Physics 2A: Lecture 15

Today's Agenda

- Review quiz 3

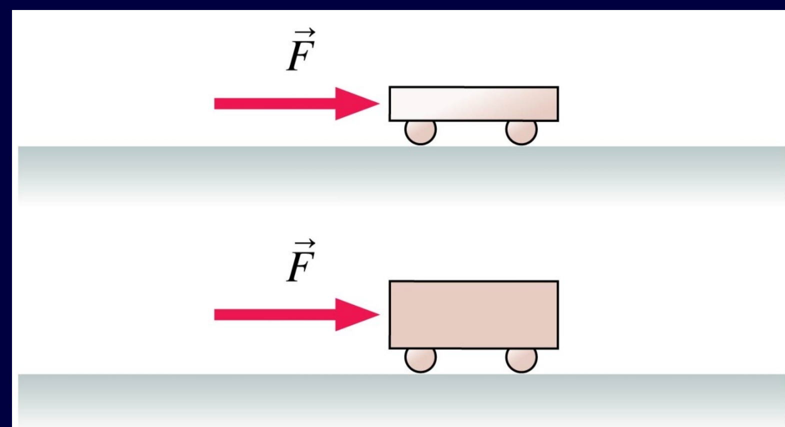
Start recording

Clicker Question 1:

A light plastic cart and a heavy steel cart are both pushed with the same force for 1.0 s, starting from rest. After the force is removed, the momentum of the light plastic cart is _________ that of the heavy steel cart.

Constant force

$$\vec{J} = \Delta \vec{p} = \underline{F}\, \underline{\Delta t}$$



$\downarrow m_L \; v_L \uparrow$

$\uparrow m_H \; v_H \downarrow$

A. greater than

B. equal to

C. less than

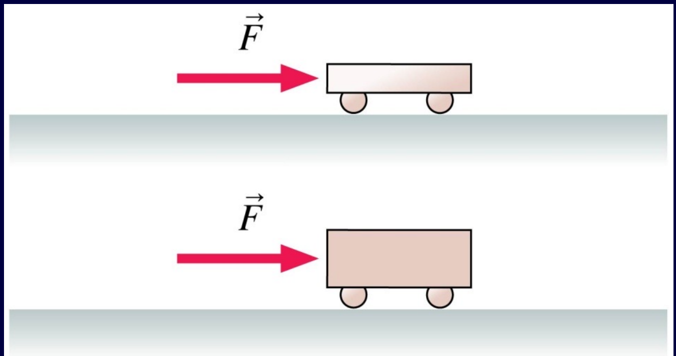
D. Can’t say. It depends on how big the force is.

Clicker Question 2:

A light plastic cart and a heavy steel cart are both pushed with the same force for a distance of $1.0\ \mathrm{m}$, starting from rest. After the force is removed, the kinetic energy of the light plastic cart is __________ that of the heavy steel cart.

$W_{TOT} = \Delta K$

$\underline{F}\,\underline{d} = \Delta K$



A. greater than

B. $\boxed{\text{equal to}}$

C. less than

D. Can't say. It depends on how big the force is.

Clicker Question 3:

$J_x = \int F_x \, dt = 2N \frac{1}{2} s = 1 \; Ns$

$+x \rightarrow$

A 2.0 kg object moving to the right with speed 0.50 m/s experiences the force shown. What are the object's speed and direction after the force ends?

$J_x = \Delta p_x$

$J_x = p_f^x - p_i^x$

$p_f^x = 2Ns$

$mv_f = 2Ns$

$v_f = \frac{2Ns}{2.0kg}$

$= 1 m/s$

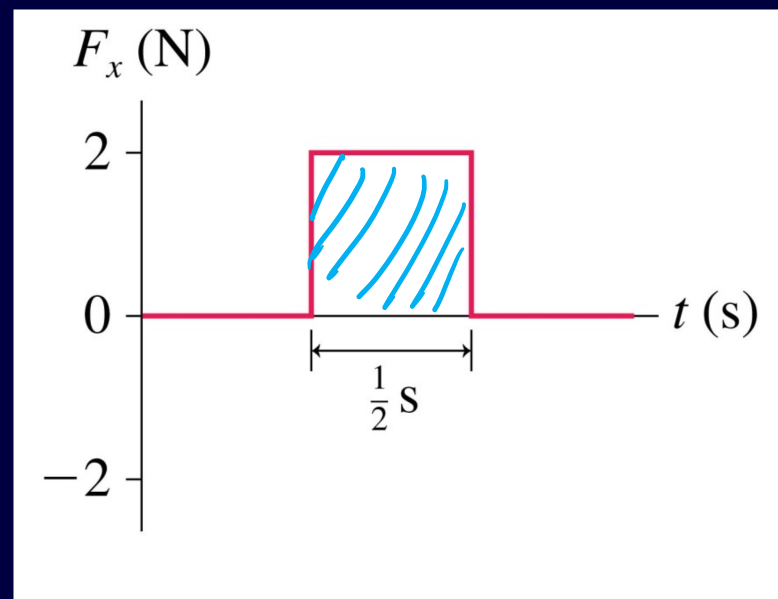
A. 0.50 m/s left.

