

**possible score = +1 or -2** *Question 1*

Elon Musk and SpaceX launched his Tesla Roadster piloted by a mannequin in a space suit into a highly elongated orbit

*One small step for Musk.  
One giant leap for mannequankind.*

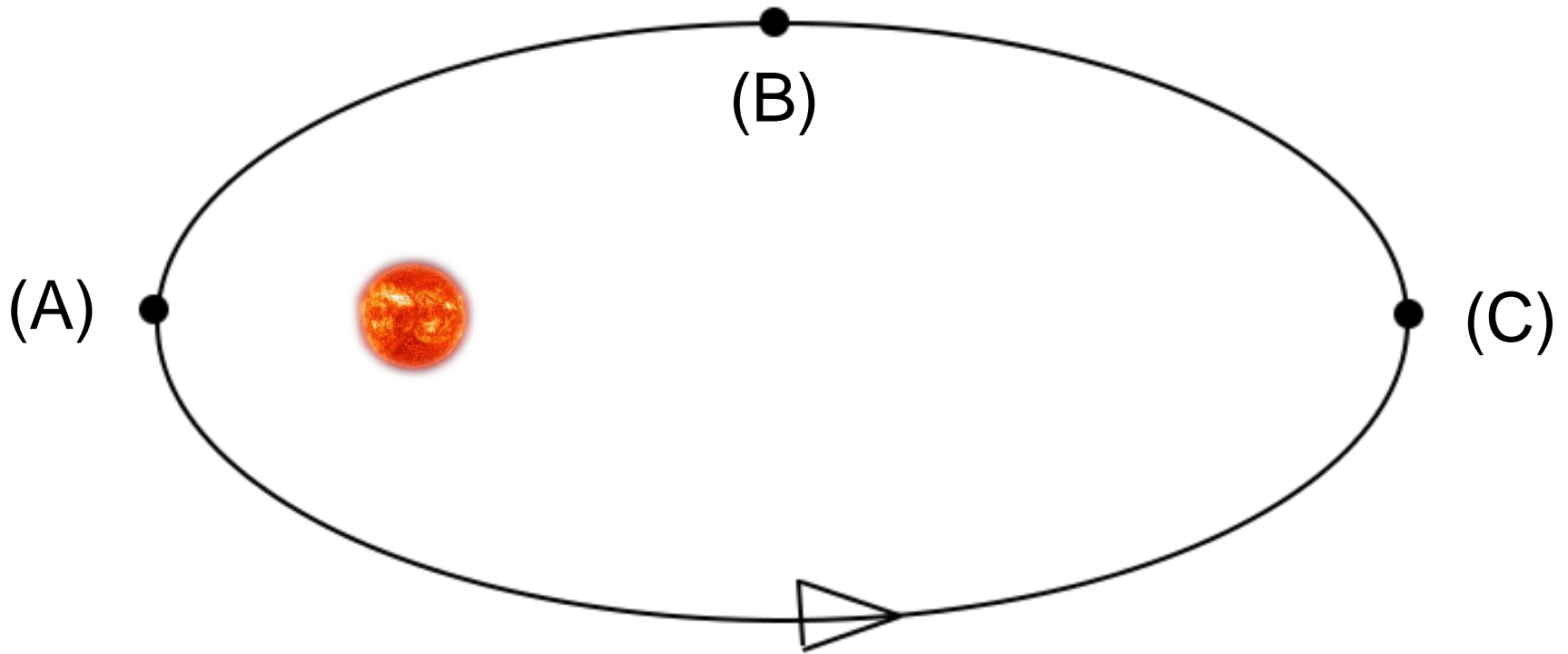


**possible score = +1 or -2**    *Question 1*

If Elon had hidden a rocket thruster on the Roadster, and “Starman” wanted to escape from the Sun using minimum fuel, where should he fire that thruster?

