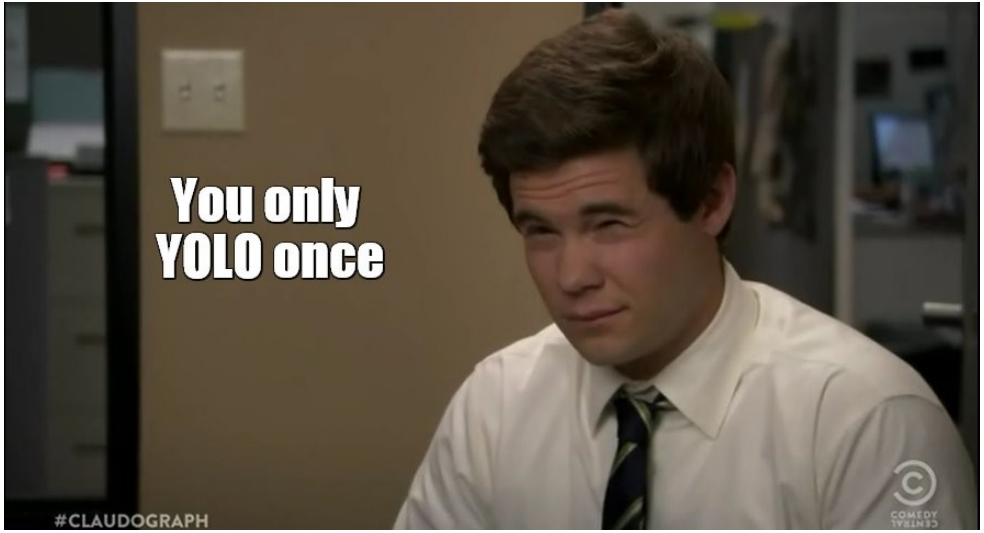
Thursday March 2

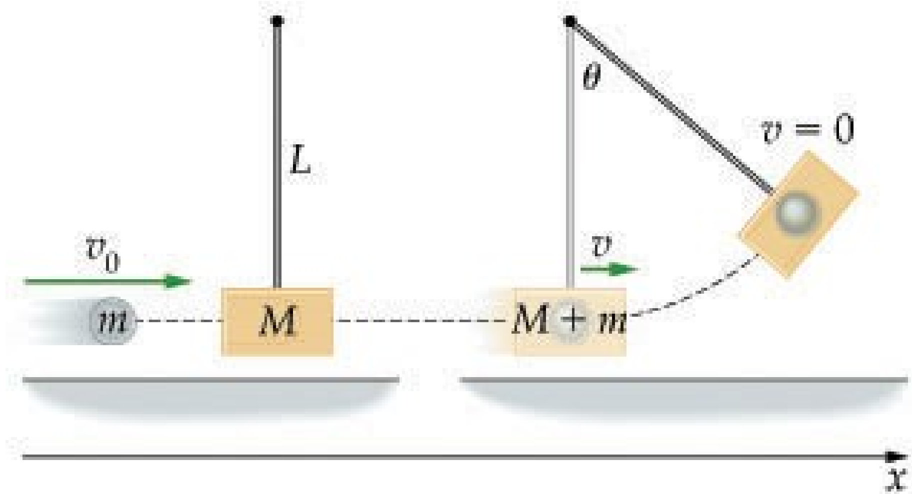
Topics for this Lecture:

- *Energy & Momentum*

- Assignment 8 due Friday ***after spring break***
- Pre-class due 15min before class
- Help Room: Here, 6-9pm Wed/Thurs
- SI: Morton 326, M&W 7:15-8:45pm
- Office Hours: 204 EAL, 10-11am Wed
  or by appointment (meisel@ohio.edu)



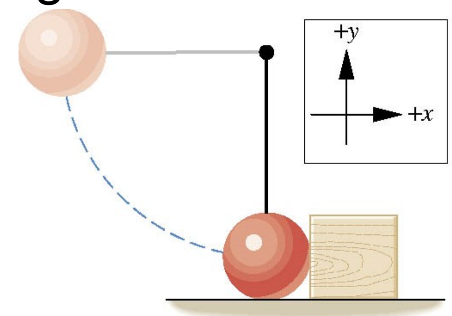
“Ballistic Pendulum” (lab after ‘wooo, spring break’)



- Perfectly inelastic collision: Ball launched via spring mechanism into pendulum
- Will determine change in KE
- Will get final KE using conservation of energy (measuring final PE) & conservation of momentum
- Will get initial KE by measuring initial velocity (using 1D kinematics)

A ball is attached to a wire, held horizontally, and dropped.
It strikes a block that is sitting on a horizontal, frictionless surface.
Air resistance is negligible and the collision is elastic.
The block is more massive than the ball.
Which of the following are conserved as the ball swings down?