B. At rest.

C. 0.50 m/s right.

$\boxed{\text{D. 1.0 m/s right.}}$ ✓

E. 2.0 m/s right.



$p_f^x = p_i^x + J_x$

$= p_i^x + J_x$

$= mv_i + J_x$

$= (2.0kg)0.50m/s + 1 \; Ns$

$= 2 \; Ns$

Clicker Question:

1. Suppose a cable pulls an elevator of mass M up a height h at constant speed v. What is the net work done (sum of the work done by all external forces) on the elevator as it moves up this height h?

A. $M g h$

B. $\boxed{0}$

C. $(1/2) M v^2$

D. $-M g h$

E. $-(1/2) M v^2$

$\sum \vec{F}_{net} = m\vec{a} = 0$ $W_{TOT} = \overset{0}{F_{net}}\, d$

$= 0$

$\boxed{W_{TOT} = \Delta K = 0}$

Clicker Question 5:

The linear momentum of a system is conserved

(a) when no external forces act on the system.
(b) when only conservative forces are present.
(c) only during a collision.
(d) always

Conservation of Linear Momentum

The total momentum of an isolated system remains constant

$$\vec{\mathrm{P}}_i = \vec{\mathrm{P}}_f$$

$$\vec{p}_{1i} + \vec{p}_{2i} = \vec{p}_{1f} + \vec{p}_{2f}$$

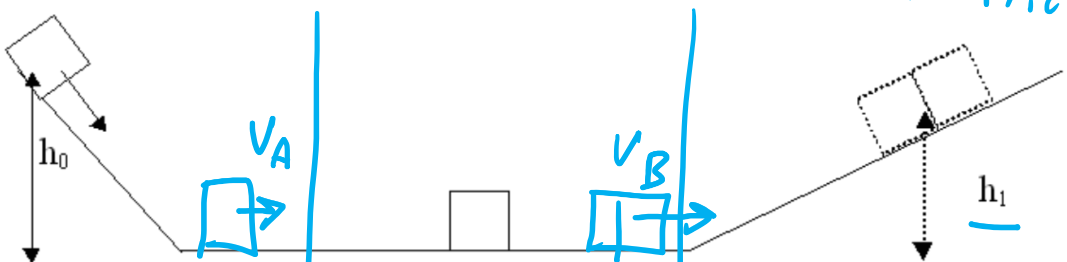
If the motion is along a single axis, the motion is 1-d and we can write the equation about that axis:

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

Question 3

A block of mass M slides down a ramp of height h_0 and collides with an identical block that is initially at rest. The two blocks stick together and slide up a different ramp, reaching a maximum height h_1. Assume all surfaces are frictionless and that the blocks transition "smoothly" down and up the ramp. What is the height h_1?