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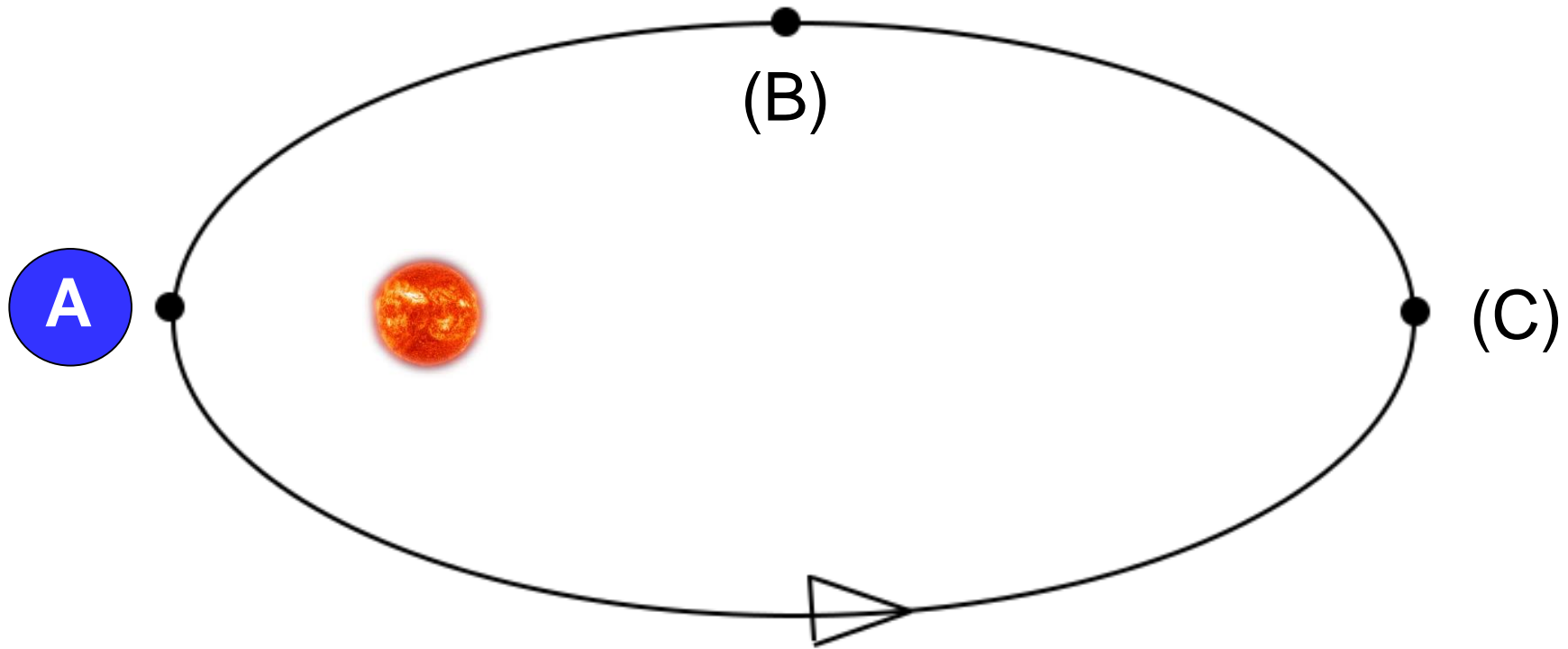


(D) Anywhere on the orbit (E) Who's Elon Musk?

