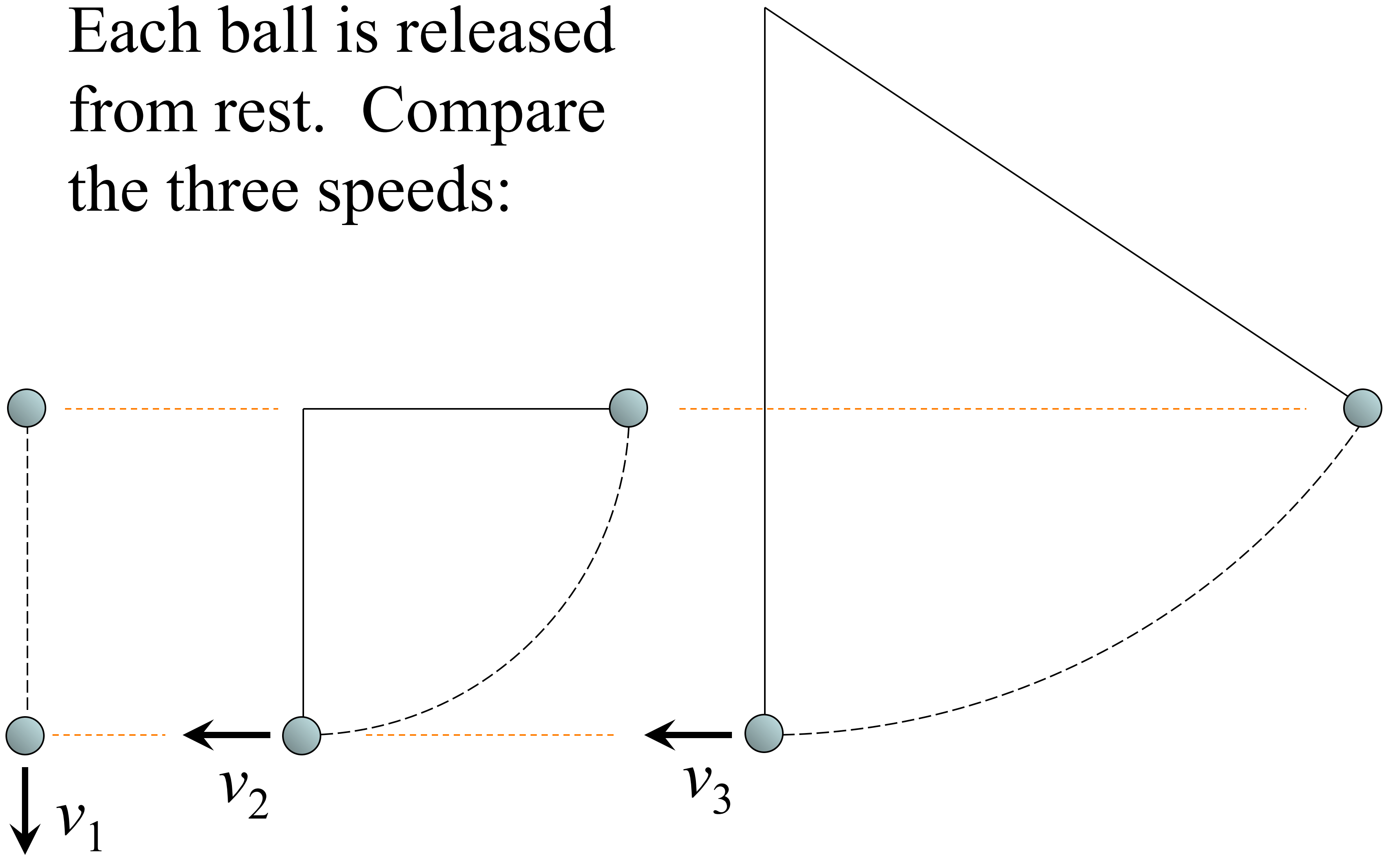
Each ball is released from rest. Compare the three speeds:



Potential Energy

Conservative Forces

Work and Energy

I. Work
- dot product
- varying force

II. Work-Energy Theorem
- Kinetic Energy

III. Potential Energy
- Conservative Forces

IV. Machines, Power, Efficiency

	The student will be able to:	HW:
1	Define and apply the concept of work (and the joule) for constant or varying force and solve related problems.	1 – 10
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What *is* Potential Energy?

