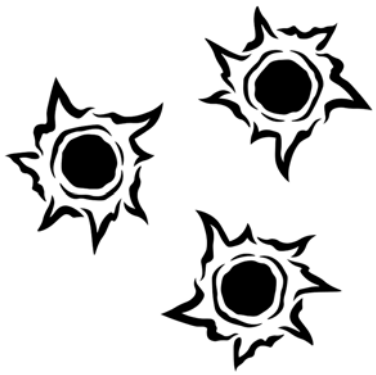
Name _____

Formulas you may need:

- "Escape Velocity: $v = \sqrt{\frac{2GM}{r}}$"
- "Gravitational Force: $F = \frac{GMm}{r^2}$"
- "$G = 6.674 \times 10^{-11}\,\mathrm{Nm^2/kg^2}$"

Mission to the Black Hole

Mission Brief: You are the chief physicist aboard the *S.S. Horizon*, en route to investigate a newly discovered black hole. Your crew needs your help solving key gravitational calculations to avoid being pulled past the event horizon. Use formulas, logic, and your math skills to save the mission!



Problem 1: Pull of the Abyss

The black hole you're observing has a mass of 4×10^{30} kg (about two times the Sun's mass). Your science drone is hovering 1×10^{7} m from the center of the black hole. What is the **gravitational force** acting on a 1,000 drone at that distance?

Problem 2: Stay or Stray?

You want to determine the **escape velocity** needed for your probe to avoid being pulled into the black hole at the same distance (r=1×10^{7} m) and mass (4×10^{30} kg). What is the escape velocity?

Problem 3: Event Horizon Limit

A supermassive black hole in another galaxy has a mass of 1×10^{40} kg. You need to calculate the **Schwarzschild radius**, which is the distance at which the escape velocity equals the speed of light. Use the escape velocity formula and set v = c = 3×10^{8} times. Solve for r:

$$r = \frac{2GM}{c^2}$$

Problem 4: Freefall to Doom

Suppose a small object is dropped from a height of 20 km above the event horizon. Assuming negligible resistance and constant gravity near the surface (use g = 1000 m/s^2), how long will it take to fall that distance?

$$\text{Use: } d = \frac{1}{2}gt^2$$