1



(A) Ball’s Kinetic Energy

(B) Ball’s Momentum

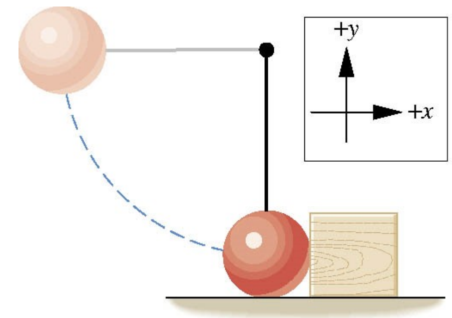
(C) Ball’s Total Mechanical Energy

(D) A &B (E) A & C (F) B & C

(G) A, B, & C

1. Initial kinetic energy is zero (at rest) …but clearly moving at the bottom of the swing. So KE clearly not conserved (Nor need it be!)
2. Similarly, momentum clearly zero (at rest) but moving at bottom of swing. Why is momentum not conserved? The ball is acted-on by an external force! (gravity)
3. Even if the pendulum were initially swinging, velocity would be downward at first, then horizontal. The tension is another outside force acting on the ball.
4. Energy is always conserved. Here PE is converted into KE.

A ball is attached to a wire, held horizontally, and dropped.
It strikes a block that is sitting on a horizontal, frictionless surface.
Air resistance is negligible and the collision is elastic.
The block is more massive than the ball.
Which of the following are conserved **<u>during</u> the collision**?