- Potential energy is sometimes described as energy due to position or arrangement.
- Considering that energy is the ability to do work, potential energy is the potential *for work to be done* by a certain force.
- A potential energy function yields the work that a certain force can do, depending on position of an object.
- Potential energy can <u>only</u> be defined for *conservative* forces.

Potential Energy Functions

A potential energy function U for a certain conservative force F is defined by:

$$U = -W_{RP}$$

$$U = -\int_R^P \vec{F} \cdot d\vec{r}$$

where: U = potential energy at point P
R = an arbitrary reference point
W_{RP} = work done by F, as object moves from R to P

What is a **Conservative Force**?

- The work done by a **conservative** force acting on an object that moves between two points *does not depend upon the path* taken.
- Alternatively, the net work done by a **conservative** force acting on an object *over a closed path is zero*.
- Work done by a **nonconservative** force <u>does</u> depend upon the path taken and is <u>not</u> equal to zero over a closed path.

More about Conservative Forces

- In order to be **conservative**, a force must depend *only* upon position.
- Forces that vary with respect to time, speed, etc. are **nonconservative**.
- Conservative forces include: gravity, spring forces, electrostatic force, etc.
- Nonconservative forces include: friction, air resistance, normal force, tension, etc.

Conservation of Energy

Work done by a conservative force may be thought of as a *transformation* of potential energy into kinetic energy:

$$\Sigma W = \Delta K$$

Conservation of Energy

Work done by any conservative force may be thought of as a *transformation* of potential energy into kinetic energy:

$$\Sigma W = \Delta K$$

$$\underbrace{\Sigma W_{NC} + \Sigma W_C}_{\Sigma W} = K_2 - K_1$$

ΣW_{NC}: work done by nonconservative forces

ΣW_C: work done by conservative forces

Conservation of Energy

Work done by a conservative force may be thought of as a *transformation* of potential energy into kinetic energy:

$$\Sigma W = \Delta K$$

$$\Sigma W_{NC} + \Sigma W_{C} = K_2 - K_1$$

$$\Sigma W_{NC} + \left(-\Delta U\right) = K_2 - K_1$$

$$\Sigma W_{NC} - \left(U_2 - U_1\right) = K_2 - K_1$$

$$\Sigma W_{NC} + U_1 + K_1 = U_2 + K_2$$

Conservation of Energy

$$\Sigma W_{NC} + U_1 + K_1 = U_2 + K_2$$

total energy at one point

total energy at another point

work done by nonconservative forces as object moves from one point to the other

Gravitational Potential Energy

$$U = -W_{RP}$$

$$U = -\int_R^P \vec{F} \cdot d\vec{r}$$

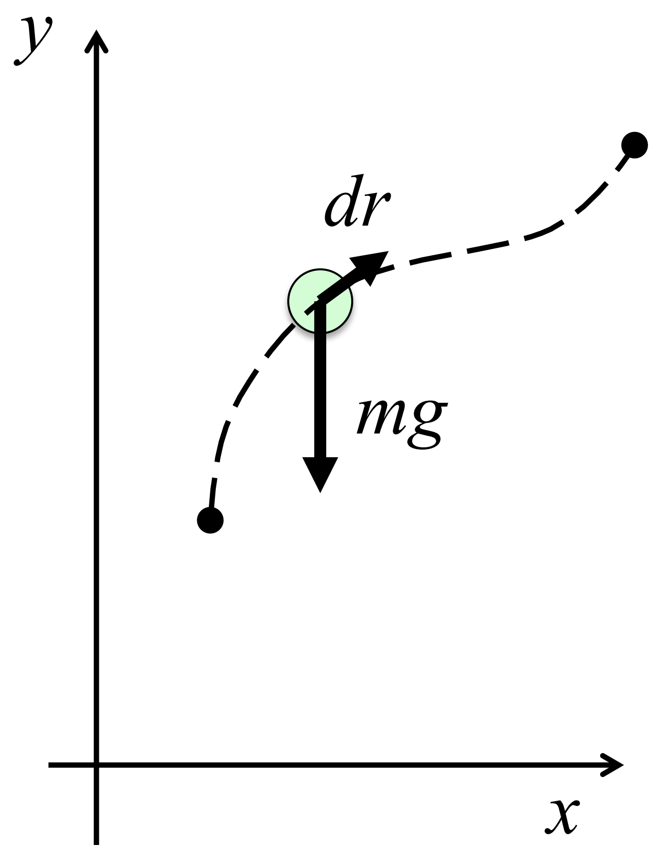
$$U = -\left(\int_{x_1}^{x_2} F_x \, dx + \int_{y_1}^{y_2} F_y \, dy\right)$$

