Theory of Relativity — Full One■Page Summary

Albert Einstein's **Theory of Relativity** transformed modern physics by redefining time, space, energy, and gravity. It has two major parts: **Special Relativity** (1905) and **General Relativity** (1915). Both are essential for modern astronomy, GPS, particle physics, and cosmology.

Special Relativity (SR)
SR applies to objects moving at constant velocity. It is based on two principles: 1) The laws of physics are identical in all inertial frames. 2) The speed of light in vacuum (c = 3×10■ m/s) is constant for all observers. Key consequences include: • **Time dilation:** A fast-moving clock runs slower compared to a stationary one. • **Length contraction:** Objects contract along the direction of motion when moving near light speed. • **Relativity of simultaneity:** Events that seem simultaneous for one observer may not be for another. • **Mass–energy equivalence:** Expressed by $E = mc^2$, showing that mass is a form of stored energy. These ideas explain particle accelerator behavior, muon decay, and high■speed spacecraft predictions.

General Relativity (GR)
GR extends relativity to accelerated motion and gravity. The central idea is that **gravity is not a force** but the **curvature of spacetime** caused by mass and energy. Key GR concepts include: • **Spacetime curvature:** Massive bodies bend spacetime, causing nearby objects to follow curved paths. • **Geodesics:** Free■falling objects move along the straightest possible paths in curved spacetime. • **Gravitational time dilation:** Time runs slower in stronger gravitational fields. • **Gravitational lensing:** Light bends around massive objects, magnifying distant galaxies. • **Black holes:** Regions where curvature becomes infinite and nothing—not even light—can escape. • **Gravitational waves:** Ripples in spacetime caused by massive accelerating bodies (detected in 2015). GR correctly predicts Mercury's orbit, black hole shadows, and the expansion of the universe.

Modern Applications
• **GPS:** Requires both SR (satellite motion) and GR (weaker gravity in orbit) corrections to remain accurate. • **Astrophysics:** Used to model neutron stars, galaxy formation, black holes, and cosmic evolution. • **Cosmology:** Foundation of the Big Bang theory and dark matter/dark energy research. • **High■energy physics:** Helps interpret observations in particle accelerators and cosmic■ray studies.

Famous Confirmations
• 1919 Eddington expedition proved that starlight bends around the Sun. • 1971 Hafele–Keating experiment showed measurable time dilation on atomic clocks flown on airplanes. • LIGO (2015–present) confirmed gravitational waves predicted a century earlier. **This full one■page text includes enough detail for generating quizzes, flashcards, or advanced conceptual questions.**