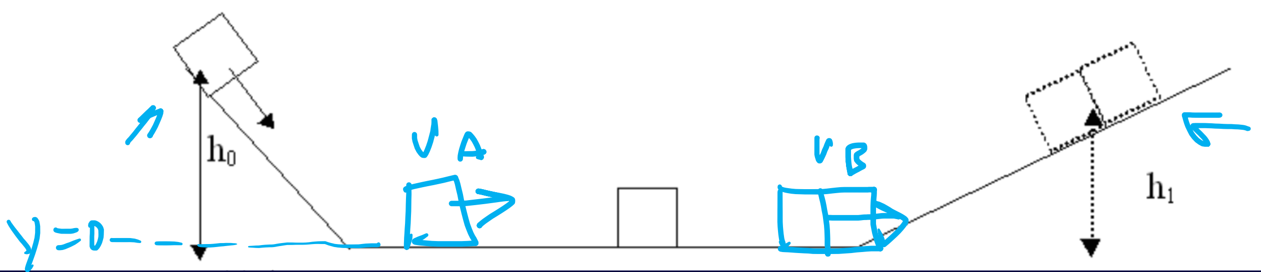
no friction



(a) h_0
(b) $2h_0$
(c) $4h_0$
(d) $h_0/2$
(e) $h_0/4$

I   II   III

I A Energy
~~B Momentum~~
C Both



$$E_i = E_f$$

$$\cancel{m} g h_0 = \frac{1}{2} \cancel{m} v_A^2$$

$$v_A = \sqrt{2 g h_0}$$

II

$$\boxed{\text{Inelastic}}$$

$$p_i^x = p_f^x$$

$$m v_A = 2 m v_B$$

$$v_B = \frac{v_A}{2}$$

$$v_B = \frac{\sqrt{2 g h_0}}{2} = \sqrt{\frac{g h_0}{2}}$$

$$=$$

III

$$E_i = E_f$$

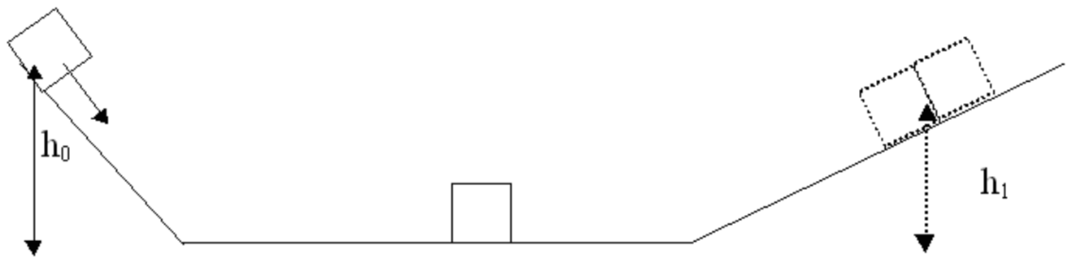
$$\frac{1}{2} \cancel{2m} v_B^2 = \cancel{2m} g h_1$$

$$h_1 = \frac{\frac{1}{2} v_B^2}{g} = \frac{\frac{1}{2} \frac{g h_0}{2}}{g}$$

$$= \frac{h_0}{4}$$

$$v_B^2 = \left(\sqrt{\frac{g h_0}{2}}\right)^2$$

$$= \frac{g h_0}{2}$$



h0
h1

Clicker Question 6:

A mosquito and a truck have a head-on collision. Which has a larger change of momentum?

$$|J| = \int F\,dt$$

$$= F_{AV}\,\Delta t$$

A. The mosquito.

B. The truck.

C. They have the same change of momentum.

D. Can't say without knowing their initial velocities.

$$|J| = |\Delta P|$$

Clicker Question 7:

A bomb explodes into 3 identical pieces. Which of the following configurations of velocities are possible?

