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

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?

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

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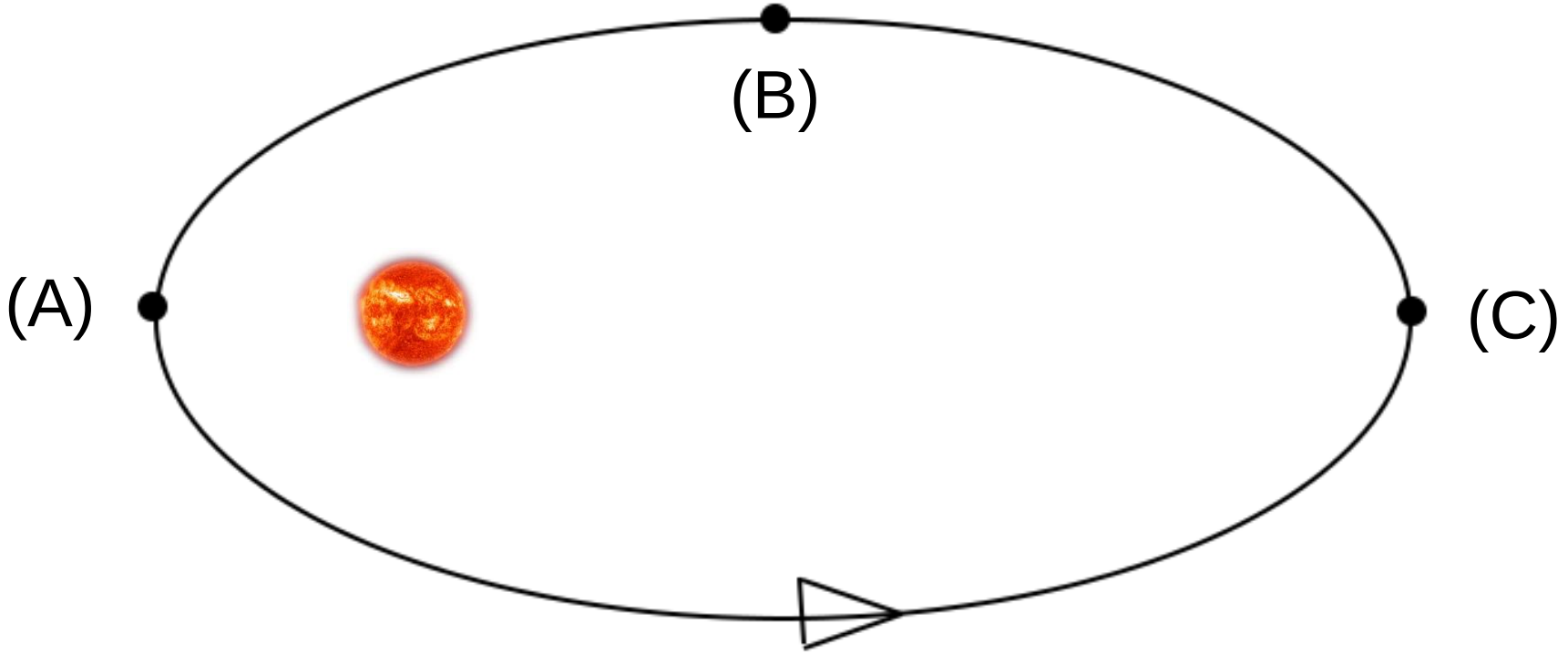

(D) Anywhere on the orbit (E) Who’s Elon Musk?

