A large globe, with a radius of about 5 m, was built in Italy between 1922 and 1927. Imagine that such a globe has a radius $R$ and a frictionless surface. A small block of mass $m$ starts to slide with a tiny (negligible) speed from the very top of the globe and slides along the surface of the globe. The block leaves the surface of the globe when it reaches a height $h_{eq}$ above the ground. The geometry of the situation is shown in the figure for an arbitrary height $h$. (Figure 1)

**Part A**

Consider what happens at the moment when the block leaves the surface of the globe. Which of the following statements are correct?

a. The net acceleration of the block is directed straight down.

b. The component of the force of gravity toward the center of the globe is equal to the magnitude of the normal force.

c. The force of gravity is the only force acting on the block.

- View Available Hint(s)

  - a only
  - b only
  - c only
  - a and b
  - a and c
  - b and c
  - a and b and c

*Without contact, the normal force must be zero. Since no friction, the only force is now the gravity force. So C is true. Since the only force is the force of gravity, the acceleration must be down. So A is true. The normal force has just become zero and the force of gravity still has a component toward the center, B is not true.*
A large globe, with a radius of about 5 m, was built in Italy between 1922 and 1927. Imagine that such a globe has a radius $R$ and a frictionless surface. A small block of mass $m$ starts to slide with a tiny (negligible) speed from the very top of the globe and slides along the surface of the globe. The block leaves the surface of the globe when it reaches a height $h_{\text{crit}}$ above the ground. The geometry of the situation is shown in the figure for an arbitrary height $h$. (Figure 1).

**Figure**

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**Part B**

Which of the following statements is also true at the moment when the block leaves the surface of the globe?

- The centripetal acceleration is zero.
- The normal force is zero.
- The net acceleration of the block is parallel to its velocity.
- The kinetic energy of the block equals its potential energy.

**First**-false. The component of weight toward center still instantaneously maintains the centripetal acceleration. 
**Second**-true. The normal force has just become zero. 
**Third**-false. The only force is the force of gravity (ie down) the net acceleration is down. The velocity must still be instantaneously parallel to the surface. 
**Fourth**-false. The magnitude of the potential energy of gravity is arbitrary.

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**Part C**

Using Newton's 2nd law, find and expression for $v_{\text{crit}}$, the speed of the block at the critical moment when the block leaves the surface of the globe.

Assume that the height at which the block leaves the surface of the globe is $h_{\text{crit}}$.

Express the speed in terms of $R$, $h_{\text{crit}}$, and $g$, the magnitude of the acceleration due to gravity. Do not use $\theta$ in your answer.
A large globe, with a radius of about 5 m, was built in Italy between 1682 and 1987. Imagine that such a globe has a radius $R$ and a frictionless surface. A small block of mass $m$ starts to slide with a tiny (negligible) speed from the very top of the globe and slides along the surface of the globe. The block leaves the surface of the globe when it reaches a height $h_{crit}$ above the ground. The geometry of the situation is shown in the figure for an arbitrary height $h$. (Figure 1)

### Part C

Using Newton's 2nd law, find and expression for $v_{crit}$, the speed of the block at the critical moment when the block leaves the surface of the globe.

Assume that the height at which the block leaves the surface of the globe is $h_{crit}$.

Express the speed in terms of $R$, $h_{crit}$, and $g$, the magnitude of the acceleration due to gravity. Do not use $\theta$ in your answer.

\[ v_{crit} = \sqrt{g(h_{crit} - R)} \]

\[ \text{Correct} \]

### Part D

Use the law of conservation of energy to find and expression for $h_{crit}$. This will give you a different expression for $h_{crit}$ than you found in the previous part.

Express $v_{crit}$ in terms of $R$, $h_{crit}$, and $g$.

\[ h_{crit} = R + R\sin \theta \Rightarrow \sin \theta = \frac{h_{crit} - R}{R} \]

\[ v_{crit} = \sqrt{g \left( \frac{h_{crit} - R}{R} \right)} \]

Thus $v_{crit} = \sqrt{g \left( \frac{h_{crit} - R}{R} \right)}$
A large globe, with a radius of about 5 m, was built in Italy between 1962 and 1967. Imagine that such a globe has a radius $R$ and a frictionless surface. A small block of mass $m$ starts to slide with a tiny (negligible) speed from the very top of the globe and slides along the surface of the globe. The block leaves the surface of the globe when it reaches a height $h_{	ext{crit}}$ above the ground. The geometry of the situation is shown in the figure for an arbitrary height $h$. (Figure 1)

**Figure**

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**Part D**

Use the law of conservation of energy to find and express for $h_{\text{crit}}$. This will give you a different expression for $h_{\text{crit}}$ than you found in the previous part.

Express $h_{\text{crit}}$ in terms of $R, h_{\text{crit}},$ and $g$.

$\checkmark$ View Available Hint(s)

$$v_{\text{crit}} = \sqrt{2g(2R - h_{\text{crit}})}$$

$\checkmark$ Correct

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**Part E**

Find $h_{\text{crit}}$, the height from the ground at which the block leaves the surface of the globe.

Express $h_{\text{crit}}$ in terms of $R$.

$\checkmark$ View Available Hint(s)

$$h_{\text{crit}} = \frac{1}{2}R$$

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$n$ is perpendicular to motion, thus $n$ does no work.

No work due to friction. Thus $W_{\text{friction}} = 0$

Thus $\Delta E = 0$, with $E = k + U_g$.

Take initial at top of globe, and final at condition of $v_{\text{crit}}$. Let $y = 0$ at top of globe.

$E_i = K_i + U_{gi} = 0 + 0 = 0$.

Thus $E_f = E_i = K_f + U_{gf}$.

$$E_f = \frac{1}{2}mv_{\text{crit}}^2 + mg(h_{\text{crit}} - 2R)$$

$$v_{\text{crit}} = \sqrt{2g(2R - h_{\text{crit}})}$$

$$h_{\text{crit}} = \sqrt{2g(2R - h_{\text{crit}})}$$

Square both expressions for $v_{\text{crit}}$ equal to each other.

$$v_{\text{crit}}^2 = 2g(h_{\text{crit}} - R)$$

$$3h_{\text{crit}} - R = 4R - 2h_{\text{crit}}$$

$$3h_{\text{crit}} = 5R \quad \rightarrow \quad h_{\text{crit}} = \frac{5}{3}R$$