(a) ***A*** $\boxed{\text{(b) } \textbf{\textit{B}}}$ (c) ***both***

y

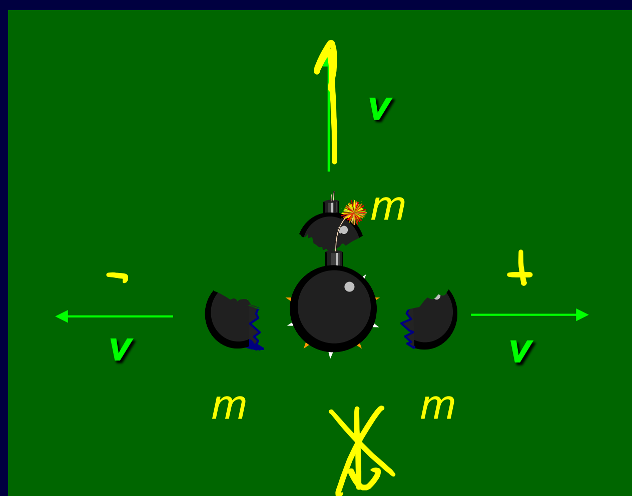
x

0

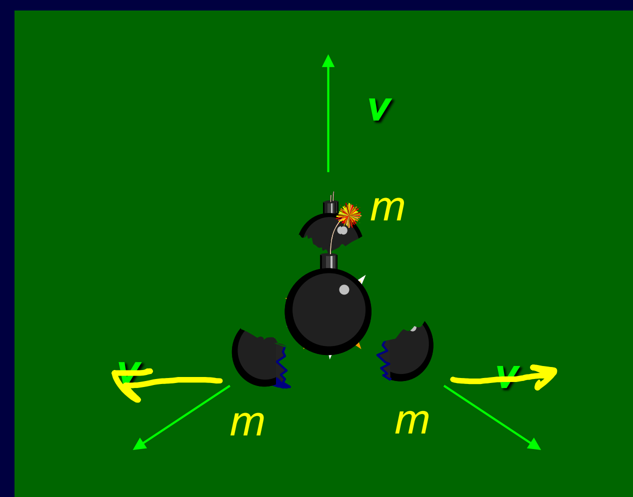
$\vec{P}^{\,in}_{T,I} =$

$= m\vec{v}$

$= 0$



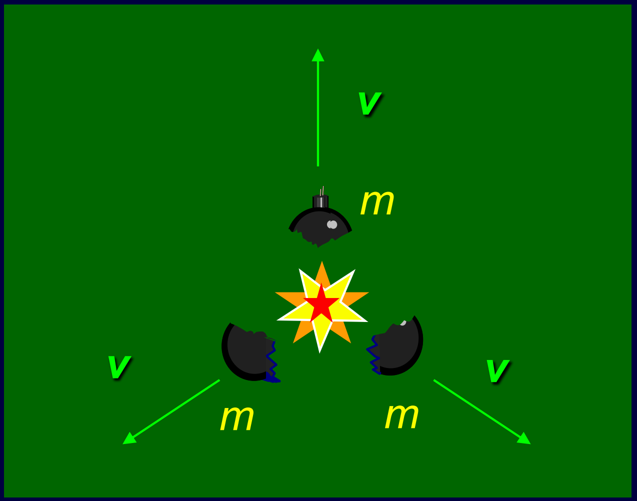
(A)



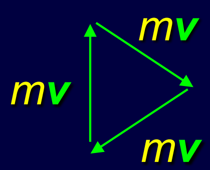
(B)

Clicker Question 7:

- No external forces, so ***P*** must be conserved.
- All the momenta cancel out.
- $\boldsymbol{P_{final}} = 0$.

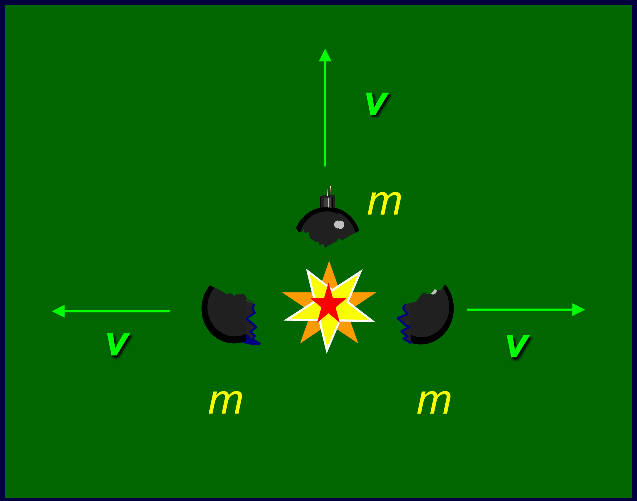


(B)

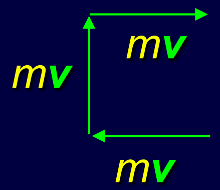


Clicker Question 7:

- No external forces, so ***P*** must be conserved.
- Initially: ***P*** = *0*
- In explosion *(A)* there is nothing to balance the upward momentum of the top piece so $\mathbf{P}_{final} \neq 0$.



(A)



$|p| = mv$

Clicker Question 8:

A bomb that is initially at rest explodes into two unequal fragments. Right after the explosion what can we say about their kinetic energy? Assume all other forces are very small as compared with the internal forces of the explosion.

(a) The more massive fragment has the same kinetic energy than the less massive fragment.

$|P_s| = |P_m|$

(b) The more massive fragment has less kinetic energy than the less massive fragment.

$K = \frac{1}{2} m v^2$

(c) The more massive fragment has more kinetic energy than the less massive fragment.