$$U = -\int_{y_1}^{y_2} -mg \, dy$$

$$U = mgy_2 - mgy_1$$

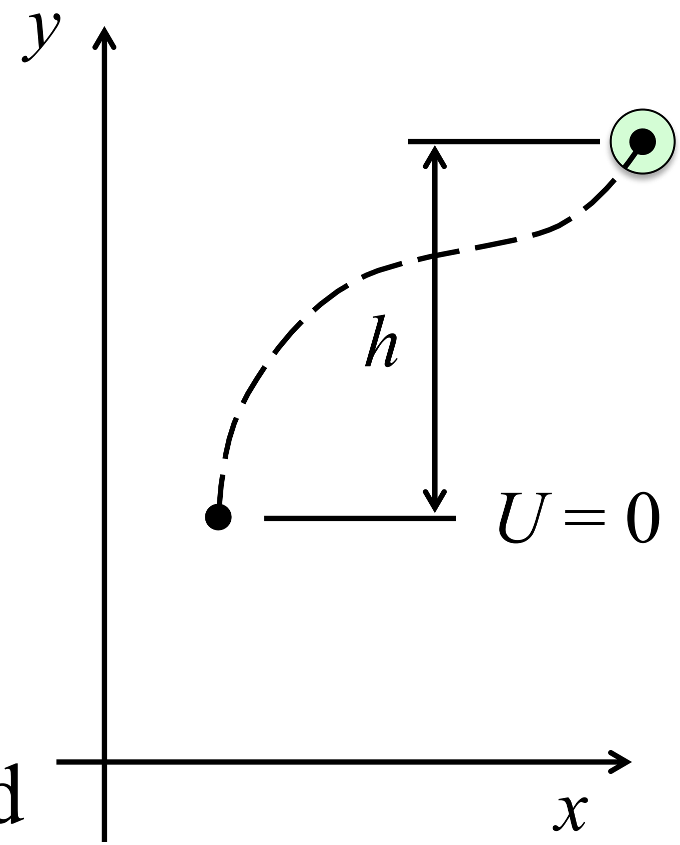
$$U = mg\Delta y$$

$$U = mgh$$



Gravitational Potential Energy

$$U_g = mgh$$



where: m = mass of object in field

g = gravitational field strength

h = elevation or height above reference

U = potential energy relative to reference position

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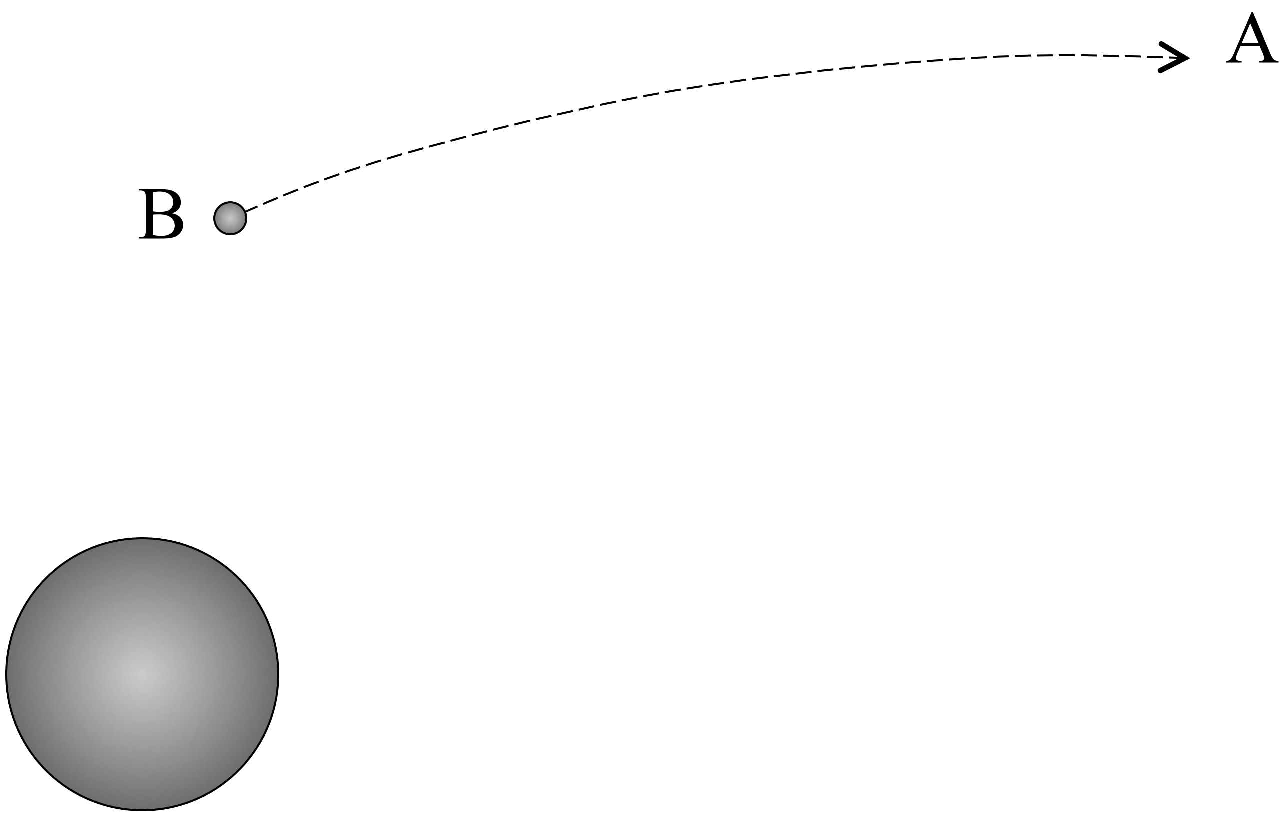
Gravitational Potential Energy