possible score = +1 or –2 *Answer 1*

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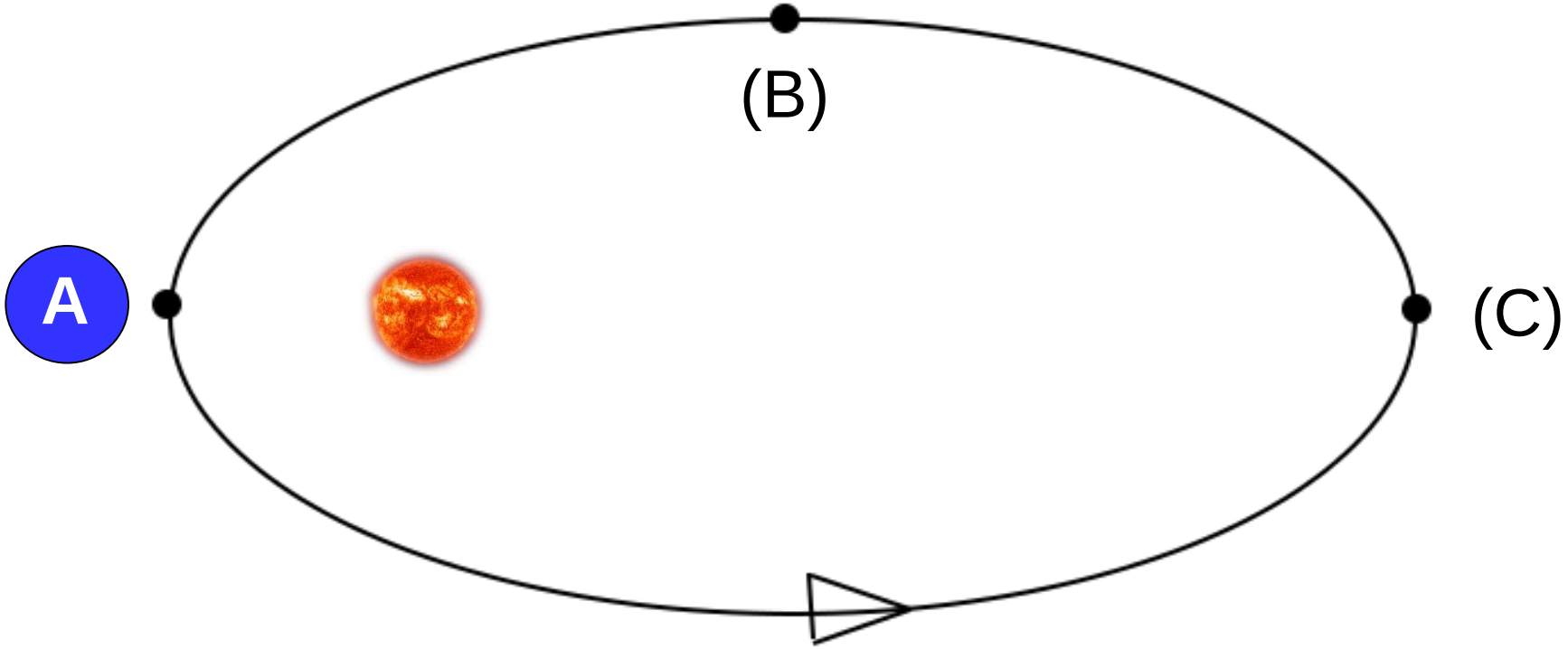
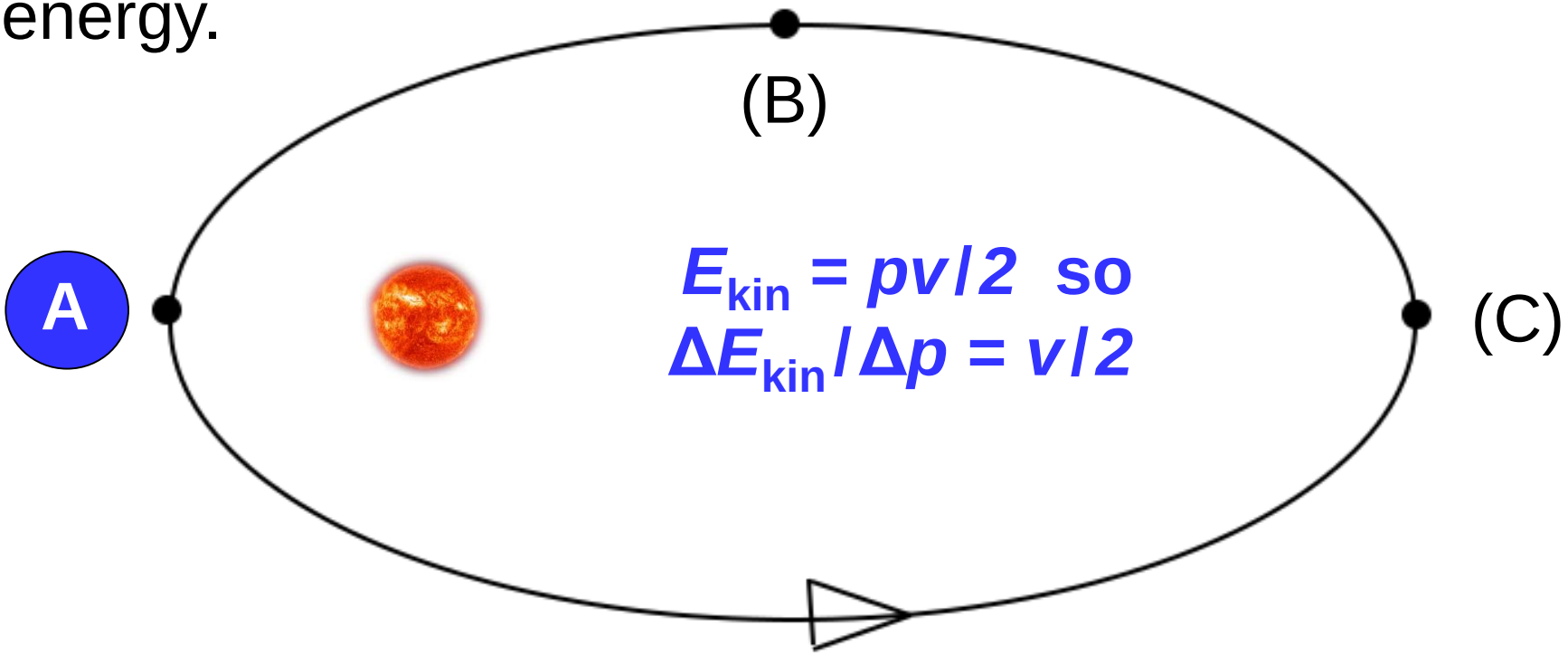


