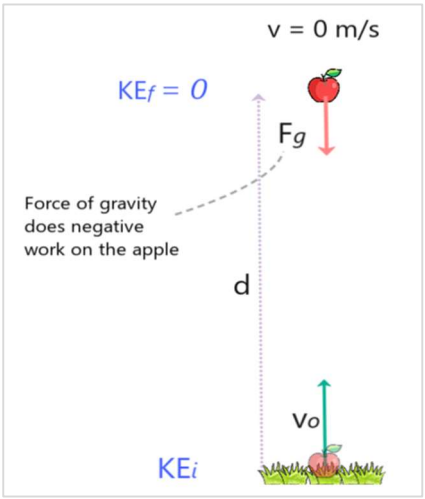
Work Done by Gravitational Force

Key Idea

Gravitational Force like any other force does work on an object, if it acts on it.

- It does positive work when the direction of displacement is same as the direction of the force. Positive work results in increase of KE.
- It does negative work when the displacement is in the opposite direction. This negative work results in loss of KE



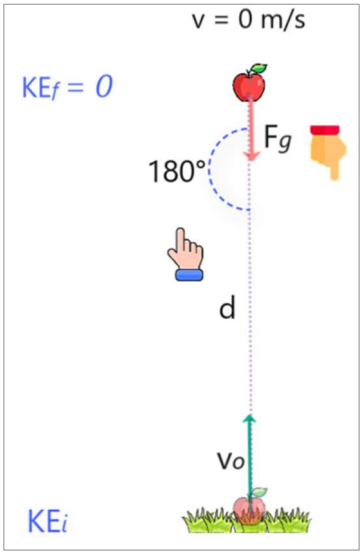
In this case the apple is thrown up. Displacement is in upward direction while force of gravity is downward. Therefore, the force of gravity does negative work, thereby reducing the KE to zero

Analysing the Apple's Flight

Rising up

- Initial velocity v_0 imparts the initial kinetic energy KE*i*
- Gravity's Effect: As the apple rises, its velocity decreases to zero due to the force of gravity acting downwards; and therefore, the initial KE*i* also reduces to zero
- Since the force of gravity reduces the velocity and KE, we say it does negative work.

Work done by gravity



- At peak: velocity = 0; displacement = d.
- Work done = dot product of force of gravity and displacement

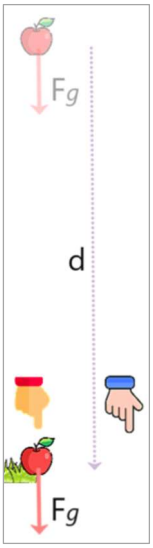
  $W_g = F_g \cdot d = |F_g|\,|d| \cos(\theta)$
- θ = 180° (force and displacement vectors are opposite)
- Work done = $-F_g\, d = -mgd$ (a negative quantity)

Example

- For a 1 kg apple thrown up, d = 10 meters, g = 10 m/s^2,
- Work done = -1 x 10 x 10 = -100 Joules.

  What it means – The apple lost 100 J of energy as it moved up to the top

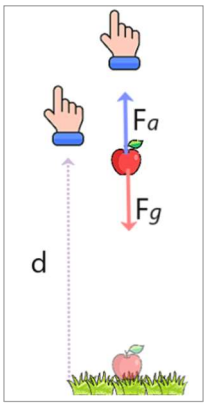
Coming Down



- Force and displacement vectors are parallel when apple is coming down
- Work Done: $W = |F_g|\,|d| \cos(0) = F_g\, d = mgd$ (a positive quantity)
- Since the apple's velocity and KE increases, we say gravity does *positive work*

Lifting the Apple

- Lifting involves an upward Applied Force F*a* and displacement d.
- Applied force F*a* does work W*a*. This work is positive (since displacement d and F*a* are in the same direction)
- Force of gravity F*g* does work W*g*. This is negative (d and F*g* are in the opposite direction)



Total Work Done and Change in Kinetic Energy

$$\Delta K = K_f - K_i = W_a + W_g \qquad (1)$$

Remember: Change in KE is always determined by total work done *by all* forces on an object

- At start of the lift, velocity = 0
- At the end of the lift, velocity = 0
- Therefore $K_f = K_i = 0$. Putting K values as zero in (1), we get-

$$W_a + W_g = 0$$

$$W_a = - W_g \qquad (2)$$

Work done in different scenarios:

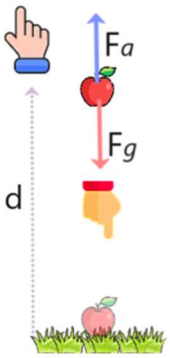
using equation (2)

- When lifting the apple

  $W_a = -W_g = -(-mgd)$

  $W_a = mgd$

  applied force does +ve work



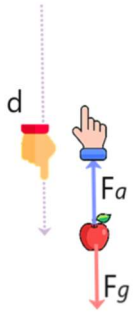
Apple being lifted. Force of gravity and displacement are opposite

- When lowering the apple

  $W_a = -W_g = -(mgd)$

  $W_a = -mgd$

  Applied force does negative work



Apple being lowered. Force of gravity and displacement are in the same direction

Equation (2) is valid only if the initial and the final velocity is zero or is the same