5. Mind Map: Gravitational Potential Energy

THE SCIENCE CUBE

GPE

1 The Big Idea

Objects near Earth are held by Earth's gravity
→Escaping means overcoming this gravitational trap
→This requires energy input (positive work W)

2 2 Formulas

(a) For near Earth problems, use: U = mgh (g ≈ constant)
(b) For long distance problems, use: U = –GMm / r

3 U = –GMm / r

1. At r = R_e (U most negative)
   - Gravitational binding strongest
   - Object fully bound to Earth
2. As r ↑ (U → less negative)
   - Binding weakens
   - Object less bound
3. At r = ∞ (U = 0)
   - Gravitational force = 0
   - Object fully unbound

Key question: How much energy is required to fully escape Earth's gravity?

Answer: Work required W = –ΔU = +GMm / r

In (a) U = 0 at r = Earth's surface.
In (b) U = 0 at r =∞
In both, ΔU is the same if an object moves from h1 to h2

U is system energy shared by M and m

Bound state - Object is under influence of Earth's gravity. (U<0)
Unbound state - Object not under influence of Earth's gravity and is free. (U≥0)

4 Physical interpretation of U = -GMm/r

How do you move an object from bound to unbound state?
Answer-
1. Do positive work W on system
2. Positive work W provides the force to move the system into an unbound state

Energy needed to separate masses infinite distance apart is W = |U| or W = -U = GMm/r

See example in the next slide

PHYSICAL MEANING OF THE FORMULA -

$$U = -GMm / r$$

NOTE: Positive work is done by the upward force produced by burning of fuel

Example

(a) Take a 100 kg rocket 100 km above Earth. U is about −6.2 billion joules.

(b) If we add 1 B J of energy, U becomes −5.2 BJ. The rocket moves farther out.

(c) Add another 1 BJ, and U becomes −4.2 BJ, indicating even greater separation.

(d) Continue this way, and once a total of 6.2 BJ is added, U reaches 0 — the rocket is now infinitely far and free from Earth's gravity or unbound

U = 0 Rocket is Unbound

W = 4.2 B J

U = -5.2 +1 = -4.2 B J

W = 1 B J

U = -6.2 +1 = -5.2 B J

W = 1 B J

100 Km, U = -6.2 B J