(D) Anywhere on the orbit (E) Who’s Elon Musk?

possible score = +1 or –2 *Answer 1*

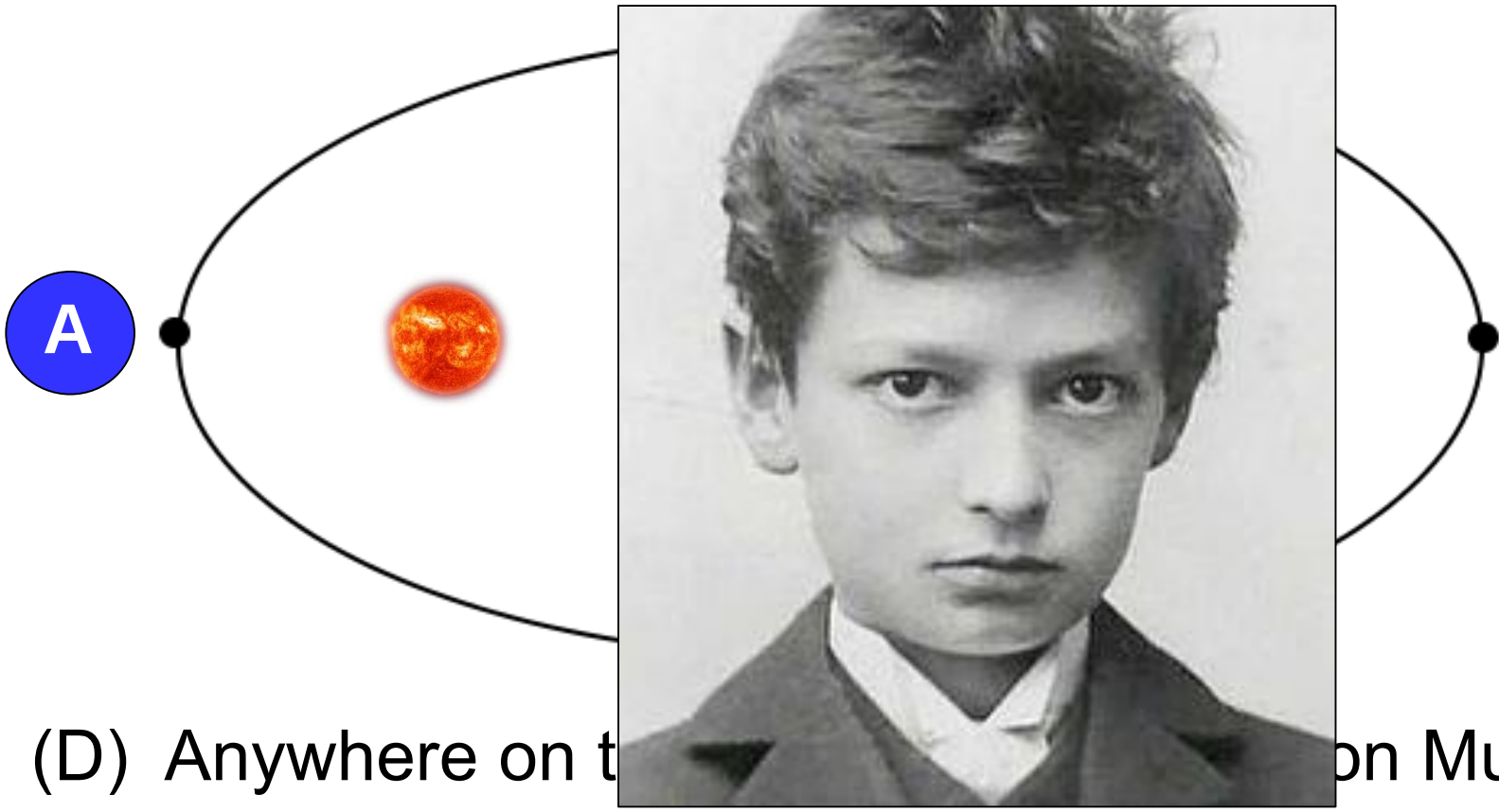
Point A is where the Tesla has the highest velocity in the Sun's frame. By firing a thruster here, the change in momentum produces the largest change in kinetic energy.



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

possible score = +1 or –2 *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.