$$U_G = -\frac{Gm_1m_2}{r}$$

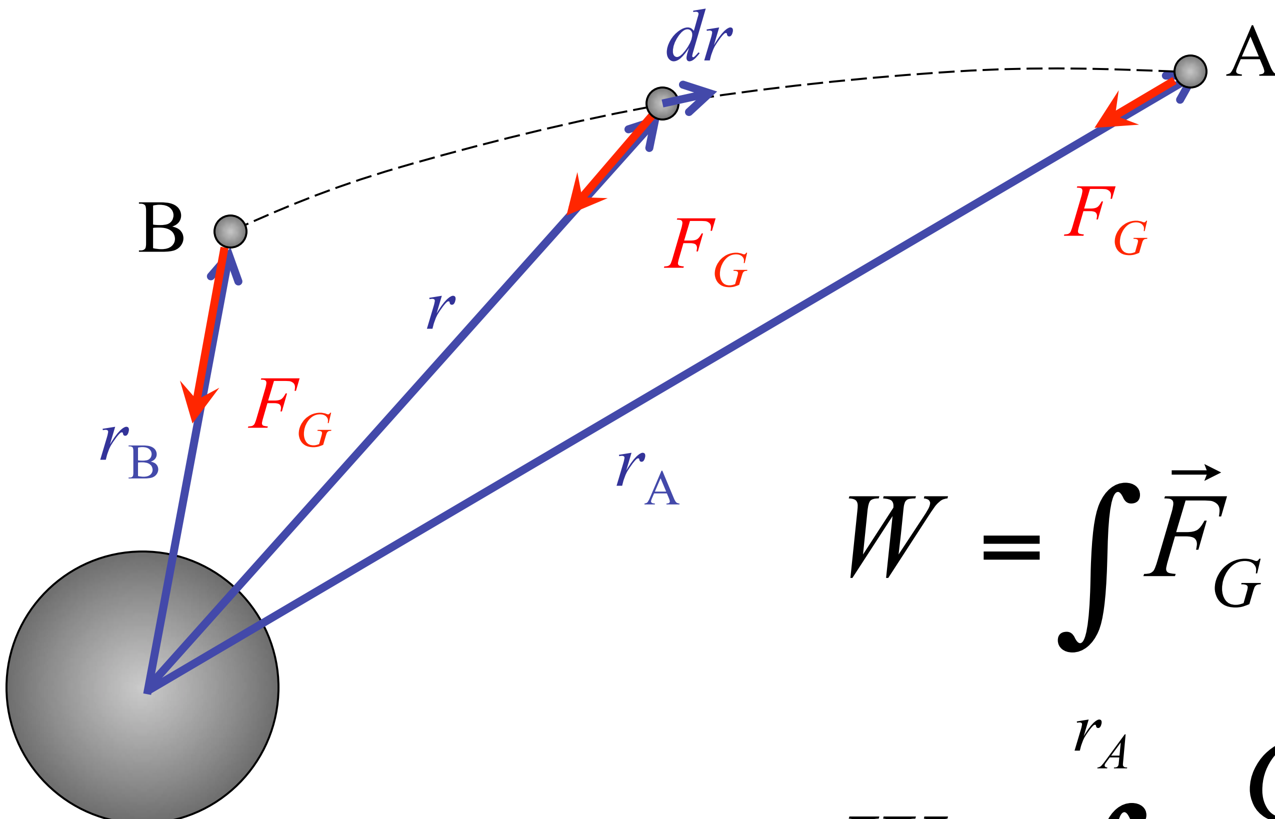
where: m = mass (spherical or point-like)
r = separation center to center
U = potential energy relative to infinity