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Answer 1

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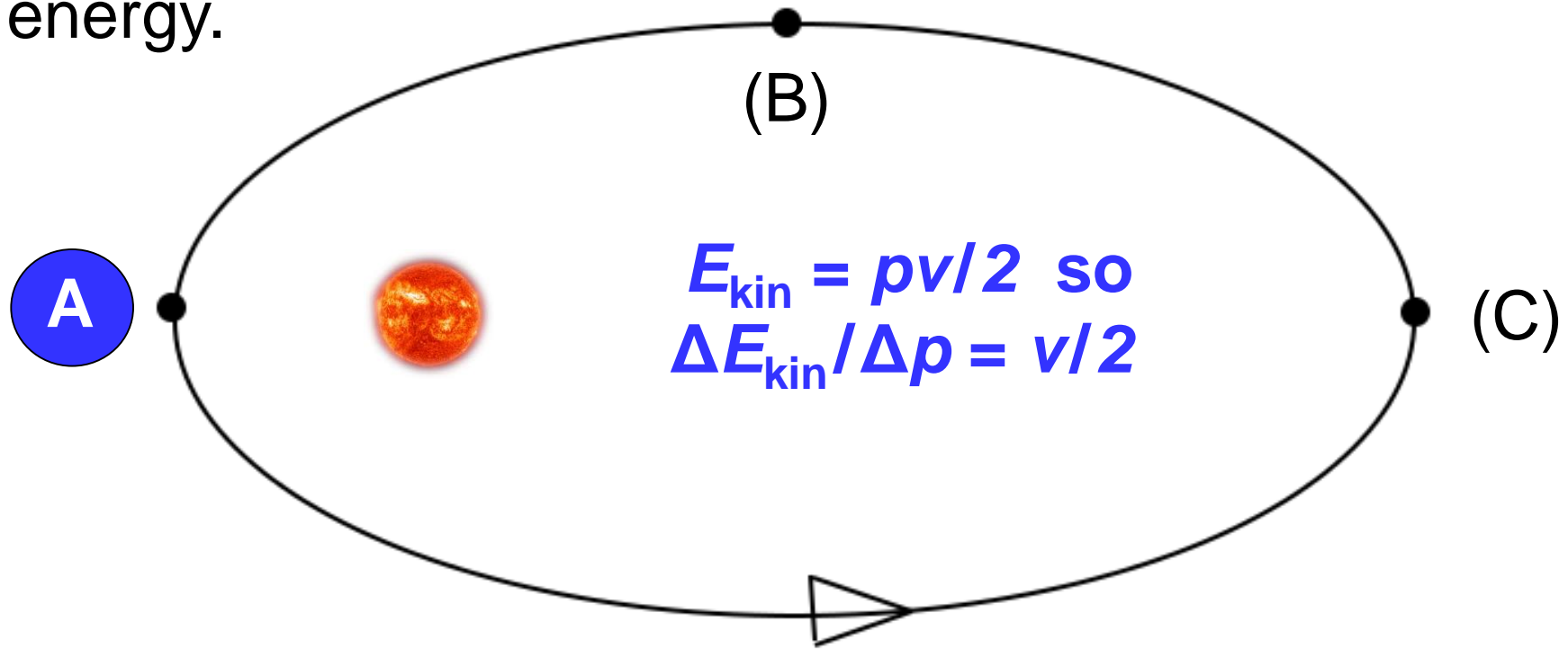


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Answer 1

Point A is where the Tesla has the highest velocity in the Sun's frame. By firing a thruster here, the change in momentum produces the largest change in kinetic energy.