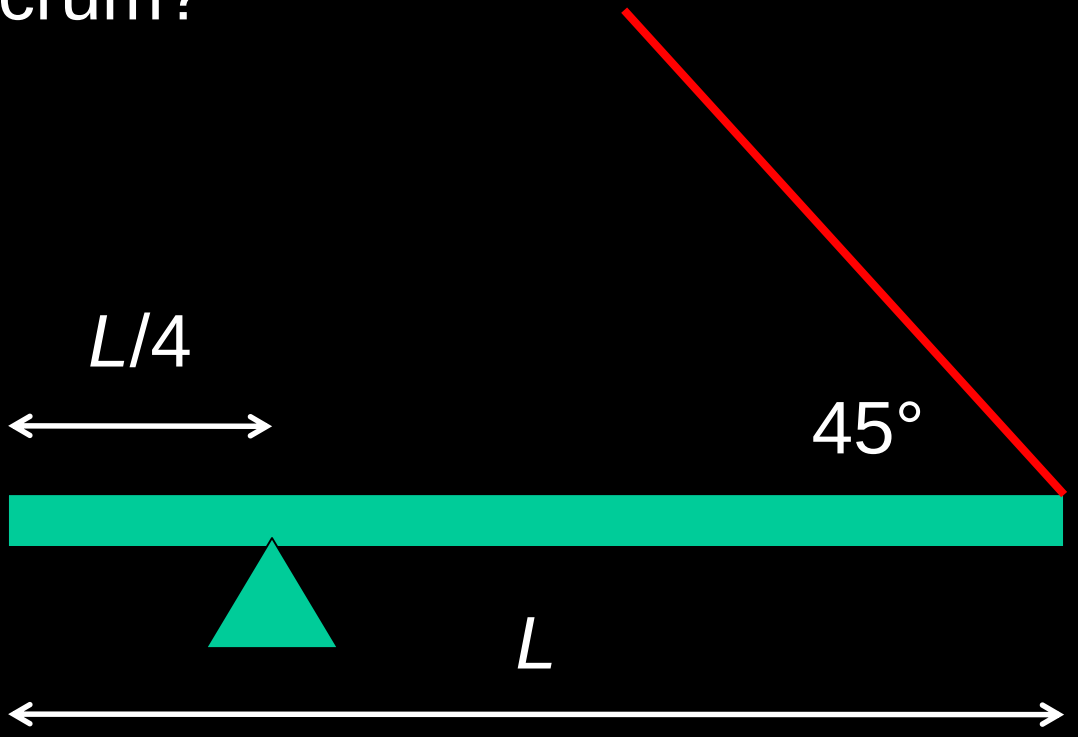
(C)

(D) Anywhere on t on Musk?

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?



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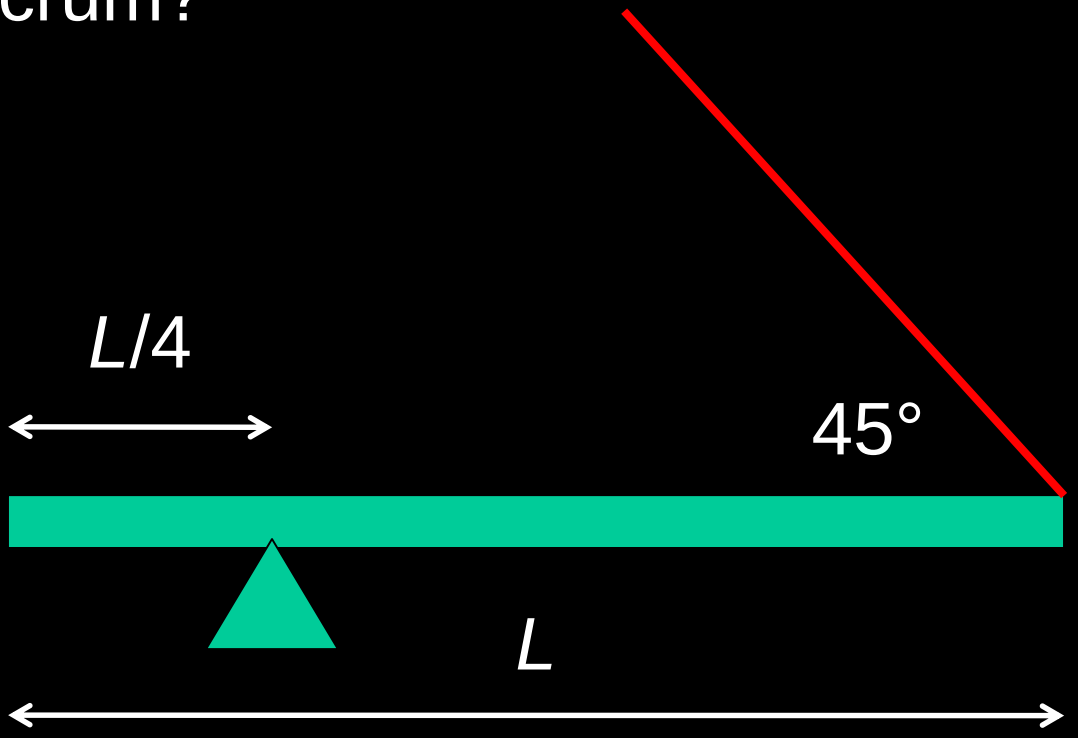

