

Name: _____

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AP Physics C: Mechanics — Practice Exam

Instructions: A calculator is permitted. Use $g = 9.8$ meters per second squared. Show all working, including the integrals and differential equations you set up.

Time Limit: 55 minutes

Multiple Choice (12 questions)

- [1 point] 1. A particle moves along the x-axis with acceleration $a(t) = 6t$ (SI units). At $t = 0$ it is at $x = 0$ with velocity $+2$ m/s. Where is the particle at $t = 2$ s?
- A. $x = 8$ m
 - B. $x = 12$ m
 - C. $x = 14$ m
 - D. $x = 16$ m
- [1 point] 2. A ball is thrown straight up and later returns to the launch height. Throughout the flight it experiences a drag force of magnitude bv opposing its motion. Let t_{up} be the time to reach the highest point and t_{down} the time to fall back. Which statement is correct?
- A. $t_{up} < t_{down}$, and the ball returns slower than it was launched
 - B. $t_{up} > t_{down}$, and the ball returns slower than it was launched
 - C. $t_{up} = t_{down}$, and the ball returns slower than it was launched
 - D. $t_{up} < t_{down}$, and the ball returns at the launch speed
- [1 point] 3. A 2.0 kg object starts from rest at $x = 0$ and moves along the x-axis under a single force $F(x) = 3x^2$, with F in newtons and x in metres. What is its speed at $x = 2.0$ m?
- A. 2.0 m/s
 - B. $2\sqrt{2}$ m/s
 - C. 4.0 m/s
 - D. 8.0 m/s
- [1 point] 4. A particle moves along the x-axis with potential energy $U(x) = x^3 - 12x$, with U in joules and x in metres. At which position is the particle in STABLE equilibrium?
- A. $x = -2$ m
 - B. $x = 0$
 - C. $x = 2$ m
 - D. $x = 4$ m

- [1 point] 5. A thin rod of length L lies along the x -axis from $x = 0$ to $x = L$. Its linear mass density increases linearly from zero at $x = 0$: $\lambda(x) = \lambda_0 x/L$. Where is the center of mass of the rod?
- $x = L/3$
 - $x = L/2$
 - $x = 2L/3$
 - $x = 3L/4$
- [1 point] 6. A block of mass m moving at speed v on a frictionless surface makes a head-on elastic collision with a block of mass $3m$ at rest. What is the speed of the $3m$ block after the collision?
- $v/4$
 - $v/3$
 - $v/2$
 - $2v/3$
- [1 point] 7. A uniform solid sphere ($I = \frac{2}{5}MR^2$) rolls without slipping from rest down an incline, descending a vertical height h . What is the speed of its center of mass at the bottom?
- $\sqrt{gh}$
 - $\sqrt{10gh/7}$
 - $\sqrt{4gh/3}$
 - $\sqrt{2gh}$
- [1 point] 8. A block of mass m hangs from a light string wrapped around a uniform solid cylinder of mass M and radius R ($I = \frac{1}{2}MR^2$) that turns on a frictionless horizontal axle. The system is released from rest. What is the downward acceleration of the block?
- g
 - $\frac{mg}{m+M}$
 - $\frac{2mg}{2m+M}$
 - $\frac{mg}{m+2M}$
- [1 point] 9. A 2.0 kg particle moves with constant velocity 4.0 m/s in the $+x$ direction along the line $y = 3.0$ m. Its angular momentum about the origin:
- has magnitude $24 \text{ kg} \cdot \text{m}^2/\text{s}$ and is constant
 - has magnitude $24 \text{ kg} \cdot \text{m}^2/\text{s}$ and increases as the particle moves away from the origin
 - is zero, because the particle moves in a straight line
 - has magnitude $8.0 \text{ kg} \cdot \text{m}^2/\text{s}$ and is constant
- [1 point] 10. A 0.50 kg object on a frictionless surface experiences a net force $F = -32x$, with F in newtons and x in metres. What is the period of its oscillation?
- $\pi/8 \text{ s}$
 - $\pi/4 \text{ s}$
 - $\pi/2 \text{ s}$
 - $\pi \text{ s}$

[1 point] 11. A satellite of mass m is in a circular orbit of radius r around a planet of mass M . What minimum work must be done on the satellite to move it to a circular orbit of radius $2r$?

- A. $\frac{GMm}{8r}$
- B. $\frac{GMm}{4r}$
- C. $\frac{GMm}{2r}$
- D. $\frac{GMm}{r}$

[1 point] 12. The escape speed from the surface of Earth is about 11.2 km/s. A planet has twice Earth's mass and twice Earth's radius. What is the escape speed from its surface?

- A. 5.6 km/s
- B. 7.9 km/s
- C. 11.2 km/s
- D. 22.4 km/s

Calculations (2 questions)

[12 points] 13. Drag. A motorboat of mass $m = 200$ kg is moving at $v_0 = 6.0$ m/s across still water when its engine is shut off at $t = 0$. The water exerts a resistive force on the hull of magnitude bv , directed opposite to the velocity, where $b = 40$ kg/s. Ignore all other horizontal forces.

[2 points] (a) Write Newton's second law for the boat as a differential equation for its speed $v(t)$, and give the numerical value of the constant that appears.

[3 points] (b) Solve the differential equation to obtain $v(t)$, showing the separation of variables and the use of the initial condition.

[2 points] (c) Calculate the time at which the boat's speed has fallen to half its initial value.

[3 points] (d) Calculate the total distance the boat travels after the engine is shut off (that is, as $t \rightarrow \infty$).

[2 points] (e) Suppose instead that the resistive force had magnitude cv^2 , where c is a positive constant. Using the differential equation (you need not solve for $v(t)$), argue whether the boat would travel a finite or an unbounded distance before its speed reaches zero.

[12 points] 14. Rod and putty. A thin uniform rod of mass $M = 1.5$ kg and length $L = 1.0$ m hangs at rest from a frictionless pivot at its upper end and is free to swing in a vertical plane. A lump of putty of mass $m = 0.50$ kg moving horizontally at $v_0 = 4.0$ m/s strikes the lower end of the rod and sticks to it. Use $g = 9.8$ m/s².

[3 points] (a) Starting from $I = \int r^2 dm$, derive the rotational inertia of the rod about the pivot. Then calculate the total rotational inertia of the rod-and-putty system about the pivot after the collision.

[3 points] (b) Calculate the angular speed of the rod-and-putty system immediately after the collision.

[2 points] (c) Explain why angular momentum about the pivot is conserved during the collision, but the linear momentum of the rod-and-putty system is not.

- [4 points]** (d) Calculate the maximum angle, measured from the vertical, through which the rod swings after the collision.