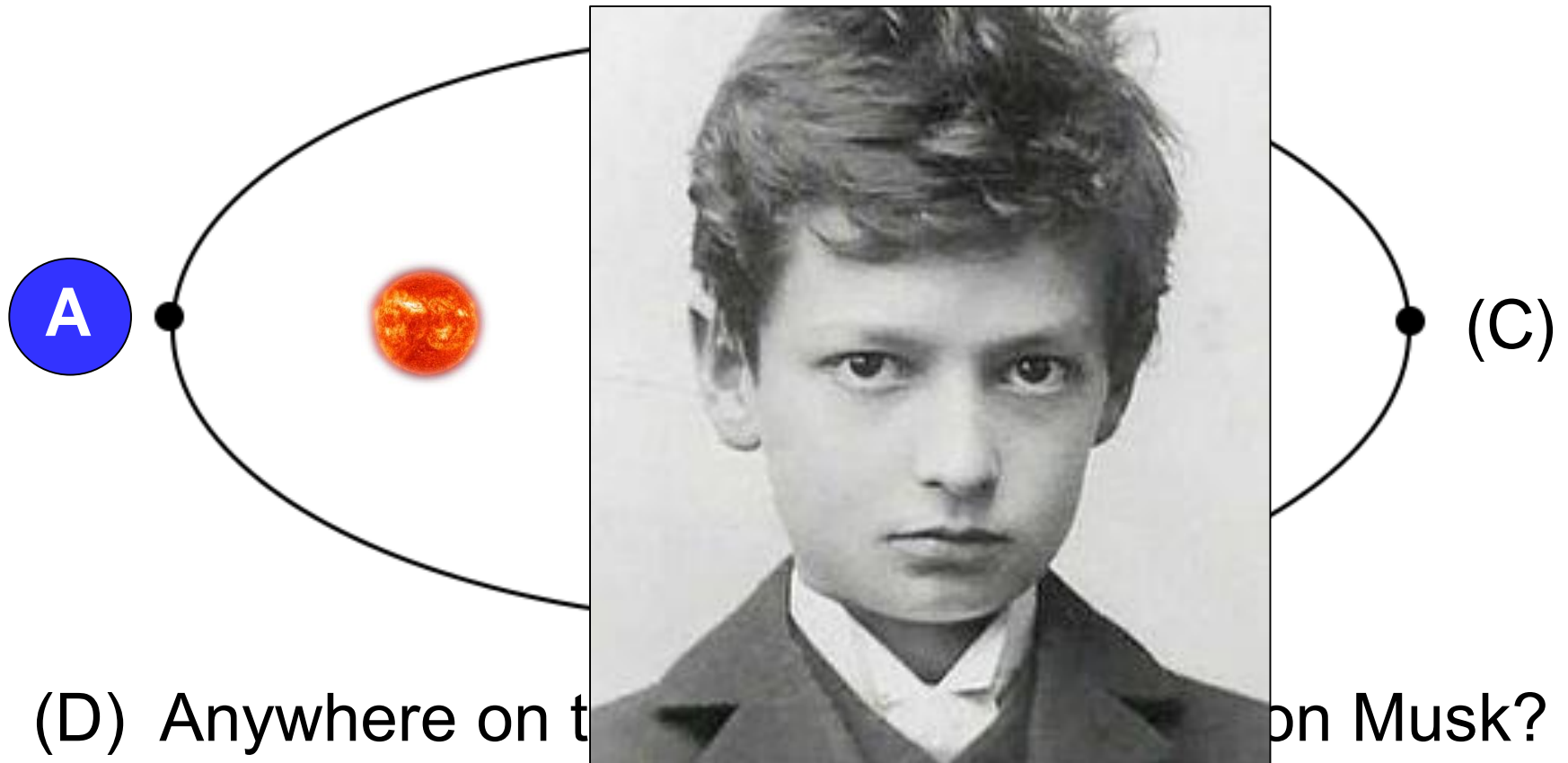


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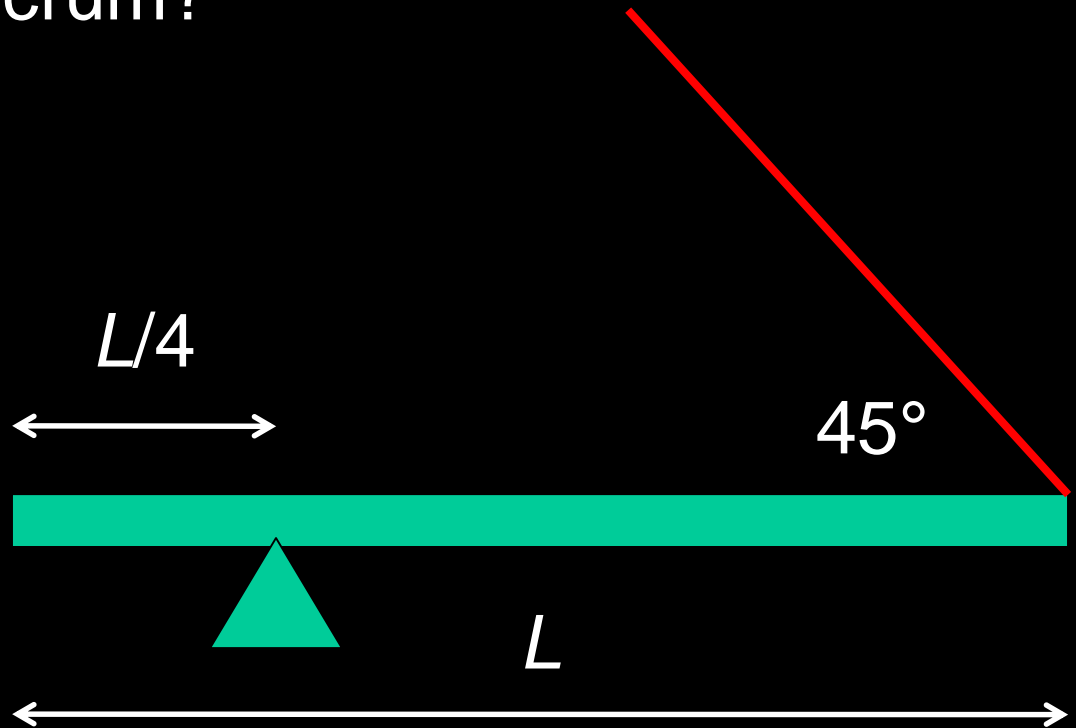
Answer 1

The **Oberth Effect**, is named after Austro-Hungarian-born German physicist Hermann Oberth, a founder of modern rocketry, who first described this in 1927.