$p^2 = 2mK \qquad K = \frac{p^2}{2m}$

$K = \frac{1}{2} m v^2 \left(\frac{m}{m}\right) = \frac{1}{2} \frac{m^2 v^2}{m} = \frac{p^2}{2m}$

Collisions

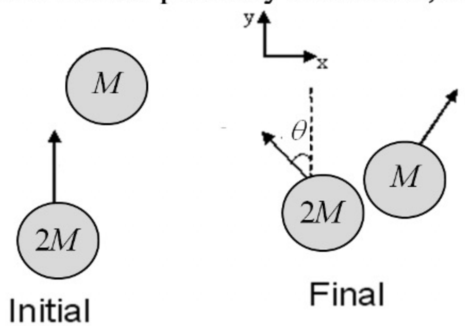
- Momentum is almost always conserved during as collision (external forces are generally small compared to collision forces)
- Two kinds of collisions
  - Elastic-KE is conserved
    - Very special case
  - Inelastic-KE is not conserved
    - Can be assumed if
      - Objects stick together
      - Damage is done during collision

Collisions and Explosions

- Conservation of momentum is very useful for analyzing collisions and explosions
- In collisions/explosions, forces are very complicated; momentum gives us a useful way to solve these problems (treat colliding/exploding particles as system)
- Momentum is almost always conserved during a collision/explosion (external forces are generally small compared to collision/explosion forces)
- This is one reason why momentum is so important

$$F_{avg\,y}\Delta t = \Delta p$$

Two disks are on a frictionless air hockey table as shown. The first disk, with mass M is initially at rest. The second disk with mass $2M$ has an initial velocity of 6.00 m/s in the y direction before colliding with the first disk. The table is perfectly horizontal, and this view is looking down from above.



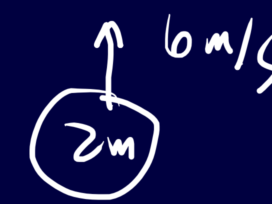
$$V^{2m}_{f_y} = 3\,m/s\ \cos 15 = 2.89\,m/s$$

$$V^{2m}_{f_x} = 3\,m/s\ \sin 15 = 0.78\,m/s$$

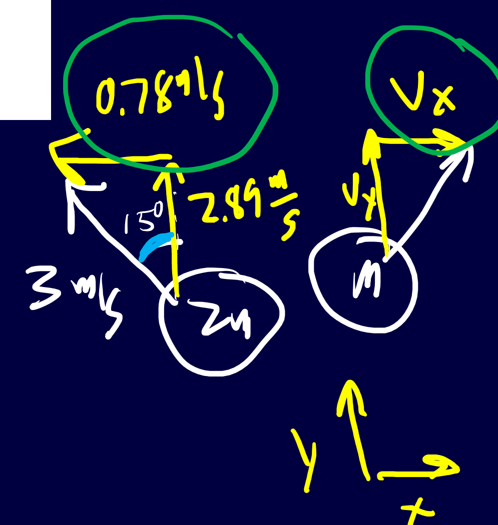
After the collision, the disk with mass $2M$ is deflected $\theta = 15.0°$ and has speed 3.00 m/s as shown in the figure.

What is the final speed of the mass M?

initial



final



x - direction

$$p_i^x = p_f^x$$

✓ $$0 = 2\cancel{m}(-0.78\,m/s) + \cancel{m} V_x$$

$$V_x = 2(0.78\,m/s) = 1.56\,m/s$$

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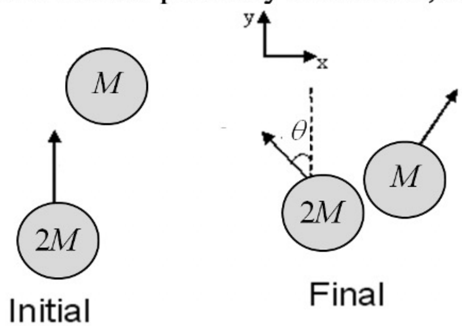