Note that this potential energy function equals zero when separation is infinite. At any other amount of separation the potential energy is always negative! Although the negative sign may be confusing, what really matters is the change in potential energy as illustrated in the following…

Find the work done by gravity as the object moves from point B to point A.



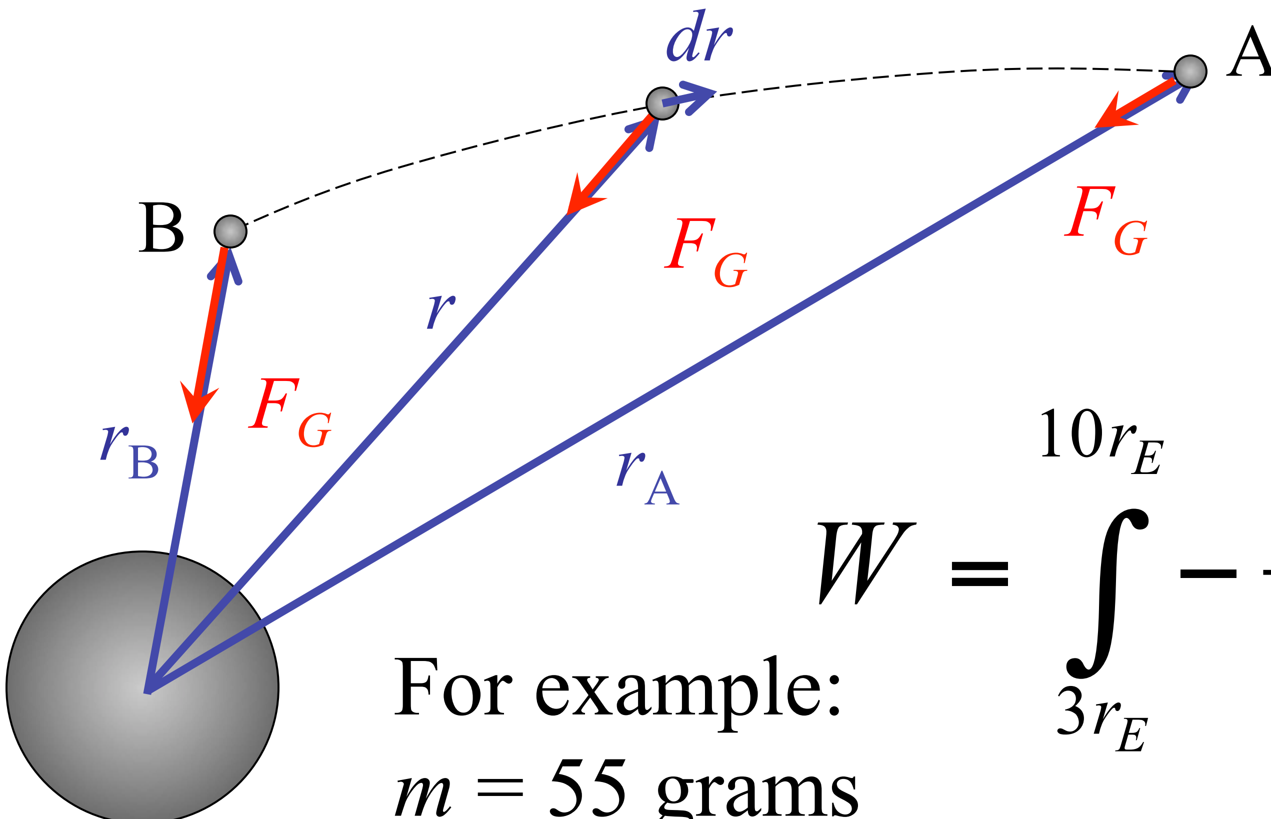
Find the work done by gravity as the object moves from point B to point A.



$$W = \int \vec{F}_G \cdot d\vec{r}$$

$$W = \int_{r_B}^{r_A} -\frac{GMm}{r^2}\,dr$$

Find the work done by gravity as the object moves from point B to point A.