**possible score = +5 or -6** Question 5

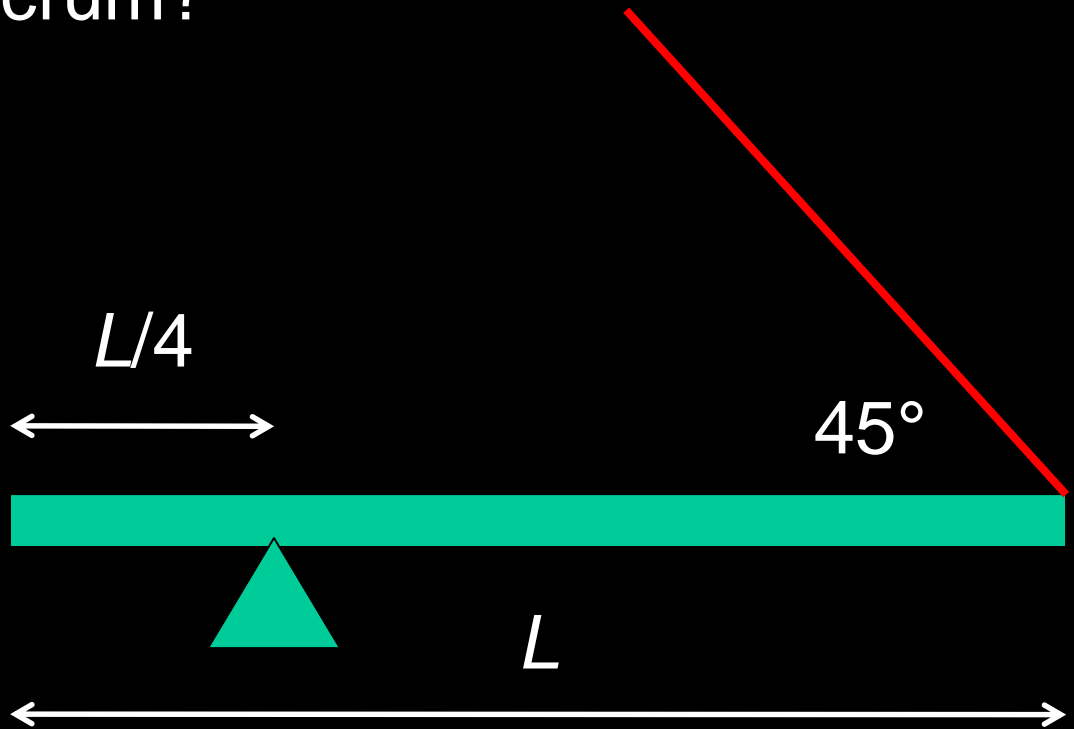
What tension in the red string is necessary for the uniform board with mass  $m$  and length  $L$  to be in equilibrium on the fulcrum?



**possible score = +5 or -6** Question 5

What tension in the red string is necessary for the uniform board with mass  $m$  and length  $L$  to be in equilibrium on the fulcrum?

- (A)  $mg/2$
- (B)  $mg/3$
- (C)  $\sqrt{2}mg/3$
- (D)  $mg$
- (E) Equilibrium impossible



