your answer sheet*, draw an arrow to represent the direction of the net force acting on the car when it is in position *A*. [1]

21-22 Calculate the magnitude of the centripetal acceleration of the car. [Show all work, including the equation and substitution with units.] [2]

23-24 Calculate the magnitude of the average gravitational force between Earth and the Moon. [Show all work, including the equation and substitution with units.] [2]

Base your answers to questions 25 through 27 on the information below.

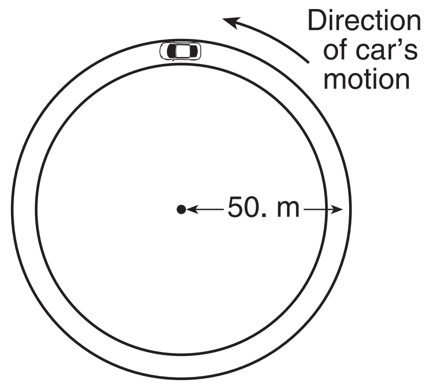
A 28-gram rubber stopper is attached to a string and whirled clockwise in a horizontal circle with a radius of 0.80 meter. The diagram in your answer booklet represents the motion of the rubber stopper. The stopper maintains a constant speed of 2.5 meters per second.

25–26 Calculate the magnitude of the centripetal acceleration of the stopper. [Show all work, including the equation and substitution with units.] [2]

27 On the diagram *in your answer booklet*, draw an arrow showing the direction of the centripetal force acting on the stopper when it is at the position shown. [1]

Base your answers to questions 28 through 30 on the information and diagram below and on your knowledge of physics.

A 1.5×10^3-kilogram car is driven at a constant speed of 12 meters per second counterclockwise around a horizontal circular track having a radius of 50. meters, as represented below.



Track, as Viewed from Above

28 On the diagram *in your answer booklet*, draw an arrow to indicate the direction of the velocity of the car when it is at the position shown. Start the arrow on the car. [1]

29–30 Calculate the magnitude of the centripetal acceleration of the car. [Show all work, including the equation and substitution with units.] [2]

Part C

Answer all questions in this part.

Directions (31–43): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *2006 Edition Reference Tables for Physical Setting/Physics.*

Base your answers to questions 31 through 33 on the passage and data table below.

The net force on a planet is due primarily to the other planets and the Sun. By taking into account all the forces acting on a planet, investigators calculated the orbit of each planet.

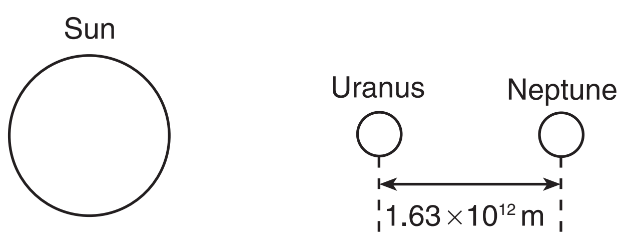
A small discrepancy between the calculated orbit and the observed orbit of the planet Uranus was noted. It appeared that the sum of the forces on Uranus did not equal its mass times its acceleration, unless there was another force on the planet that was not included in the calculation. Assuming that this force was exerted by an unobserved planet, two scientists working independently calculated where this unknown planet must be in order to account for the discrepancy. Astronomers pointed their telescopes in the predicted direction and found the planet we now call Neptune.

Data Table

Mass of the Sun	1.99×10^{30} kg
Mass of Uranus	8.73×10^{25} kg
Mass of Neptune	1.03×10^{26} kg
Mean distance of Uranus to the Sun	2.87×10^{12} m
Mean distance of Neptune to the Sun	4.50×10^{12} m

31 What fundamental force is the author referring to in this passage as a force between planets? [1]

32-33 The diagram below represents Neptune, Uranus, and the Sun in a straight line. Neptune is 1.63×10^{12} from Uranus.



(Not drawn to scale)

Calculate the magnitude of the interplanetary force of attraction between Uranus and Neptune at this point. [Show all work, including the equation and substitution with units.] [2]

34 The magnitude of the force the Sun exerts on Uranus is 1.41×10^{21} newtons. Explain how it is possible for the Sun to exert a greater force on Uranus than Neptune exerts on Uranus. [1]

Base your answers to questions 35 through 38 on the information below.

Auroras over the polar regions of Earth are caused by collisions between charged particles from the Sun and atoms in Earth's atmosphere. The charged particles give energy to the atoms, exciting them from their lowest available energy level, the ground state, to higher energy levels, excited states. Most atoms return to their ground state within 10. nanoseconds.

In the higher regions of Earth's atmosphere, where there are fewer interatom collisions, a few of the atoms remain in excited states for longer times. For example, oxygen atoms remain in an excited state for up to 1.0 second. These atoms account for the greenish and red glows of the auroras. As these oxygen atoms return to their ground state, they emit green photons ($f = 5.38 \times 10^{14}$ Hz) and red photons ($f = 4.76 \times 10^{14}$ Hz). These emissions last long enough to produce the changing aurora phenomenon.

35 What is the order of magnitude of the time, in seconds, that most atoms spend in an excited state? [1]

36–37 Calculate the energy of a photon, in joules, that accounts for the red glow of the aurora. [Show all work, including the equation and substitution with units.] [2]

38 Explain what is meant by an atom being in its ground state. [1]

Base your answers to questions 39 through 43 on the information below and on your knowledge of physics.

