Name: _____ **Date:** _____

Answer Key: Cosmic Speed Traps: A High School Freshman Modern Physics Quest

How does reality change when things get fast and small? Synthesize relativity and quantum mechanics across these 10 challenging problems.

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1. A muon particle is created in the upper atmosphere and travel toward Earth at 0.99c. From the muon's perspective, the distance to the ground appears shorter than recorded by a stationary observer. This is an example of:

Answer: B) Length Contraction

Length contraction occurs in the direction of motion for objects moving at relativistic speeds relative to an observer.

2. In the context of the wave-particle duality, the _____ experiment proves that even individual electrons create interference patterns, behaving like waves until measured.

Answer: B) Double-Slit

The double-slit experiment is the definitive evidence for wave-particle duality, showing that matter exhibits wave-like interference.

3. According to General Relativity, a clock placed at the base of a massive skyscraper will tick slightly slower than a clock at the top of the skyscraper.

Answer: A) True

Gravitational time dilation states that time moves slower in stronger gravitational fields (closer to the Earth's center).

4. If you are designing a highly sensitive scanning probe, which quantum phenomenon allows electrons to pass through a physical vacuum barrier they technically lack the energy to cross?

Answer: B) Quantum Tunneling

Quantum tunneling allows a particle to cross an energy barrier higher than its kinetic energy due to the wave-like nature of its probability distribution.

5. The concept that 'the observer affects the observed,' specifically regarding the impossibility of perfectly measuring both position and velocity, is known as _____.

Answer: C) The Heisenberg Uncertainty Principle

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Heisenberg's principle limits the precision with which certain pairs of physical properties, like position and momentum, can be known simultaneously.

6. $E=mc^2$ implies that even a small amount of mass can be converted into a massive amount of energy because the constant 'c' (the speed of light) is a very large number.

Answer: A) True

Because c is approximately 300,000,000 m/s, squaring it (c^2) results in a massive multiplier for even tiny amounts of mass.

7. Which of these provides the best evidence for General Relativity's claim that mass warps the fabric of spacetime?

Answer: B) The observation of Gravitational Waves from colliding black holes

LIGO's detection of gravitational waves confirmed that massive events cause ripples in the geometry of spacetime itself.

8. When light of a high enough frequency hits a silicon plate and ejects electrons to create current, we call this the _____ effect.

Answer: B) Photoelectric

The photoelectric effect demonstrated that light behaves as discrete packets of energy (photons), essential for technology like solar cells.

9. In the 'Twins Paradox,' one twin stays on Earth while the other travels to a distant star at light-speed and returns. Why is the traveling twin younger?

Answer: C) Special Relativity shows time elapses slower for the moving frame

Kinetic time dilation causes clocks in motion to tick slower relative to a stationary observer, resulting in less elapsed time for the traveler.

10. Quantum mechanics suggests that at the subatomic level, particles have definite, fixed locations at all times, even when we are not looking at them.

Answer: B) False

Quantum theory holds that particles exist in a 'superposition' of probabilities and do not have a single definite location until a measurement occurs.