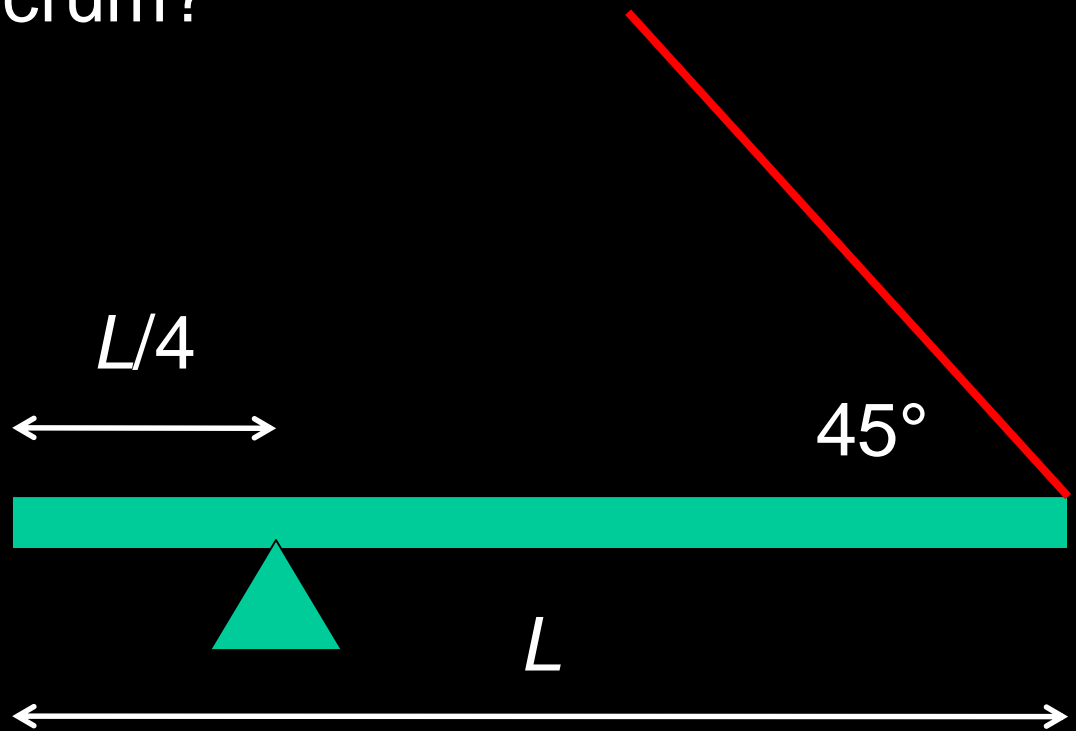


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Answer 5

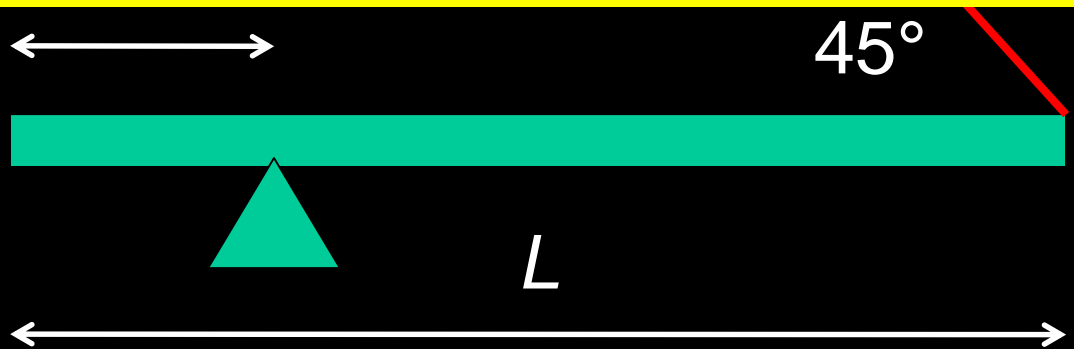
There is a force  $mg$  down at  $L/4$  from the fulcrum (centre of mass) so the vertical force component from the string at  $3L/4$  away from the fulcrum must be  $mg/3$ . Since the string is at  $45^\circ$ , the horizontal force component is the same as the vertical one, so the string tension must be (C) for equilibrium

(B)  $mg/3$

(C)  $\sqrt{2} mg/3$

(D)  $mg$

(E) Equilibrium impossible



**possible score = +9 or -10** *Question 9*

In an episode of *Game of Thrones*, Theon and Sansa are escaping Winterfell. They come to the castle wall and have no choice but to jump into the snow below.

