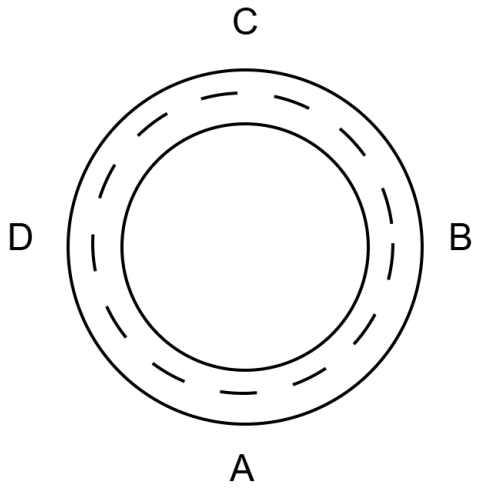
# Physics Final Exam
# Date: June 11, 2025
# Instructor: Omer

**Name:** _____ **Date:** _____

**Please read the following instructions carefully.**

- You have 90 minutes to complete this exam. This question booklet contains 5 questions and 16 pages (including the cover), totaling 100 points. Check to ensure no pages are missing. **Do not** write on this booklet. Use a separate sheet for all rough work.
- All questions are compulsory. All symbols and notations carry their standard meanings unless stated otherwise. You may use standard results if clearly stated.
- A scientific calculator is allowed. However, no programmable calculators, notes, textbooks, or other reference materials are permitted—only the **provided Equation Sheet** may be used.
- Unless otherwise stated, assume the following:
  - Acceleration due to gravity: $g = 10\,\mathrm{m/s^2}$
  - Air resistance is negligible
  - All surfaces are frictionless unless otherwise indicated
- Show all necessary work. Partial credit will be awarded where appropriate. Final answers should be boxed or clearly highlighted.

| Question | Points | Score |
|---|---|---|
| 1 | 20 | |
| 2 | 20 | |
| 3 | 20 | |
| 4 | 20 | |
| 5 | 20 | |
| Total: | 100 | |




1. A car is moving along a circular path. The radius from the center of the circular road to the middle of the road is **10 meters**. The car starts at point A and moves clockwise to B, C, D, and finally back to A.

   (a) (4 points) The table below shows different positions the car reaches, all starting from point A. Fill in the values for the total distance traveled and the displacement for each trip.

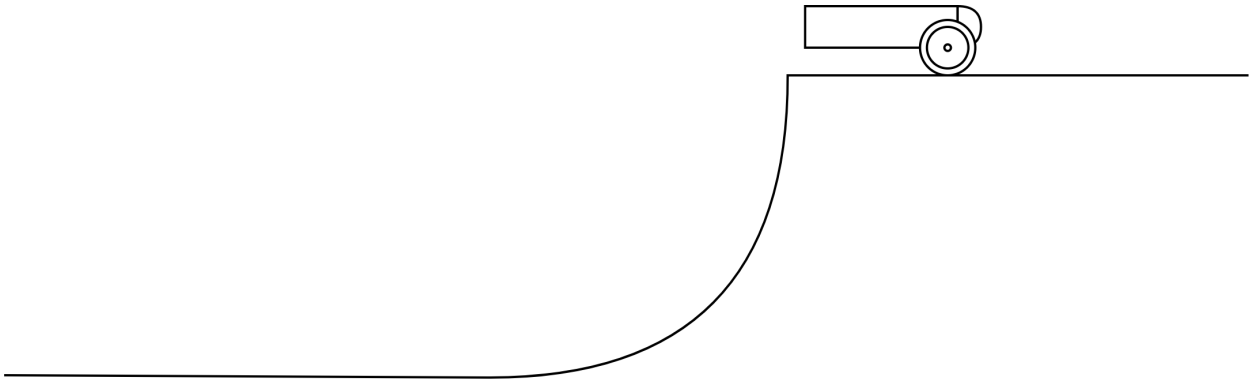
| **From → To** | A → B | A → C | A → D | A → A |
|---|---|---|---|---|
| **Distance (m)** | | | | |
| **Displacement (m)** | | | | |

(b) (2 points) If the car moves with a constant speed throughout the circular path, will it experience acceleration? Justify your answer briefly.