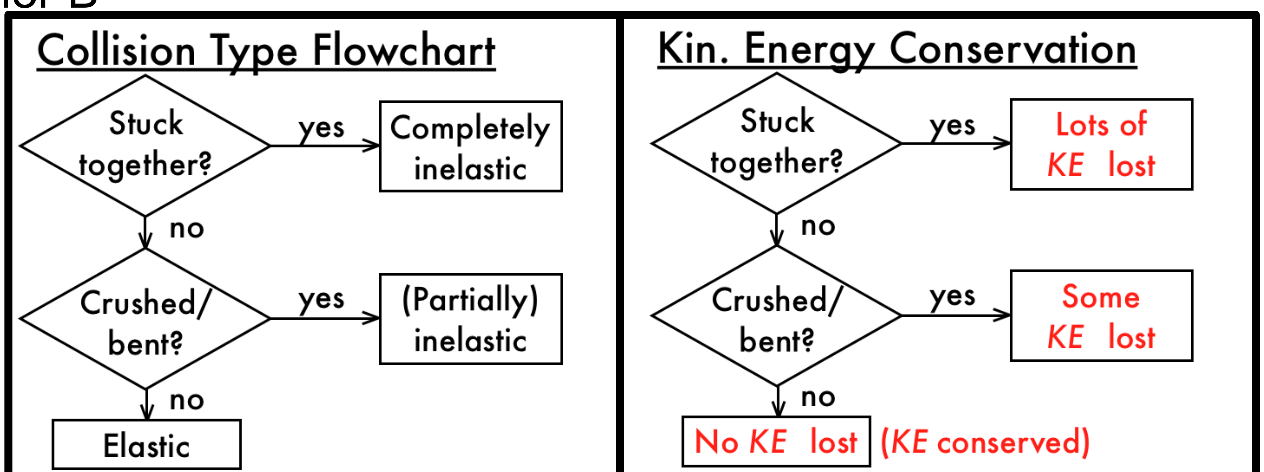


(A) Horizontal component of momentum for ball+block system

(B) Total KE of ball+block system

(C) Both A & B

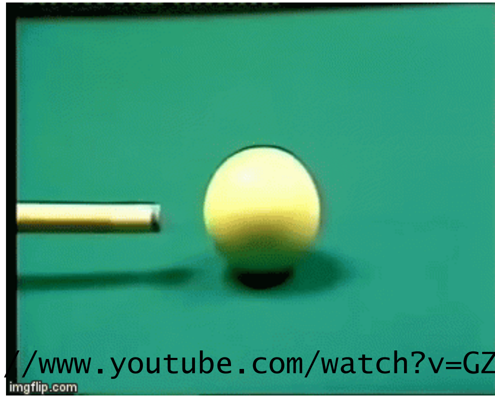
(D) Neither A nor B



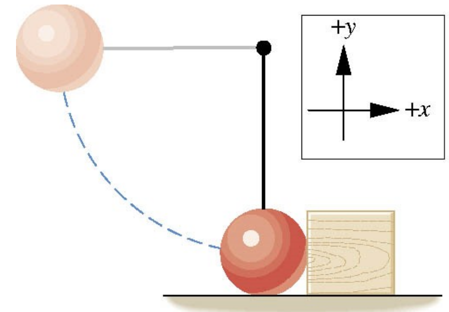
Patrick M. Len

A ball is attached to a wire, held horizontally, and dropped.
It strikes a block that is sitting on a horizontal, frictionless surface.
Air resistance is negligible and the collision is elastic.
The block is more massive than the ball.
Which direction will the ball be traveling after the collision?

(A) Left
(B) At rest
(C) Right



https://www.youtube.com/watch?v=GZHJaLMnI1o



- Say initially object 1 is moving and object 2 is at rest.

i.e. $m_1 v_{1,i} = m_1 v_{1,f} + m_2 v_{2,f}$ and $\frac{1}{2} m_1 v_{1,i}^2 = \frac{1}{2} m_1 v_{1,f}^2 + \frac{1}{2} m_2 v_{2,f}^2$

…using these two equations and some algebra: $v_{1,f} = \frac{1}{2}\left(1 - \frac{m_2}{m_1}\right) v_{2,f}$

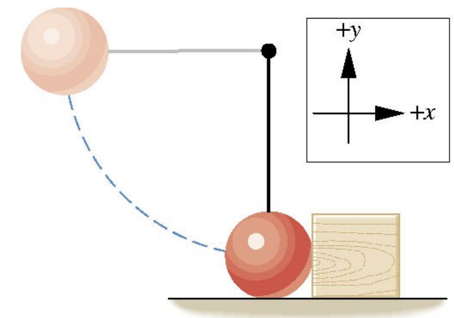
If:

A.$m_1 > m_2$: $\frac{m_2}{m_1} < 1$ …meaning: $v_{1,f} > 0$ …so both 1 and 2 move forward

B.$m_1 < m_2$: $\frac{m_2}{m_1} > 1$ …meaning $v_{1,f} < 0$ …so 1 bounces back & 2 moves slowly forward

C.$m_1 = m_2$: $v_{1,f} = 0$ …meaning $v_{2,f} = v_{1,i}$ …so they swap velocities!

A 1.60kg ball is attached to a 1.20m-long wire, held horizontally, and dropped.
It strikes a 2.40kg block that is sitting on a horizontal, frictionless surface.
Air resistance is negligible and the collision is elastic.
What is the velocity of the ball just before the collision?

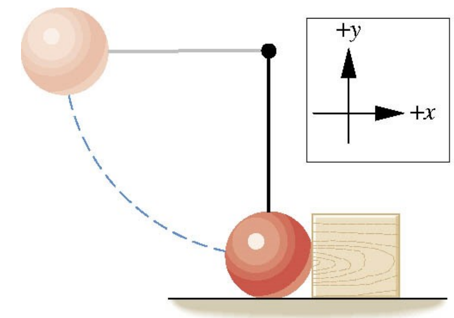


(A) 4.33m/s (B) 18.8m/s (C) 23.5m/s $\boxed{\text{(D) 4.85m/s}}$ (E) 3.96m/s

1. Total energy is conserved: $KE_i + PE_i = KE_f + PE_f$
2. Initial state: just before ball is released
    1. At rest: $KE_i = 0$.
    2. $PE_i = mgh$
3. Final: just before ball hits block
    1. At reference height h=0: $PE_f = 0$
    2. $KE_f = (1/2)mv_f^2$
4. $KE_f = (1/2)mv_f^2 = PE_i = mgh$
5. $v_f = \sqrt{\frac{2}{m}mgh} = \sqrt{2gh} = \sqrt{2(9.80\frac{m}{s^2})(1.20m)} = 4.85m/s$

A 1.60kg ball is attached to a 1.20m-long wire, held horizontally, and dropped.
It strikes a 2.40kg block that is sitting on a horizontal, frictionless surface.
Air resistance is negligible and the collision is elastic.
What is the velocity of the ball just **after** the collision?