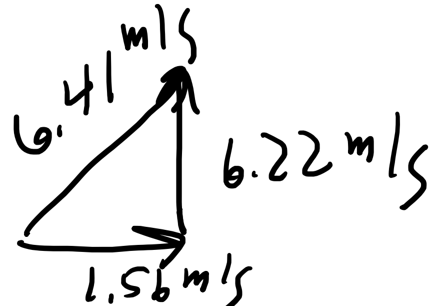

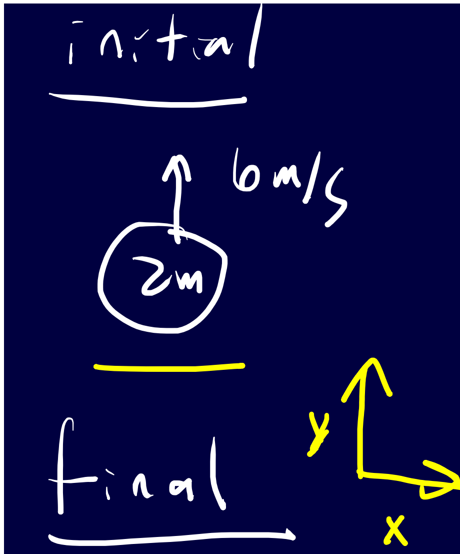

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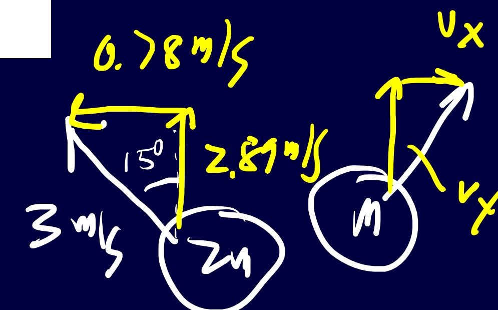
y-direction

$$p_i^y = p_f^y$$

$$12 = 5.78 + 6.22 = 12$$

$$2m(6\,m/s) = 2m(2.89\,m/s) + m v_y$$

$$v_y = 2(6\,m/s) - 2(2.89\,m/s) = 6.22\,m/s$$



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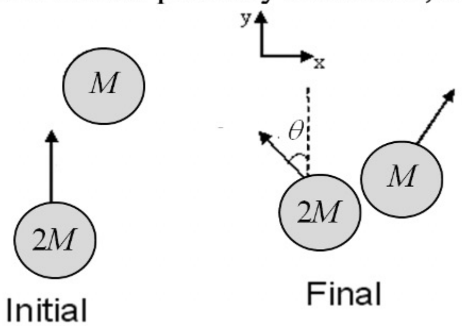
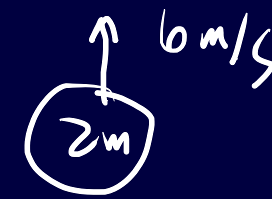


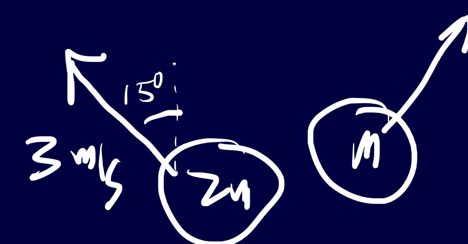
After the collision, the disk with mass $2M$ is deflected $\theta = 15.0°$ and has speed 3.00 m/s as shown in the figure.

What is the final speed of the mass M?

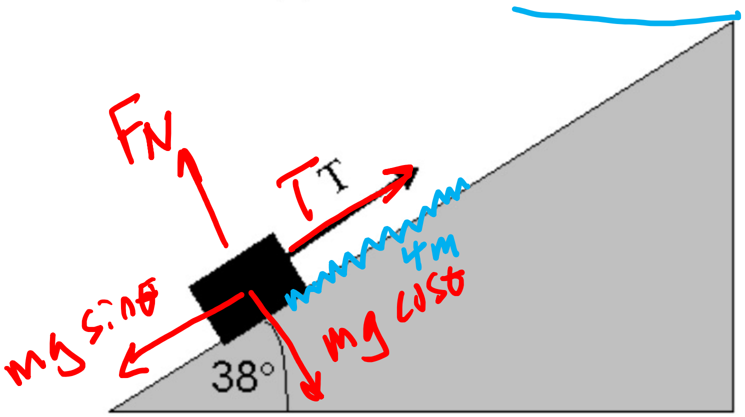
initial



final



PART A [6 points]
A block of mass 2 kg is pulled up a frictionless incline by some tension T. The block starts at rest and after being pulled up the incline 4 m has a speed of 15 m/s. (a) What is the net work done on the block? (b) What is the force of tension?



(A) $W_{TOT} = F_{net} d$

(B) $W_{TOT} = \Delta K$

(C) Both

(a) 225 J

$v_f = 15\ m/s$

$d = 4m$, T?