(A) $mg/2$

(B) $mg/3$

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

(D) mg

(E) Equilibrium impossible

possible score = +5 or –6

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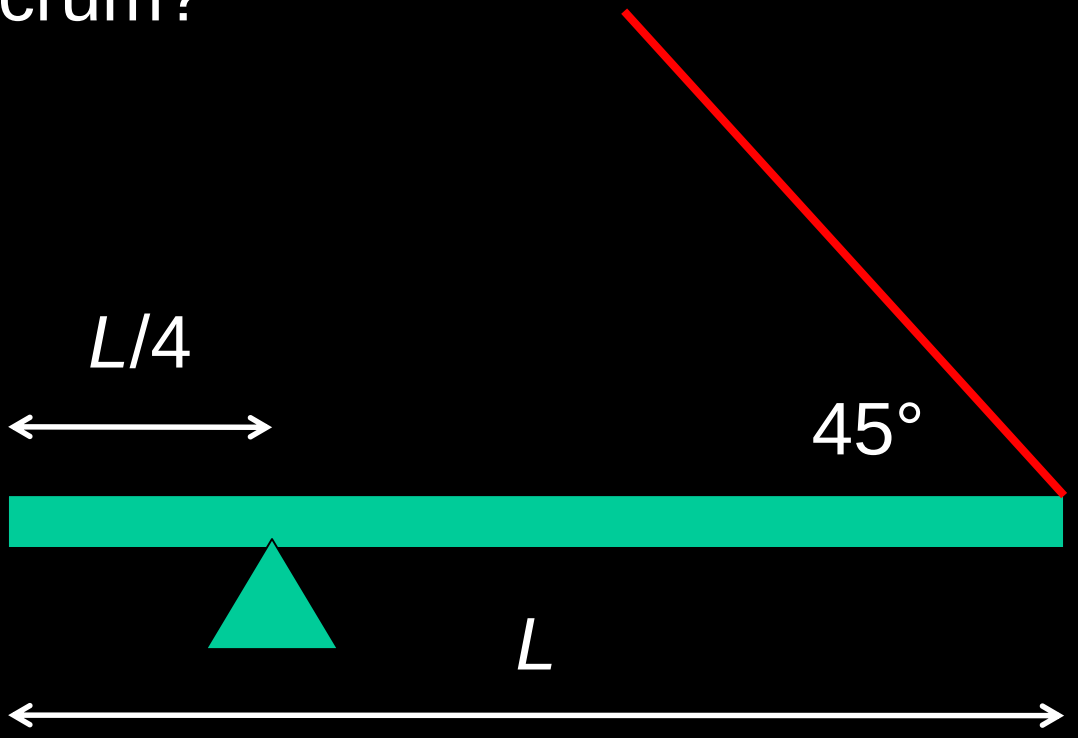

(A) $mg/2$

(B) $mg/3$

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

(D) mg

(E) Equilibrium impossible

possible score = +5 or –6

Answer 5

There is a force *mg* down at *L*/4 from the fulcrum (centre of mass) so the <u>vertical</u> force component from the string at 3*L*/4 away from the fulcrum must be *mg*/3. Since the string is at 45°, 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_{stop}) versus the time it takes them to stop moving after they hit the snow (t_{stop})?