(A) +0.97m/s (B) 0 m/s (C) -0.97m/s (D) 4.85m/s (E) -4.85m/s



1. Elastic collision, so momentum is conserved & kinetic energy is conserved.
2. For an elastic collision, object 1 colliding into object 2:
    1. $v_{ball,f} = \{(m_{ball} - m_{block})/(m_{ball} + m_{block})\}v_{ball,i}$
3. $v_{ball,f} = \{(1.60kg - 2.40kg)/(1.60kg + 2.40kg)\}4.85m/s$
4. $v_{ball,f} = -0.97m/s$

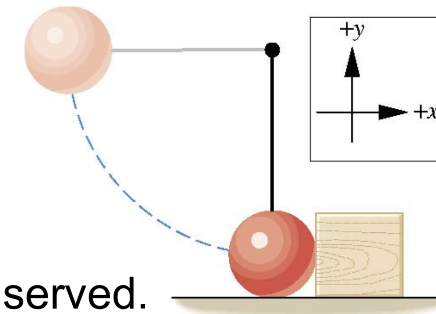
Just write this equation down.
It's a bit of a pain to prove:

For an elastic collision:

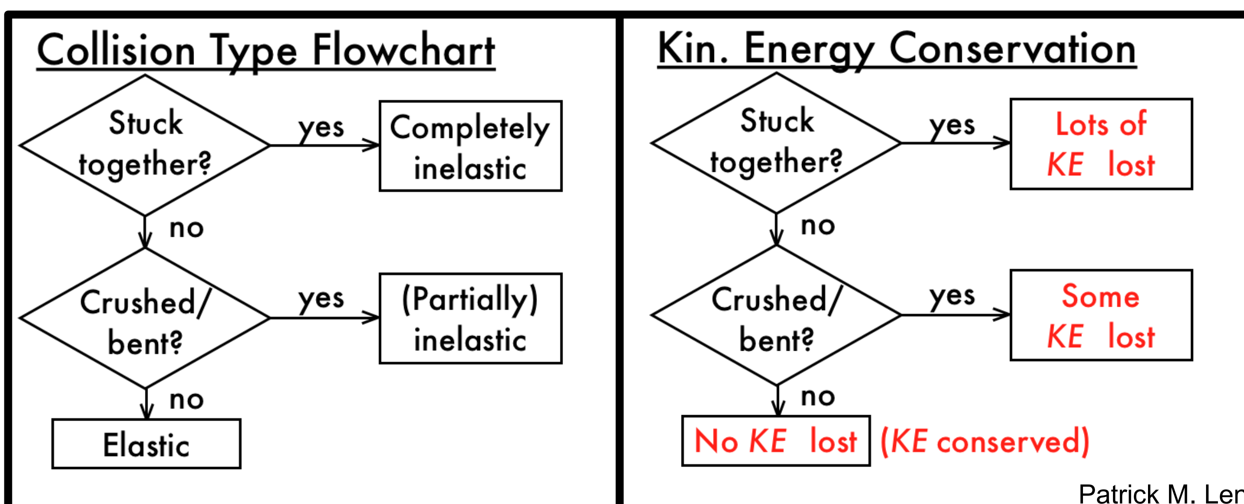
$$v_{1,f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)v_{1,i}$$

A 1.60kg ball is attached to a 1.20m-long wire, held horizontally, and dropped.
It strikes a 2.40kg block that is sitting on a horizontal, frictionless surface.
Air resistance is negligible and the collision is elastic.
What is the kinetic energy loss of the system due to the collision?