(c) (6 points) Assume that the car is moving along a straight road with a constant acceleration of $10\,\mathrm{m/s^2}$, and an initial velocity of $15\,\mathrm{m/s}$. How much time will it take for the car to travel a distance of 540 meters?

(d) (8 points) Assume that the car is at position $x = 100\,\mathrm{m}$, moving to the right with an initial velocity of $10\,\mathrm{m/s}$ and an acceleration of $2\,\mathrm{m/s^2}$, while a police car starts at position $x = 0\,\mathrm{m}$, initially at rest but accelerating at $6\,\mathrm{m/s^2}$. Assuming both vehicles travel along the same straight path, determine the distance that the police car travels before catching up to the car.

2. A cannon is placed on a 50 m high cliff and used to launch projectiles at various angles. Assume no air resistance and use $g = 10\,\mathrm{m/s^2}$. Unless otherwise stated, the launch speed is 40 m/s.



(a) (4 points) A cannonball is launched from ground level (not the cliff) at an initial velocity of 40 m/s at three different angles: 30°, 45°, and 60°.

Which of these angles will result in the greatest distance traveled? Support your answer with reasoning based on the equations of projectile motion or a simple proof.

(b) (4 points) Three cannonballs, with masses of 5 kg, 10 kg, and 15 kg, are launched from the top of the cliff with the same initial velocity of 40 m/s at the same angle.

Which of these cannonballs will travel the farthest horizontally before hitting the ground? Justify your answer clearly.

(c) (6 points) At what horizontal distance from the base of the cliff will the projectile be traveling at an angle of 5° below the horizontal? Assume the projectile is launched from the top of the cliff at 40 m/s and at a 0° angle.

(d) (6 points) A cannonball is launched from the top of a 50 m high cliff at a speed of 40 m/s and at an angle of 45°. The cannonball impacts the ground, which is at height 0 m. The power required to create a significant dent in the ground is approximately 2,000,000 W. Determine whether the cannonball has enough power upon impact to cause such a dent, assuming that the impact duration is 0.005 s and that the mass of the cannonball is 10 kg.

(Hint: Use the formula power $= \frac{KE_f}{t}$.)

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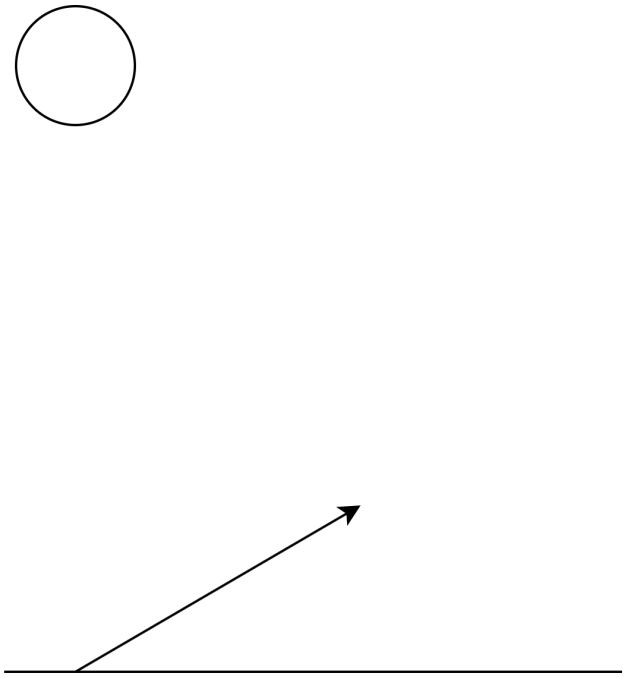
3. A ball is dropped from rest from a height of $h = 50\,\text{m}$. The mass of the ball is $m = 25\,\text{kg}$. After colliding with the ground, it rebounds with a velocity $v_f$ at an angle $\theta = 30^\circ$ above the horizontal, as shown in the diagram.



(a) (2 points) Calculate the force that gravity exerts on the ball.

(b) (3 points) Calculate the work done by gravity as the ball falls from the height of 50 m.

(c) (5 points) If the ball were dropped at an angle rather than straight down, what would be true about the magnitude of its final velocity just before impact with the ground? Justify briefly.

(d) (10 points) Determine the magnitude of the impulse delivered to the ball during the collision with the ground if it rebounds at an angle of 30° with a speed $v_f = 20\,\mathrm{m/s}$.