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

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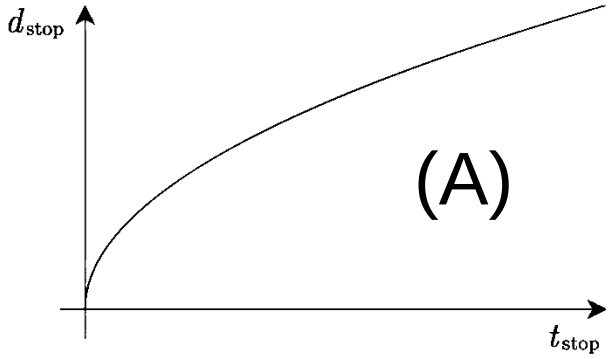

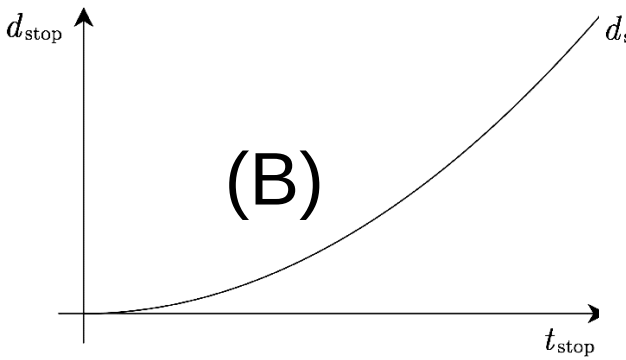

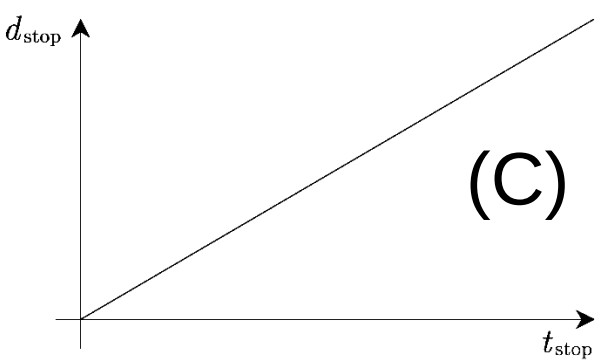

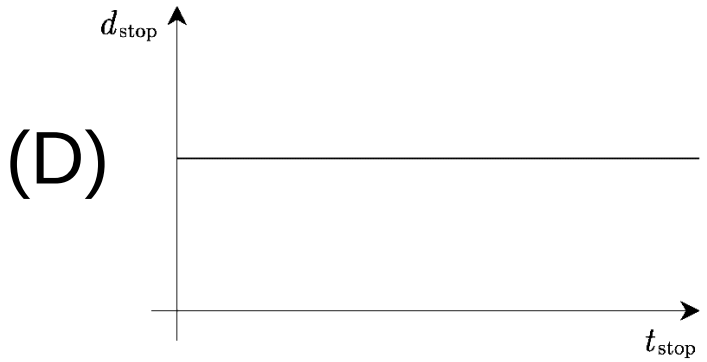

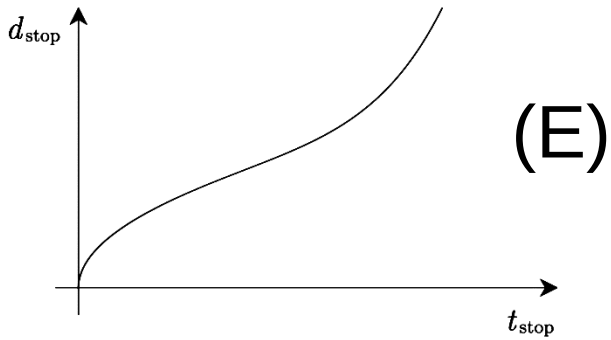

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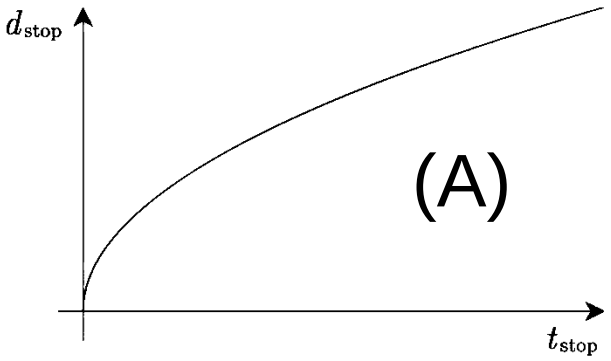
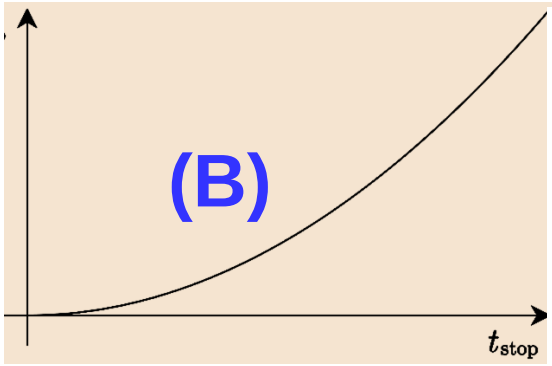
Answer 9

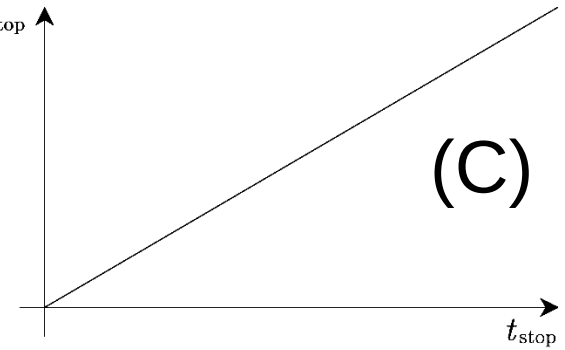
If the pile of snow is of uniform density and air friction is negligible, which graph shows the depth of snow they'll penetrate (d_{stop}) versus the time it takes them to stop moving after they hit the snow (t_{stop})?



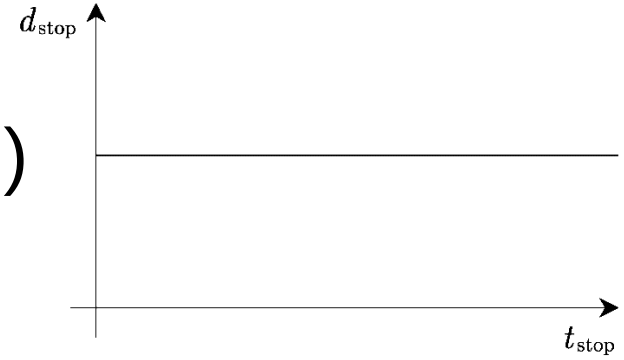
(A)



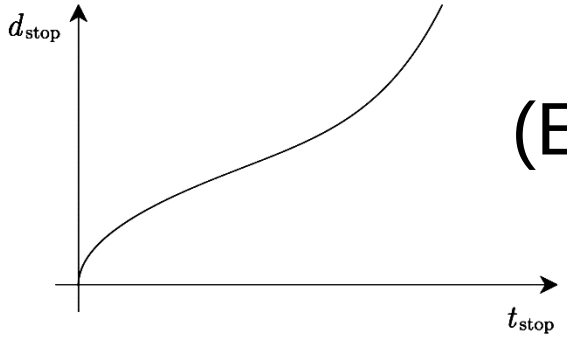
(B)



(C)



(D)



(E)

possible score = +9 or –10 *Answer 9*

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

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

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

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

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

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

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

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

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

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

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

possible score = +9 or –10

Answer 9

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

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

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

possible score = +9 or –10 *Answer 9*

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

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

This is a quadratic function

possible score = +9 or –10 *Answer 9*

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