(A) 0.0 J (B) 19 J (C) 6.2 J (D) 7.7 J (E) 1.6 J

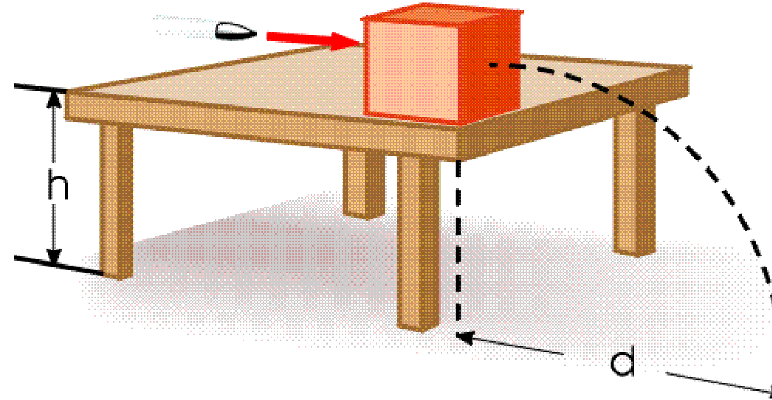


1. Elastic collision, so momentum is conserved & kinetic energy is conserved.



Multi-concept problem: *Bullet and Block* (like on HW 8)

A bullet hits a block on a table, launching the block (with the bullet embedded) off of the table. How far does the block travel?



1. Use momentum conservation/collisions to find block velocity before leaving table top.
2. Use kinematics to find:
    1. Flight-time from free-fall
    2. Range traveled in flight-time

2D Projectile motion eqns.

1. $v_x = v_{x,0}$
2. $x = x_0 + v_{x,0}t$
3. $v_y = v_{y,0} + a_y t$
4. $y = y_0 + v_{y,0}t + \frac{1}{2}a_y t^2$
5. $y = y_0 + \frac{1}{2}\left(v_{y,0} + v_y\right)t$
6. $v_y^2 = v_{y,0}^2 + 2a_y(y - y_0)$

A ball with mass m is traveling on a frictionless table-top at 2m/s and strikes an identical ball elastically, knocking it off of the table top.
Which path best represents the path of the second ball after being struck?

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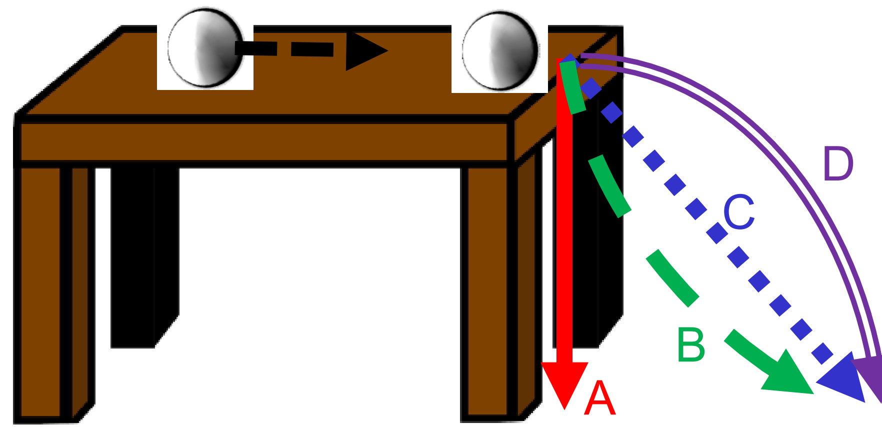
(A) A (B) B (C) C $\boxed{\text{(D) D}}$
(E) None of these

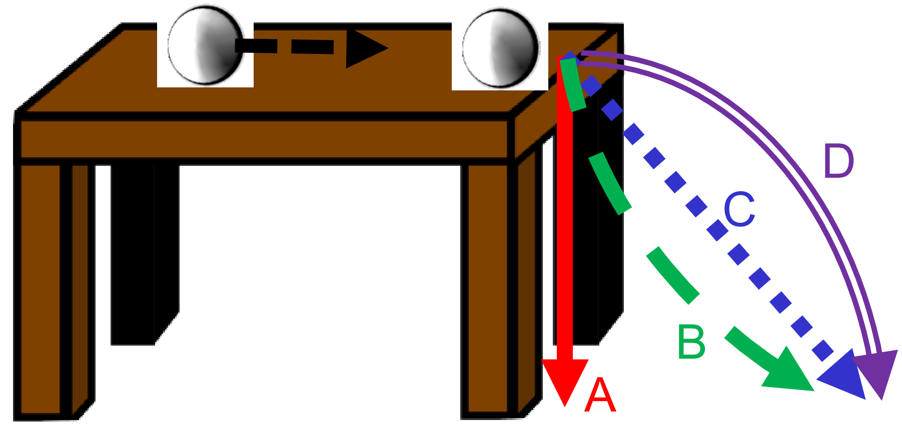


- Projectile motion looks like path D.
- Think about the fact that there is initially zero vertical velocity, but this will steadily increase due to acceleration at little g.