Pluto orbits the Sun at an average distance of 5.91×10^{12} meters. Pluto's diameter is 2.30×10^{6} meters and its mass is 1.31×10^{22} kilograms.

Charon orbits Pluto with their centers separated by a distance of 1.96×10^{7} meters. Charon has a diameter of 1.21×10^{6} meters and a mass of 1.55×10^{21} kilograms.

39–40 Calculate the magnitude of the gravitational force of attraction that Pluto exerts on Charon. [Show all work, including the equation and substitution with units.] [2]

41–42 Calculate the magnitude of the acceleration of Charon toward Pluto. [Show all work, including the equation and substitution with units.] [2]

43 State the reason why the magnitude of the Sun's gravitational force on Pluto is greater than the magnitude of the Sun's gravitational force on Charon. [1]

Tear Here

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING PHYSICS

Wednesday, June 22, 2005 — 1:15 to 4:15 p.m., only

ANSWER SHEET

Student .... Sex: ☐ Male ☐ Female Grade ....

Teacher .... School ....

Record your answers to Part A and Part B–1 on this answer sheet.

Part A

1 ....

2 ....

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10. ....

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Part A Score

☐

Part B–1

12 ....

13. ....

14 ....

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16. ....

17 ....

Part B–1 Score

☐

Write your answers to Part B–2 and Part C in your answer booklet.

The declaration below should be signed when you have completed the examination.

I do hereby affirm, at the close of this examination, that I had no unlawful knowledge of the questions or answers prior to the examination and that I have neither given nor received assistance in answering any of the questions during the examination.

____

Signature

Tear Here

The University of the State of New York

REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SETTING
PHYSICS

Part	Maximum Score	Student's Score
A	11	
B–1	6	
B–2	13	
C	13	

Total Written Test Score (Maximum Raw Score: 85) ☐

Final Score (From Conversion Chart) ☐

Raters' Initials:

Rater 1 .... Rater 2 ....

ANSWER BOOKLET

Student .... Sex: ☐ Male ☐ Female

Teacher..

School .... Grade ....

Answer all questions in Part B–2 and Part C. Record your answers in this booklet.

Part B–2

For Raters Only

18-19

18 ☐

19 ☐

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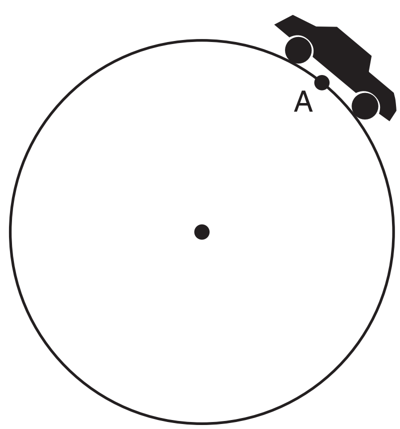

20 ☐

[OVER]

For Raters Only

21-22

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23-24

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25–26

For Raters Only

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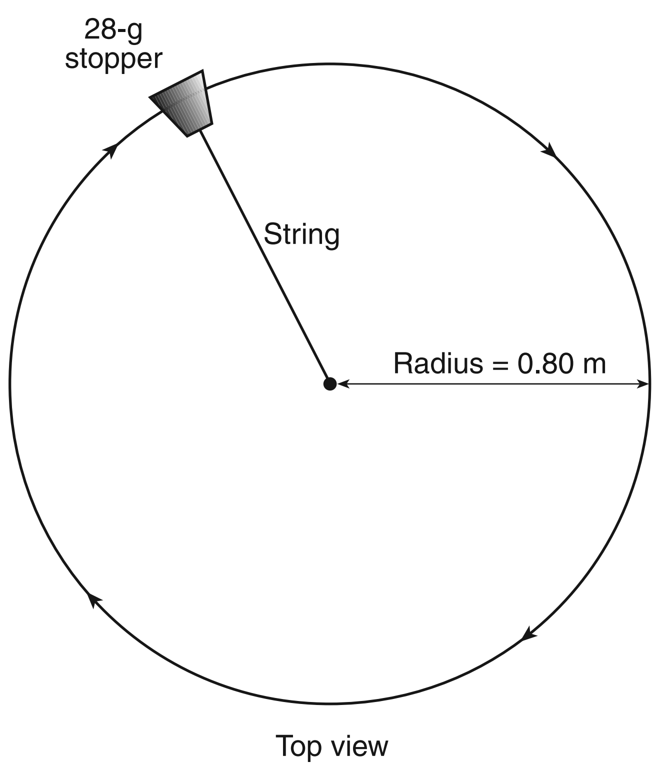

27

For Raters Only

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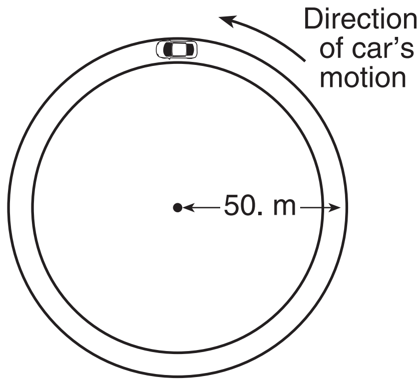

Track, as Viewed from Above

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29–30

Part C

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36–37

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38 ______________________________

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39–40

41–42

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