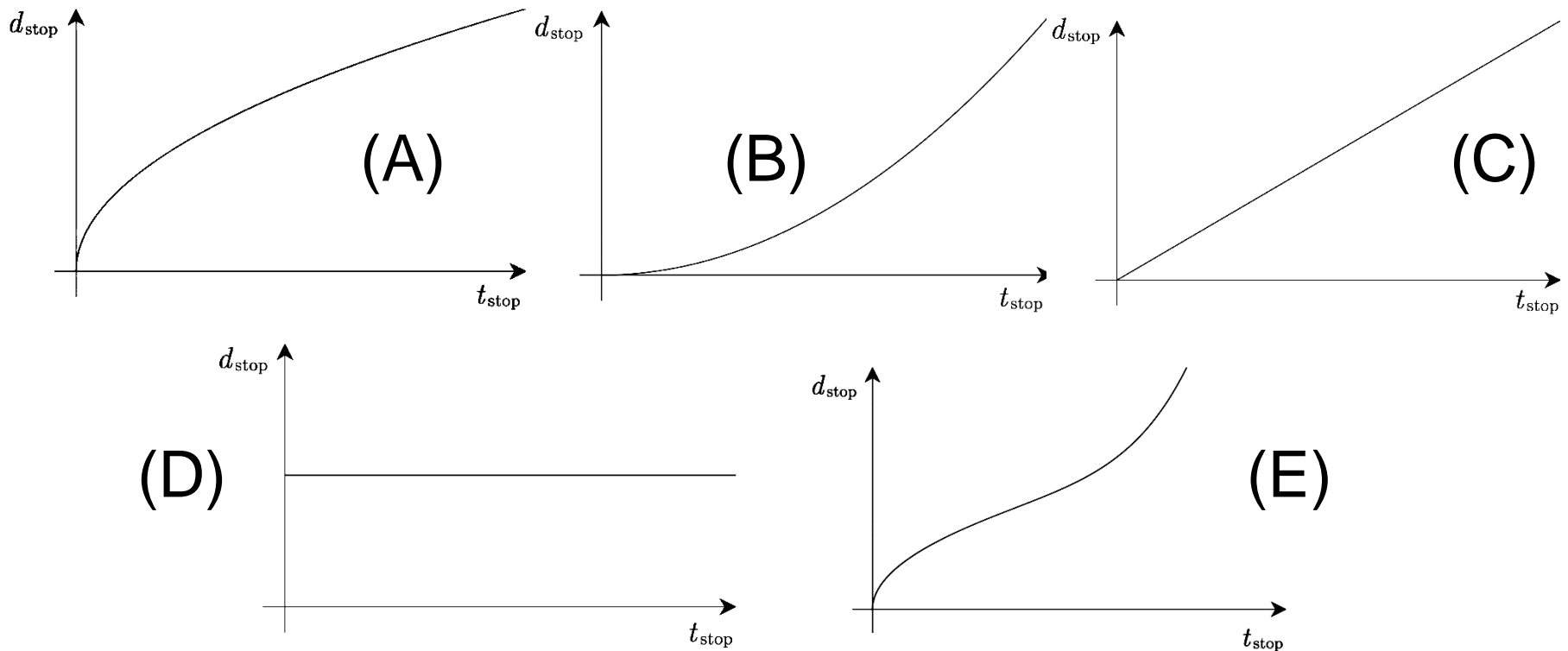


**possible score = +9 or -10** *Question 9*

If the pile of snow is of uniform density and air friction is negligible, which graph shows the depth of snow they'll penetrate ( $d_{\text{stop}}$ ) versus the time it takes them to stop moving after they hit the snow ( $t_{\text{stop}}$ )?