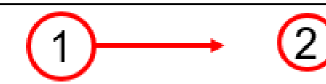
A ball with mass m is traveling on a frictionless table-top at 2m/s and strikes an identical ball elastically, knocking it off of the table top.
Which path best represents the path of the first ball, after it strikes the second ball?

(A) A (B) B (C) C (D) D

$\boxed{\text{(E) None of these}}$



1. Elastic collision with two identical masses, one initially at rest.
2. They swap velocities!
3. Therefore no path will be taken, the first ball will end at rest.



- Say initially object 1 is moving and object 2 is at rest.

  i.e. $m_1 v_{1,i} = m_1 v_{1,f} + m_2 v_{2,f}$ and $\frac{1}{2}m_1 v_{1,i}^2 = \frac{1}{2}m_1 v_{1,f}^2 + \frac{1}{2}m_2 v_{2,f}^2$

  …using these two equations and some algebra: $v_{1,f} = \frac{1}{2}\left(1 - \frac{m_2}{m_1}\right) v_{2,f}$

If:

A. $\mathbf{m_1 > m_2}$: $\frac{m_2}{m_1} < 1$ …meaning: $v_{1,f} > 0$ …so both 1 and 2 move forward

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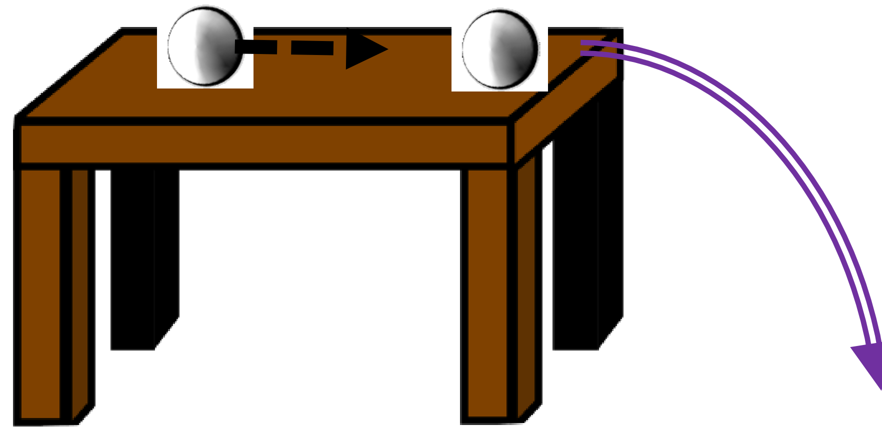
C. $\mathbf{m_1 = m_2}$: $v_{1,f} = 0$ …meaning $v_{2,f} = v_{1,i}$ …so they swap velocities!

A ball with mass m is traveling on a frictionless table-top at 2m/s and strikes an identical ball elastically, knocking it off of the table top.
If it takes 1 second for the second ball to hit the ground after leaving the table-top, how far away horizontally will the second ball be from the first when it hits the ground?

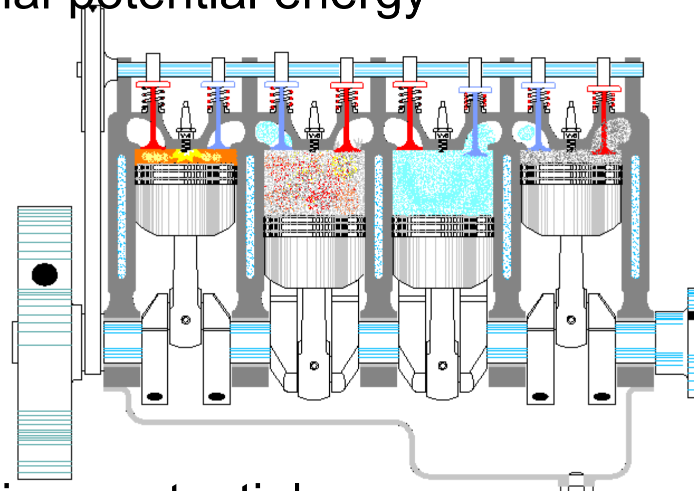
(A) 0.5m (B) 1m $\boxed{\text{(C) 2m}}$ (D) 9.8m
(E) Not enough information



