RLP-PHYA · RLP Physics A — Motion, Forces, Momentum and Gravitation

Unit 4: Gravitation, Circular Motion and Orbits

Practice Workbook. The same problems, in the same order, as the Practice sections of the online lessons.

Name _____ Period _____

Lesson 4.1 — Staying Up: Circular Motion and the Centripetal Force

FLUENCY

1. A net force of 24 N gives an object an acceleration of 3 m/s^2. What is its mass?

2. What net force gives a 1.2 kg object an acceleration of 3 m/s^2?

3. A car rounds a curve of radius 40 m at 12 m/s. Find its centripetal acceleration.

4. A child on a merry-go-round sits 2.0 m from the center, and it turns once every 4.0 s. Find the child's speed and centripetal acceleration.

5. A 0.20 kg ball whirls in a horizontal circle of radius 0.60 m at 3.0 m/s (ignore gravity's sag). Find the string tension.

6. How does the centripetal force change if the speed doubles and the radius stays the same? If the radius doubles and the speed stays the same?

APPLICATION

7. A car takes a flat 80 m radius curve at 20 m/s. What minimum coefficient of static friction is needed?

8. A flat highway exit ramp has radius 45 m. On a wet day $\mu_s = 0.60$ (illustrative). What is the fastest safe speed, in m/s and mph?

9. Earth orbits the Sun at 1.496×10^{11} m once every 365.25 days. Find Earth's orbital speed and centripetal acceleration.

CHALLENGE

10. A roller-coaster car goes over the inside top of a vertical loop of radius 6.0 m. What is the minimum speed at the top for the car to stay on the track?

REVIEW

11. A 1500 kg object moving at 12 m/s collides and sticks to a 1400 kg object at rest (same line; positive is the first object's direction). Find the total momentum and the velocity just after the collision.

12. An object is dropped from rest 10 m above the ground. Ignoring air resistance ($g = 9.8\ m/s^2$), how long does it fall and how fast is it moving at impact?

Lesson 4.2 — Pendulum Lab: Measuring the Strength of Earth's Gravity

FLUENCY

1. Find the slope of the line through $(-9, -2)$ and $(0, -1)$.

2. An object is dropped from rest 45 m above the ground. Ignoring air resistance ($g = 9.8\ m/s^2$), how long does it fall and how fast is it moving at impact?

3. An object is dropped from rest 1.2 m above the ground. Ignoring air resistance ($g = 9.8\ m/s^2$), how long does it fall and how fast is it moving at impact?

4. Find the period of a 0.50 m pendulum on Earth.

5. How long must a pendulum be to have a period of 1.00 s?

6. The same 0.50 m pendulum is taken to the Moon ($g = 1.62\ m/s^2$). What is its period?

7. A T^2-versus-L graph has slope $4.10\ s^2/m$. What value of g does it give?

APPLICATION

8. A 0.80 m pendulum takes 17.9 s for 10 swings. Find g and the percent difference from 9.8 m/s^2.

9. Use Newton's law of gravitation to predict g at Earth's surface ($G = 6.674 \times 10^{-11}$, $M = 5.972 \times 10^{24}$ kg, $R = 6.371 \times 10^{6}$ m).

10. A student measures L to the top of the bob instead of its center, so every L is 2 cm too short. Will the computed g be too high or too low? Explain.

CHALLENGE

11. Timing 10 swings of a 2.0 s pendulum with ±0.2 s reaction error, what is the percent uncertainty in T and in g? How many swings would you time to get g within 0.5%?

REVIEW

12. What net force gives a 0.5 kg object an acceleration of 4.5 m/s^2?

13. A 4 kg box is pushed with 120 N to the right against 7 N of friction. Find the net force and the acceleration.

Lesson 4.3 — The Apple and the Moon: Arguing for the Inverse-Square Law

FLUENCY

1. Convert 37 g to kg.

2. Convert 60 g to kg.

3. Find the gravitational force between Earth and the Moon (Moon mass 7.342×10^{22} kg, distance 3.844×10^{8} m; NASA fact sheet).