**possible score = +9 or -10** *Question 9*

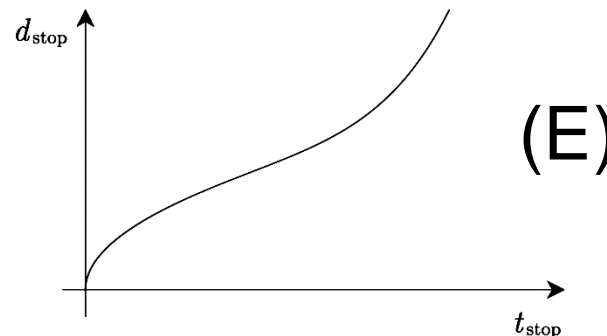
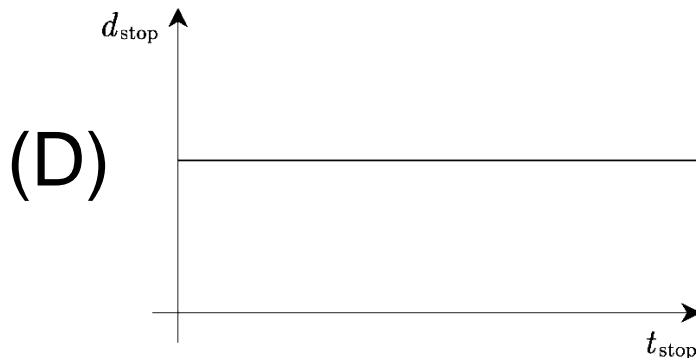
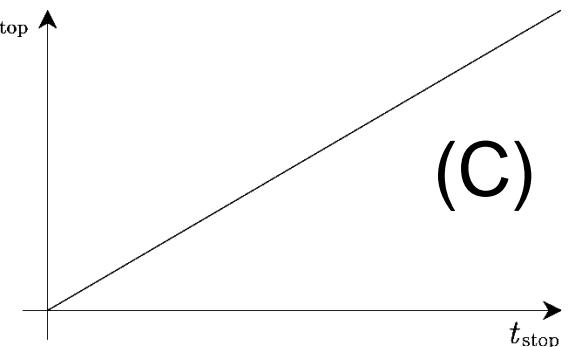
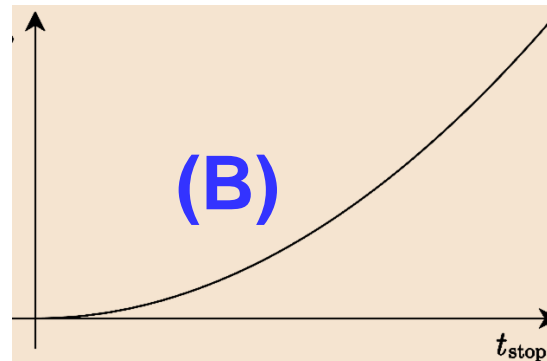
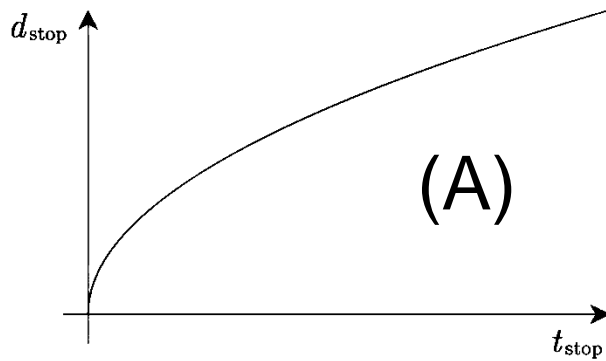
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**Answer 9**

Assume Theon & Sansa fall a height  $h$  before hitting snow.  
Use the principle of mechanical energy to estimate  $d_{\text{stop}}$

$$Fd = W = \Delta E_{\text{pot}}$$

$$F_{\text{snow}}d_{\text{stop}} = mg(h + d_{\text{stop}})$$

$$ma_{\text{snow}}d_{\text{stop}} = mg(h + d_{\text{stop}})$$

$$a_{\text{snow}}d_{\text{stop}} = g(h + d_{\text{stop}})$$

$$d_{\text{stop}} = \frac{gh}{a_{\text{snow}} - g}$$

**possible score = +9 or -10**

**Answer 9**

$$d_{\text{stop}} = \frac{gh}{a_{\text{snow}} - g}$$

Falling from height  $h$  ( $v_0 = 0$ ), final speed is  $v = \sqrt{2gh}$

We can estimate the time it takes them to stop after they hit the snow

$$v = v_0 + at_{\text{stop}}$$

$$0 = -\sqrt{2gh} + at_{\text{stop}}$$

$$t_{\text{stop}} = \frac{\sqrt{2gh}}{a}$$

$$t_{\text{stop}} = \frac{\sqrt{2gh}}{a_{\text{snow}} - g}$$



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**Answer 9**

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$$d_{\text{stop}} = \frac{a_{\text{snow}} - g}{2} (t_{\text{stop}})^2$$

This is a quadratic function

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