1. Elastic collision with two identical masses, one initially at rest.
2. They swap velocities!
3. Horizontal motion is separate from vertical motion.
4. So, in 1 second, the horizontal distance travelled will be (2m/s)*(1s) = 2m

Conservation of Energy: Including other energy types

- So far have focused on kinetic energy & gravitational potential energy
- But energy can be several forms:
  - –Electrical (e.g. power outlets, batteries)
  - –Chemical (e.g. food, gasoline)
  - –Nuclear (e.g. power-plant, the sun)
  - –Thermal (e.g. steam)
  - –Light (e.g. lasers)



- …most of these can be thought of in terms of kinetic or potential energy
  - –Thermal: Just kinetic energy of little molecules
  - –Electrical: Just kinetic energy of moving electrons
  - – Light: Just kinetic energy of photons
  - –Chemical & Nuclear: Just potential energy due to forces other than gravity
- Can convert between types
  - –….usually not perfect in real-life & so need efficiency factors.
  - –E.g. incandescent bulbs getting hot while converting electrical energy to light

A 1000kg wagon starts at rest and reaches 30m/s in 5 seconds.
How much power does this take?

(A) 30,000 W (B) 450,000 W
(C) 900,000 W $\boxed{\text{(D) 90,000 W}}$

1. Power = (Change in Energy)/Time
2. $P = (KE_f - KE_i)/\Delta t = KE_f/\Delta t$
3. $P = \{(1/2)mv^2\}/\Delta t$
4. $P = \{(1/2)(1000kg)(900m^2/s^2)\}/5s$
5. $P = 90{,}000W$

Hot Rod magazine

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A 1000kg wagon starts at rest and reaches 30m/s in 5 seconds.
Meanwhile, the wagon climbs a 10m tall hill.
How much power does this take?

(A) 109,600 W (B) 450,000 W
(C) 900,000 W (D) 90,000 W

Hot Rod magazine

1. Power = (Change in Energy)/Time
2. $P = (\Delta PE + \Delta KE)/\Delta t$
3. $P = \{(1/2)mv^2 + mgh\}/\Delta t$
4. $P = \{(1/2)(1000kg)(900m^2/s^2) + (1000kg)(9.8m/s^2)(10m)\}/5s$
5. P = 109,600W

A 1000kg top fuel dragster starts at rest and reaches 44m/s in 0.8 seconds. How much power does this take?

(A) 90,000 W   (B) 1,210,000 W

(C) 900,000 W   (D) 968,000 W

1. Power = (Change in Energy)/Time
2. $P = (KE_f - KE_i)/\Delta t = KE_f/\Delta t$
3. $P = \{(1/2)mv^2\}/\Delta t$
4. $P = \{(1/2)(1000kg)(1936m^2/s^2)\}/0.8s$
5. P = 1,210,000W

A 1000kg top fuel dragster starts at rest and reaches 44m/s in 0.8 seconds. It burns 1 gallon of nitromethane, which has an energy content of 5×10^7 J/gallon. What is the efficiency of the dragster's engine?

(A) 0.2% (B) 2%
(C) 35% (D) 100%

1. (Actual Power) = (Theoretical Power)*(Efficiency)
2. Actual Power = (Change in Energy)/Time
3. $P_{act} = (KE_f - KE_i)/\Delta t = KE_f/\Delta t$
4. $P_{act} = \{(1/2)mv^2\}/\Delta t$
5. $P_{act} = \{(1/2)(1000kg)(1936m^2/s^2)\}/0.8s$
6. $P_{act} = 1{,}210{,}000W$
7. Efficiency = $\varepsilon = P_{act}/P_{theory}$
8. $P_{theory} = (1gallon * 5x10^7 J/gallon)/0.8s = 6.25x10^7$ W
9. $\varepsilon = (1.21x10^6\ W)/(6.25x10^7\ W) \sim 0.02 = 2\%$

A typical automobile engine is ~1/3 efficient.