$$W = \int_{3r_E}^{10r_E} -\frac{GMm}{r^2}\,dr$$

For example:

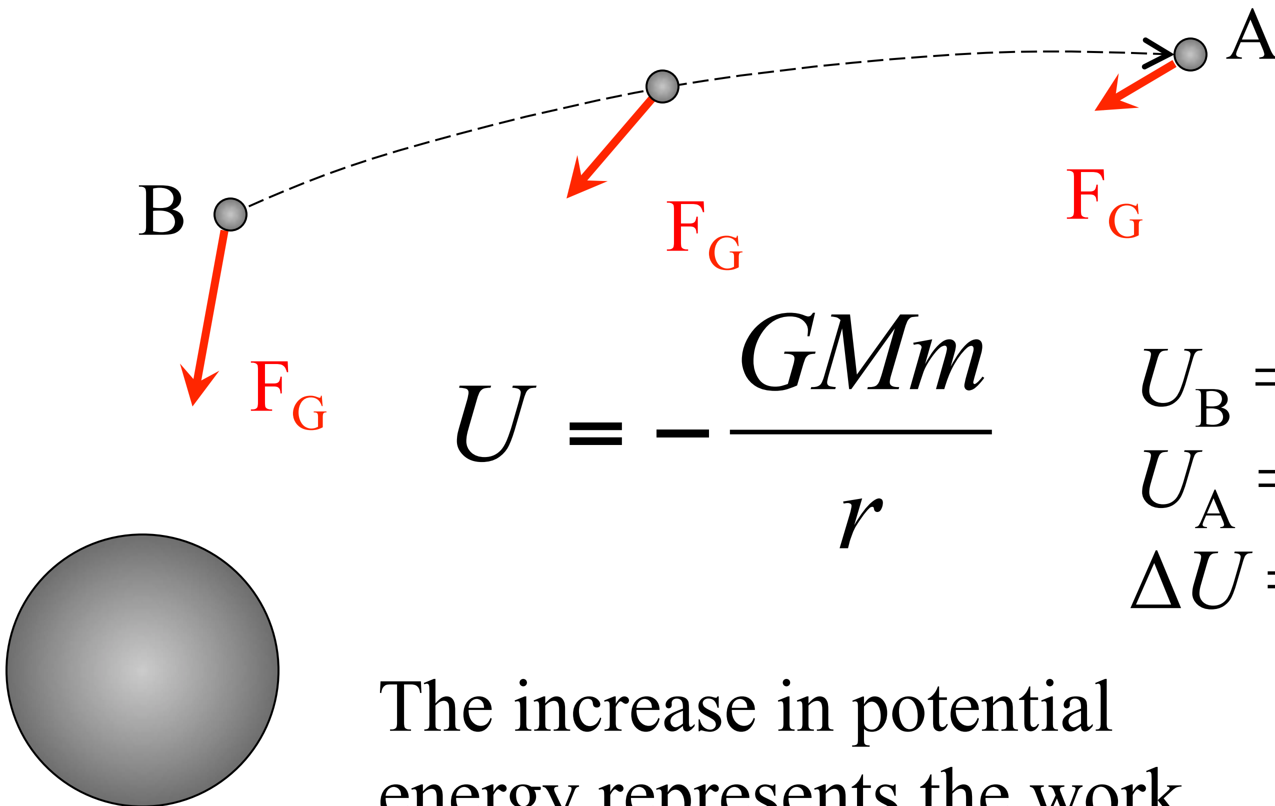
$m = 55$ grams

$r_A = 10r_E$

$r_B = 3r_E$

$W_G = -800$ kJ

Find the change in potential energy as the object moves from point B to point A.

