Quantum Nature of Gravity

Source: TH

Why in News?

Scientists are **conducting experiments** with **nanocrystals** to explore **if gravity follows quantum principles**.

- This effort aims to **bridge the gap** between **General Relativity** (explains gravity at macroscopic scales) and **Quantum Mechanics** (governs atomic and subatomic interactions)**.**
    - Since these theories are **fundamentally incompatible**, the research contributes to the pursuit of a **unified theory of quantum gravity.**

What is the Experiment Proposed to Test the Quantumness of Gravity?

- **About Experiment:** Scientists propose an experiment using **quantum superposition**, where **particles exist in multiple states until measured**.
    - **Nanocrystals** will test if gravity follows quantum mechanics.
    - A **test mass crystal** will be placed in **superposition** (existing in two places at once) while **another mass interacts with it via gravity**.
    - After **measuring the second crystal,** scientists will **check if gravity causes the test mass to collapse into a definite state,** potentially indicating that gravity follows quantum principles.
- **Significance:**
    - If successful, the experiment may prove that **gravity is not just a classical force but also exhibits quantum properties,** as current theories suggest that gravity should show quantum effects.
    - Most **quantum gravity tests rely on strong gravity** (e.g., black holes), which is i**mpractical to test.**
        - This experiment proposes **studying weak gravity near small objects**, making quantum gravity testing more feasible.
- **Challenges:**
    - The experiment requires **extreme precision** since even small disturbances (like **air molecules** or **seismic activity**) can affect the results.
    - Scientists need to create a **near-perfect vacuum** and measure the **results very quickly.**
    - The technology to perform this experiment is **still being developed.**

Read More: What are the Key Features of Quantum Mechanics?

What is Quantum Mechanics and General Relativity?

- **Quantum Mechanics:**
  - **About:**
    - **Quantum mechanics** is the branch of physics that explains how **sub-atomic particles**, like electrons and photons, can behave **both as particles** (small bits of matter) **and waves** (energy disturbances).
    - This concept is known as **wave-particle duality** and is a fundamental principle of quantum physics.
  - **Key Principles:**
    - **Wave-particle Duality:** Particles can behave both as waves and particles.
    - **Superposition:** A particle can exist in multiple states until measured.
    - **Entanglement:** Two particles can be correlated in such a way that the state of one instantly affects the other, even across vast distances.
    - **Uncertainty Principle:** The position and momentum of a particle cannot both be precisely measured at the same time.
- **General Relativity:**
  - **About:** It is the **modern theory of gravity** proposed by **Albert Einstein in 1915** as an extension of **Newton's law of universal gravitation.**
    - It describes **gravity not as a force**, **but as the curvature of spacetime** caused by mass and energy.
  - **Key Principles:**
    - **Space-time curvature:** Massive objects like the Sun bend space-time, causing planets to orbit.
    - **Time Dilation:** Time moves slower in stronger gravitational fields (e.g., near black holes).
    - **Equivalence Principle:** Acceleration and gravitational forces are indistinguishable in a closed system.

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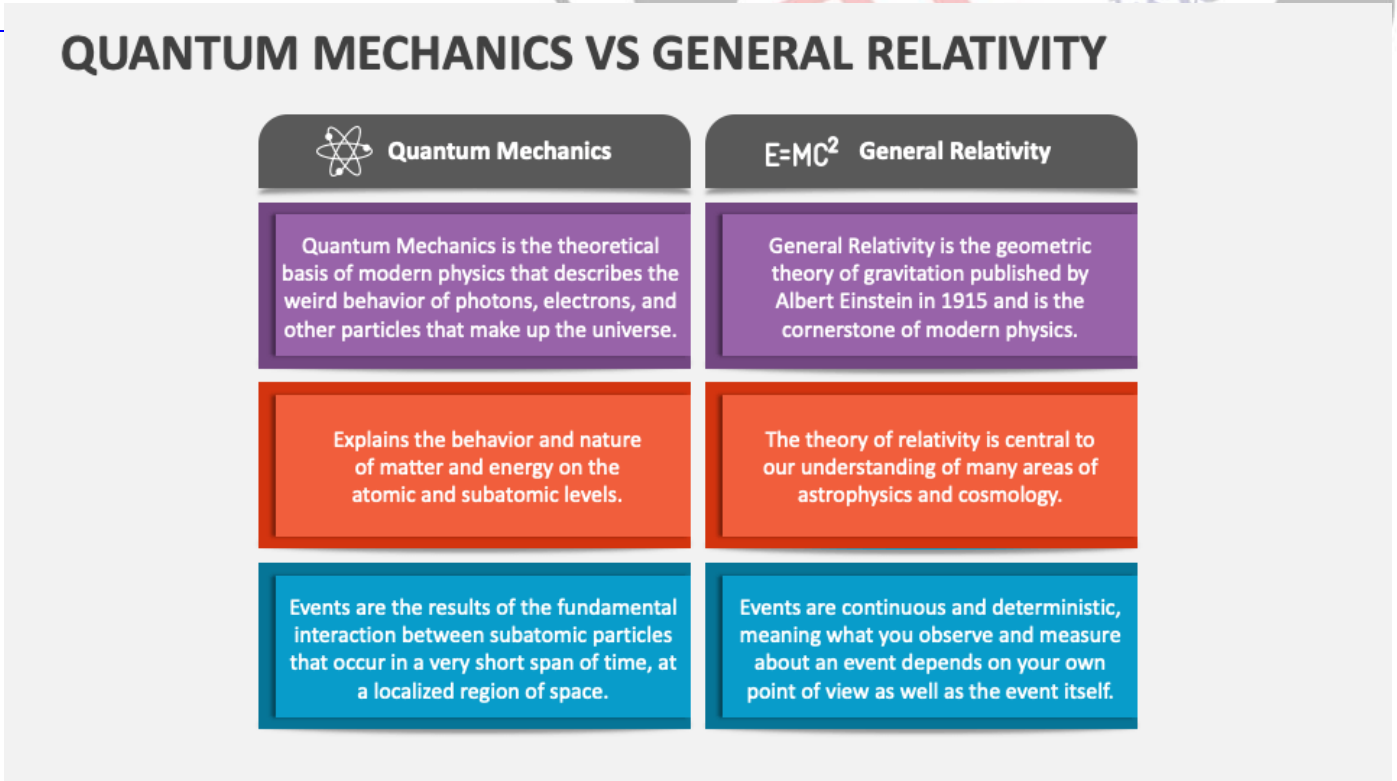

UPSC Civil Services Examination, Previous Year Question (PYQ)

Q. Consider the following phenomena: (2018)

1. Light is affected by gravity.

2. The Universe is constantly expanding.
3. Matter warps its surrounding space-time.

Which of the above is/are the prediction/predictions of Albert Einstein's General Theory of Relativity, often discussed in media?

(a) 1 and 2 only
(b) 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans: (d)