4. Two students (55 kg and 65 kg) sit 0.80 m apart. Find their gravitational attraction.

5. Find Earth's gravitational field strength at 420 km altitude (the ISS).

6. How does g at a distance of 2 Earth radii from Earth's center compare with the surface value?

APPLICATION

7. A 75 kg astronaut is on the ISS. Find the gravitational force on the astronaut, and explain why they appear weightless.

8. Use NASA's Mars fact sheet (mass 6.417×10^{23} kg, radius 3,389.5 km) to compute g on Mars.

9. A claim: "Gravity weakens as $1/r$, not $1/r^2$." The Moon is 60.3 Earth radii away. What acceleration would each model predict for the Moon, and which matches the observed 0.00272 m/s^2?

CHALLENGE

10. At what distance from Earth's center is g half its surface value? Give the answer in Earth radii and as an altitude.

REVIEW

11. A 0.5 kg object moving at 0.6 m/s collides and sticks to a 0.25 kg object moving at −0.3 m/s (same line; positive is the first object's direction). Find the total momentum and the velocity just after the collision.

12. A 1,200 kg car on a 60 m radius curve needs 4,000 N of friction. How fast is it going?

Lesson 4.4 — Orbits by the Numbers: GPS, Geostationary Satellites and Kepler's Third Law

FLUENCY

1. Convert 37 km to m.
2. Find the orbital speed and period of a satellite at 550 km altitude.
3. Find the orbital speed and period at 2,000 km altitude.
4. Mars orbits the Sun at 1.524 AU. Use Kepler's third law (T in years, a in AU) to find its period.
5. Satellite B orbits at 9 times the radius of satellite A. Compare their periods and speeds.

APPLICATION

6. A GPS satellite has a period of half a sidereal day (43,082 s). Find its orbital radius and altitude.

7. Explain why a 100 kg satellite and a 2,000 kg satellite at the same altitude orbit at the same speed.

8. A spreadsheet orbit model gives T = 95.6 min at 550 km, but a student's hand calculation gives 81 min. The student used r = 550 km + 6,371 m. Find the error.

CHALLENGE

9. How many times per day does a 550 km satellite orbit, and how far apart in longitude are consecutive ground tracks at the equator (Earth turns 360° per 86,164 s)?

REVIEW

10. A 0.75 kg object moving at 0.4 m/s collides and sticks to a 1.5 kg object moving at −0.3 m/s (same line; positive is the first object's direction). Find the total momentum and the velocity just after the collision.

11. A net force of 22.5 N acts on a 5 kg object. What is its acceleration?

12. A 20 kg box is pushed with 62 N to the right against 17 N of friction. Find the net force and the acceleration.

Unit 4 checkpoint

1. An object moves in a circle at constant speed. Its acceleration is
   A. zero
   B. toward the center
   C. along the tangent
   D. outward
2. A 1,000 kg car on a 50 m radius curve at 10 m/s needs _____ N of friction toward the center.
3. True or false: If the string of a whirling ball breaks, the ball flies straight outward from the center.
4. A 1.20 m pendulum on Earth has a period of _____ s.
5. Doubling a pendulum's mass changes its period by
   A. a factor of 2
   B. a factor of √2
   C. nothing
   D. a factor of 1/2
6. If the distance between two masses triples, the gravitational force becomes
   A. 1/3
   B. 1/9
   C. 3 times
   D. 9 times

7. True or false: Astronauts on the ISS float because there is no gravity at that altitude.
8. Earth's gravitational field at 2 Earth radii from its center is about _____ N/kg.
9. Which satellite moves fastest?
   A. GEO (35,786 km)
   B. GPS (20,200 km)
   C. ISS (420 km)
   D. They all move at the same speed
10. A satellite at 1,000 km altitude has a period of about _____ min.
11. True or false: Kepler's third law says T²/r³ is the same for all bodies orbiting the same central mass.
12. Using a spreadsheet to compare many candidate orbits before choosing one is an example of
    A. HS-ETS1-4: using a computational model to test solutions
    B. a hands-on lab
    C. a constraint
    D. a criterion

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