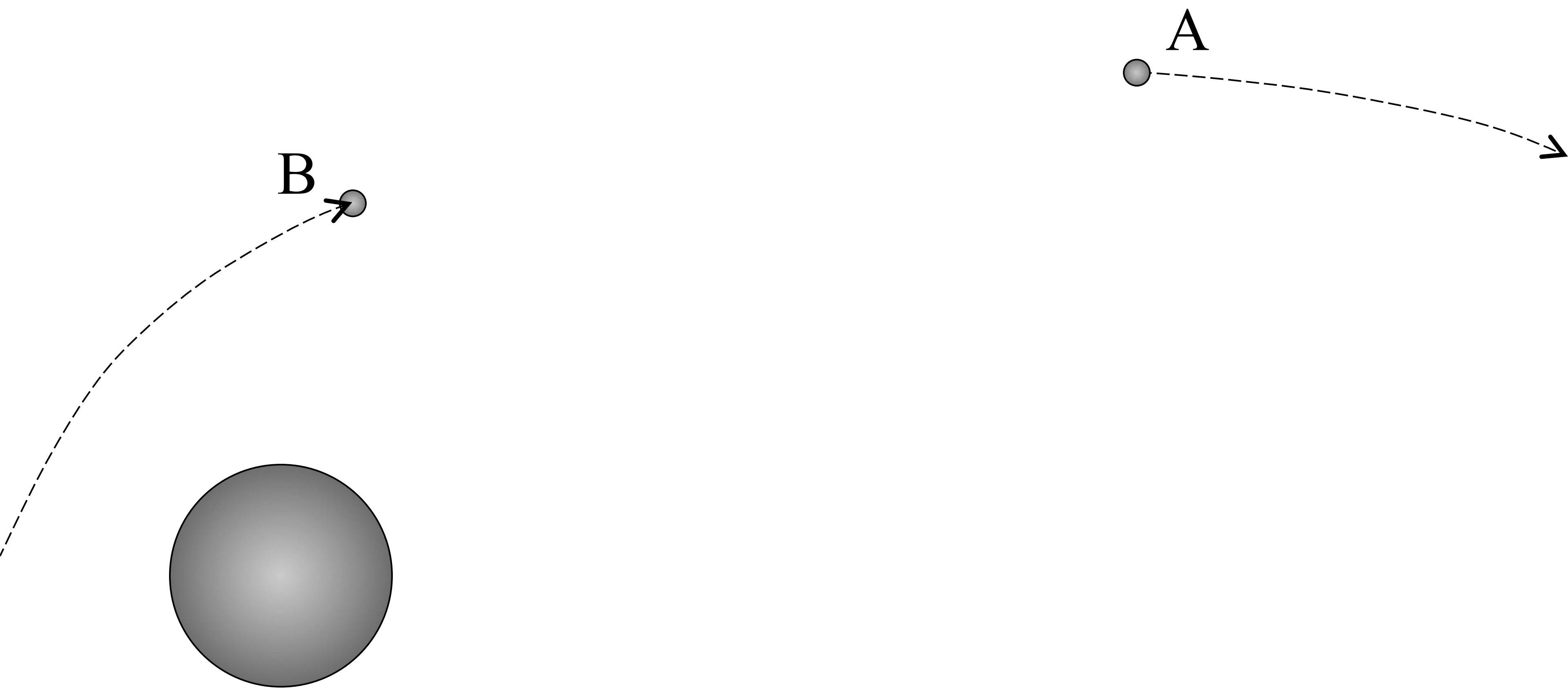


$$U = -\frac{GMm}{r}$$

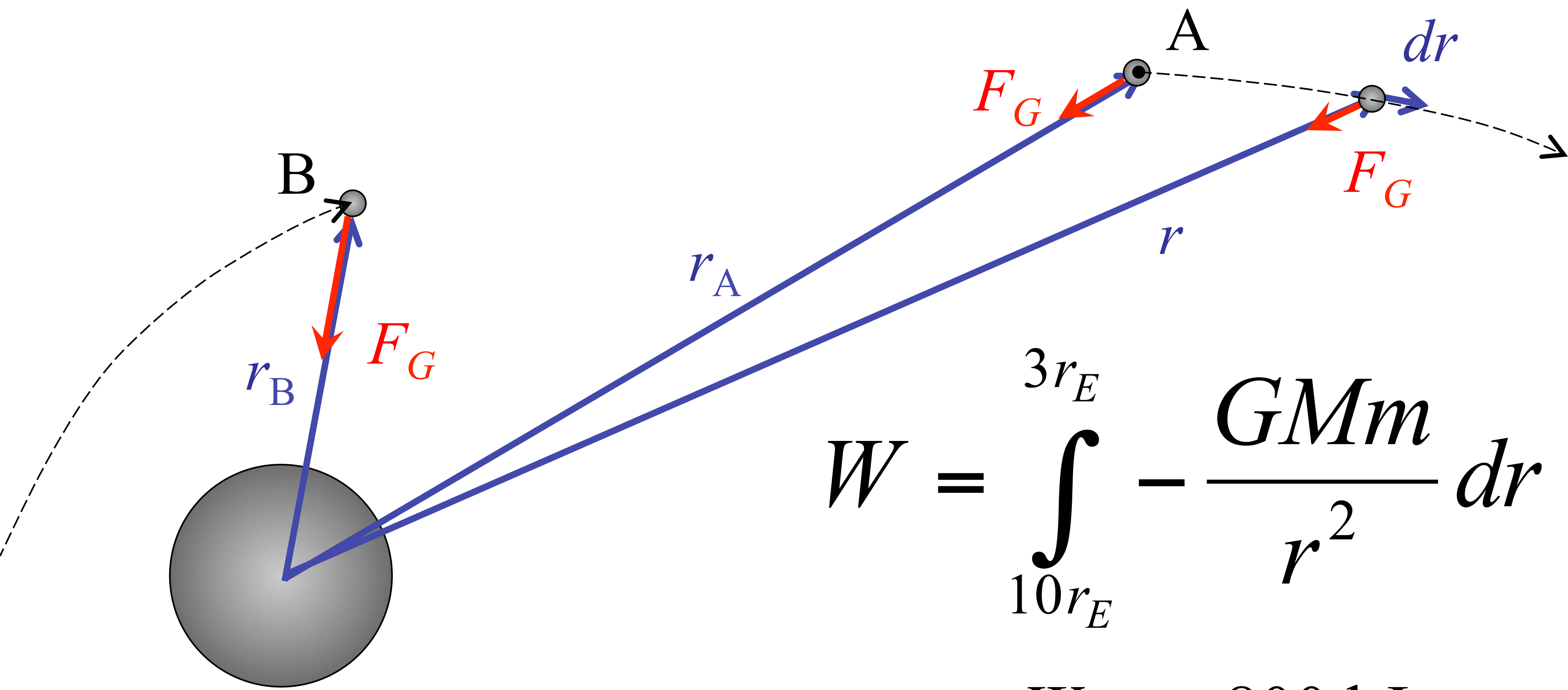
$$U_B = -1140 \text{ kJ}$$
$$U_A = -340 \text{ kJ}$$
$$\Delta U = +800 \text{ kJ}$$

The increase in potential energy represents the work that gravity would do if object returns from A to B.

Find the work done by gravity as the object moves from point A to point B.



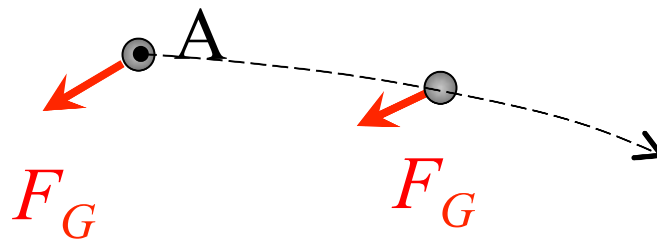
Find the work done by gravity as the object moves from point A to point B.

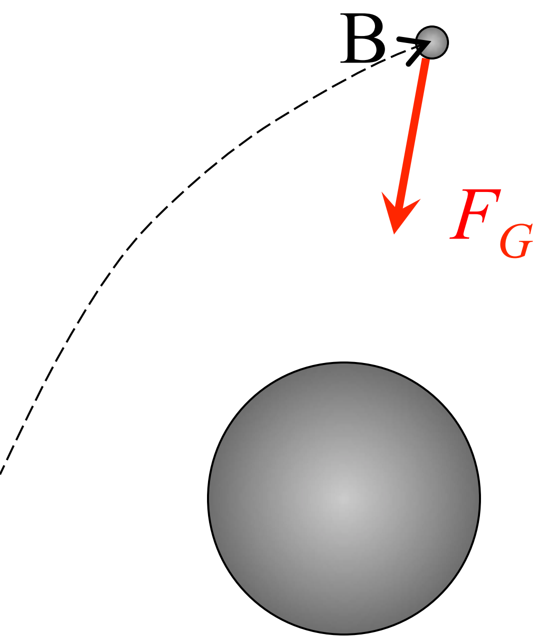


$$W = \int_{10r_E}^{3r_E} -\frac{GMm}{r^2}\,dr$$

$$W_G = +800 \text{ kJ}$$

Find the change in potential energy as the object moves from point A to point B.





$$U = -\frac{GMm}{r}$$

$$U_B = -1140\text{ kJ}$$
$$U_A = -340\text{ kJ}$$
$$\Delta U = -800\text{ kJ}$$

The decrease in potential energy represents the work that gravity does if object moves from A to B. As a result, the object may gain 800 kJ kinetic energy.

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Elastic Potential Energy

$$U_s = \frac{1}{2}kx^2$$

where: k = spring constant (from $F_s = kx$)
x = elongation or compression
U = potential energy relative to unstressed position of spring