**Hint:** Impulse is the change in momentum:

$$\vec{J} = \Delta\vec{p} = m\vec{v}_f - m\vec{v}_i$$

Use components to find $\vec{J}_x$ and $\vec{J}_y$, then find the magnitude:

$$|\vec{J}| = \sqrt{J_x^2 + J_y^2}$$

4. A ball is released from rest at the top of a hill located at a height of 50 m. The ramp has a vertical length of 10 m and transitions into a track consisting of two vertical loops. Each loop has a radius of 10 m, and the ball travels through both loops in sequence. Assume that energy is conserved throughout the motion and that friction and air resistance are negligible. The diagram below is not drawn to scale.

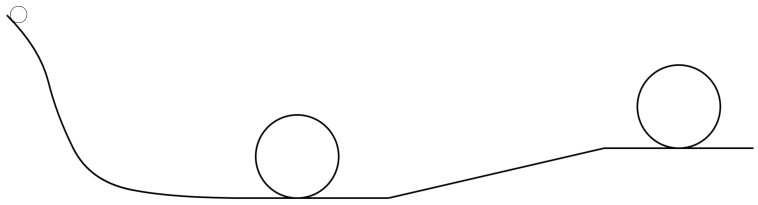


*Diagram not drawn to scale.*

(a) (3 points) Calculate the gravitational potential energy of the ball at the top of the ramp, assuming the ball has a mass 15 kg.

(b) (3 points) Determine the velocity of the ball at the top of loop #1.

(c) (3 points) Determine the velocity of the ball at the top of the ramp, just before entering loop #2.

(d) (3 points) Determine the velocity of the ball at the top of loop #2.

(e) (2 points) Identify and briefly describe the forces acting on the ball when it is at the top of loop #1 and at the top of loop #2.

(f) (6 points) Suppose instead that the initial height of the hill were reduced to 25 m. What changes, if any, would occur in the ball's potential and kinetic energy throughout its motion? Discuss any potential outcomes (e.g., whether the ball would still complete the loops).

5. The following problems involve collisions and the conservation of momentum and energy.

   (a) (4 points) Two blocks with the same mass slide toward each other on a frictionless surface. Block A moves to the right at 5 m/s, and Block B moves to the left at 3 m/s. After the collision, Block A moves to the right at 2 m/s. What is the velocity of Block B after the collision?

   (b) (4 points) The same two blocks collide again, but this time they stick together after the collision. What is the final velocity of the combined mass? State the direction clearly.

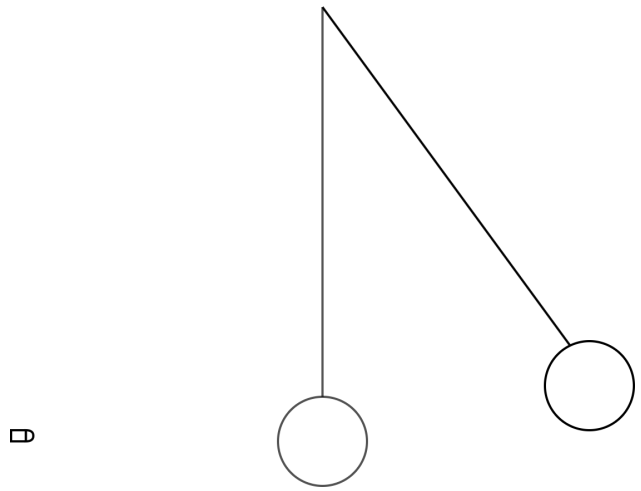


*Diagram not drawn to scale.*

(c) (6 points) A bullet of 500 grams is fired horizontally at 100 m/s toward a stationary 10 kg pendulum bob suspended from a string of length 1.5 meters. The bullet passes through the bob and emerges from the other side at 40 m/s, while the bob swings upward, reaching a maximum height $h$. Assuming conservation of momentum and energy as appropriate, determine the final height $h$ reached by the pendulum bob after the bullet passes through it. Also, calculate the angle between the vertical and the string when the bob is at its maximum height.

(d) (6 points) Now consider the same setup as in part (c), except this time the bullet embeds itself inside the 10 kg pendulum bob (perfectly inelastic collision). Determine the new final height $h$ reached by the combined system, and calculate the angle between the vertical and the string at the maximum height.



End of exam.