(A) $W_{TOT} = F_{net}\, d$

$= [T - mg\sin\theta]\, d$

$W_{TOT} = \Delta K = \frac{1}{2} m v_f^2 - \cancel{\frac{1}{2} m v_i^2}$

$= \frac{1}{2} m v_f^2 = \frac{1}{2}(2kg)(15\ m/s)^2$

$= 225\ J$

$$W_{nT} = \Delta K = 225\,J$$

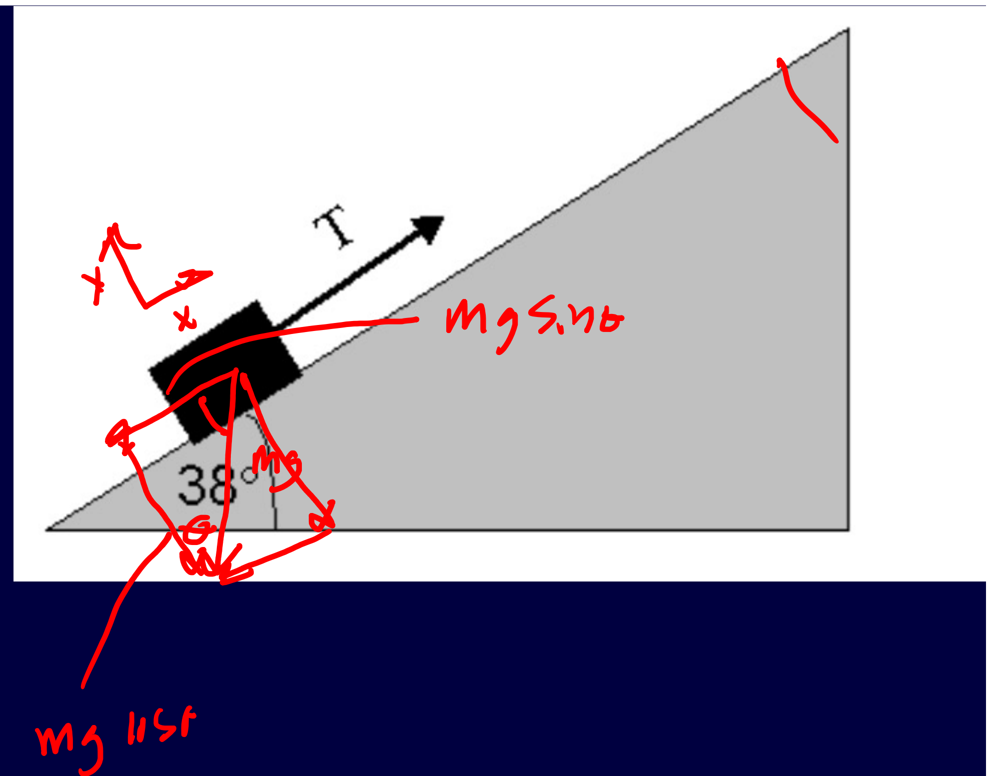
$$[T - mg\sin\theta]d = 225\,J$$

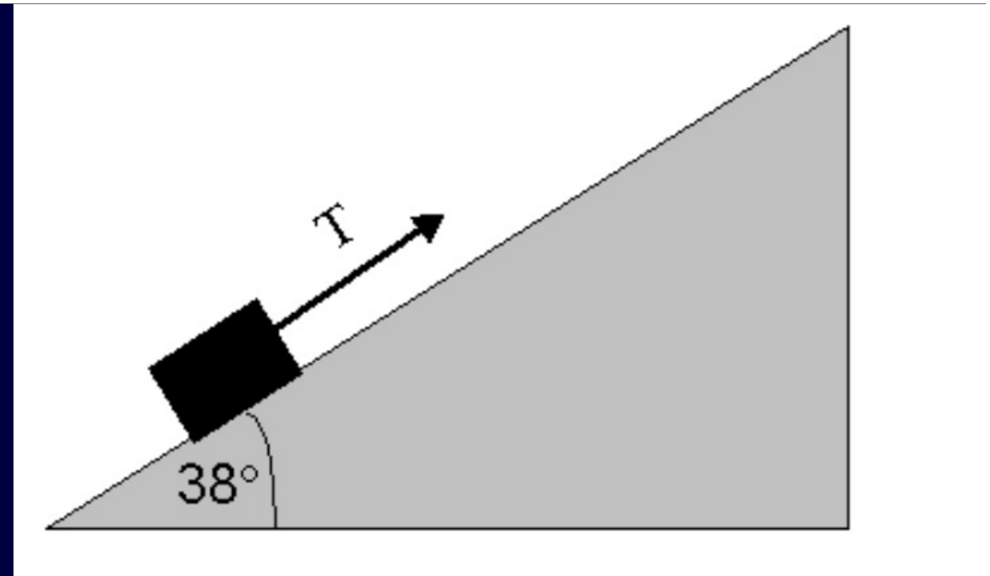
$$Td - mg\sin\theta\, d = 225\,J$$

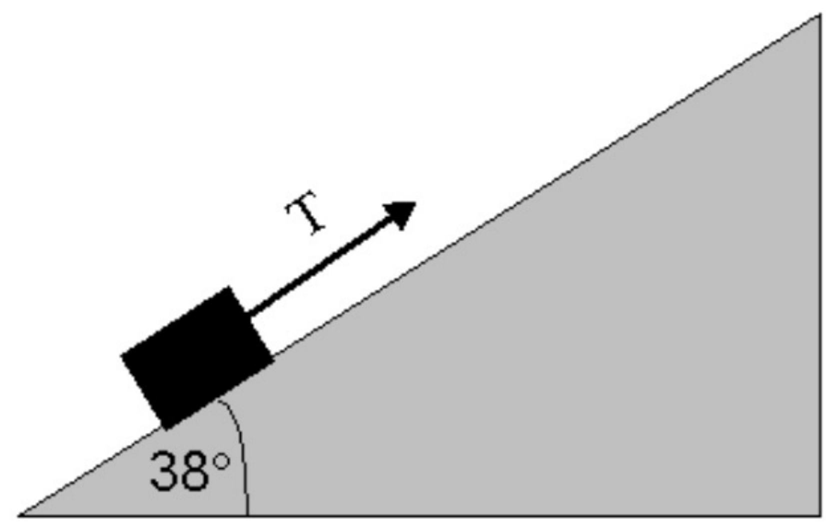
$$Td = 225\,J + mg\sin\theta\, d$$

$$T = \frac{225\,J + mg\sin\theta\, d}{d}$$

$$= 68.3\ N$$

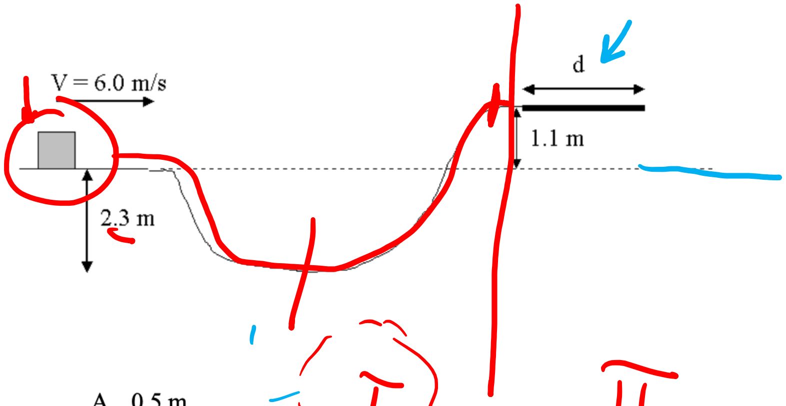



T
38°


T
38°

Thanks for your time.

7. A bobsled is initially moving with a speed of 6.0 m/s. It encounters a valley as below. When it makes it back to the top it climbs a hill of 1.1 m and encounters a rough surface with $\mu_K = 0.60$. What distance ***d*** will it take the bobsled to stop once it reaches the rough surface? (assume all other surfaces are friction free)



A. 0.5 m
B. 1.2 m
C. 4.3 m
D. 2.2 m
E. 1.9 m

A $\boxed{\text{Energy}}$
B Momentum
C Both

$V_f = V_A$

$V_f = 3.79\,\frac{m}{s}$

$E_i = E_f$

$2\left[\frac{1}{2}\cancel{m}v_i^2 = \cancel{m}g(1.1\,m) + \frac{1}{2}\cancel{m}v_f^2\right]$

$v_f^2 = v_i^2 - 2g\,1.1\,m$

$W = \Delta K$

$-f_k d = \frac{1}{2}\cancel{m}v_B^2 - \frac{1}{2}mv_A^2$

$-f_k d = -\frac{1}{2}mv_A^2$

$-\mu_k F_N d = -\frac{1}{2}mv_A^2$

$+\mu_k \cancel{m}g\,d = +\frac{1}{2}\cancel{m}v_A^2$

$d = \dfrac{\frac{1}{2}v_A^2}{\mu_k g} = 1.2\,m$