Physics 211

Sections 1 & 70

Dr. Geoffrey Lovelace

Fall 2012

Lecture 18 (11/01/12)

Lecture 18 outline

- Announcements
- Linear momentum wrap up
  - Center of mass
  - Completely inelastic
    - Example: 2D ball collision
  - Elastic collisions
    - Newton’s cradle revisited
    - Double ball bounce revisited
  - Class participation worksheet (time permitting)

Announcements

- Homework
  - Homework #8: due 11:59PM today
- Exams: plan to post grades today
- Reading: For Tuesday: begin chapter 7
- Office hours: 10AM-11AM, 4PM-5PM today
  - McCarthy Hall room 601B
  - Feel free to just come & work on the homework
- SI sessions resume Tuesday, November 6
- Exam #3: 2 weeks from todday

Today

Oct 23	**Exam 2**
Oct 25	Linear momentum, conservation of linear momentum
Oct 30	Conservation of linear momentum, collisions
Nov 1	Center of mass, rockets, *HW #8 due*
Nov 6	Circular motion, gravitation
Nov 8	Gravitation, Kepler's laws *HW #9 due*
Nov 13	Special feature: temperature, heat, entropy
Nov 15	**Exam 3**
Nov 20	*Fall Recess — No class*
Nov 22	*Fall Recess — No class*
Nov 27	Rigid body rotation, torque, rotational dynamics
Nov 29	Rotational dynamics, rotational energy, *HW #10 due*
Dec 4	Angular momentum, conservation of angular momentur
Dec 6	Harmonic motion, *HW #11 due*
Dec 11	Harmonic motion & waves
Dec 13	Gravitational waves, harmonic motion, black holes, *HW*
Dec 20	**Final exam 9:30AM–11:20AM**

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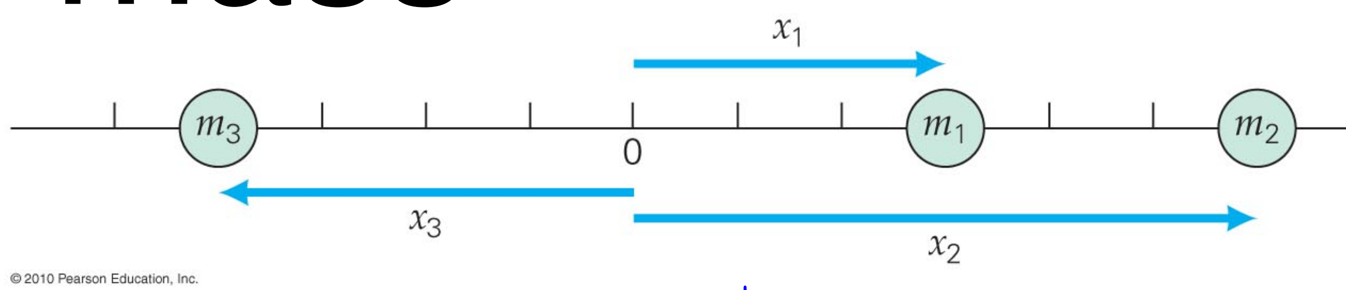
Center of mass

- Definition



$$\vec{\mathbf{x}}_{\mathrm{CM}} = \frac{\sum_i m_i \vec{\mathbf{x}}_i}{\sum_i m_i}$$

$$x_{\mathrm{CM}} = \frac{m_1 x_1 + m_2 x_2 - m_3 x_3}{m_1 + m_2 + m_3}$$

- Newton's second law on a system

$$\vec{\mathbf{F}}_{\mathrm{net}} = \left(\sum_i m_i \right) \vec{\mathbf{a}}_{\mathrm{CM}}$$

- Demo: baton
  https://www.youtube.com/watch?v=nCTxemGXv78

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Collisions

- Impulse-momentum theorem

  $I \equiv \vec{\mathbf{F}}_{\mathrm{avg}} \Delta t = \Delta \vec{\mathbf{p}}$ $\qquad$ $\vec{\mathbf{p}} \equiv m \vec{\mathbf{v}}$

  - Collision: happens very quickly $\Delta t \approx 0$
  - So $\Delta \vec{\mathbf{p}} \approx 0$
  - Quantitative collision problems
    - Momentum conserved: $\Delta \vec{\mathbf{p}} = 0$
    - Elastic: KE conserved: $\Delta KE = 0$
    - Totally inelastic: stick together
  - Motion before/after collision:
    - If external force, momentum not cons.

Completely inelastic

- Particles stick together
- Momentum conservation

$$m_1\vec{\mathbf{v}}_1 + m_2\vec{\mathbf{v}}_2 = (m_1 + m_2)\,\vec{\mathbf{v}}$$

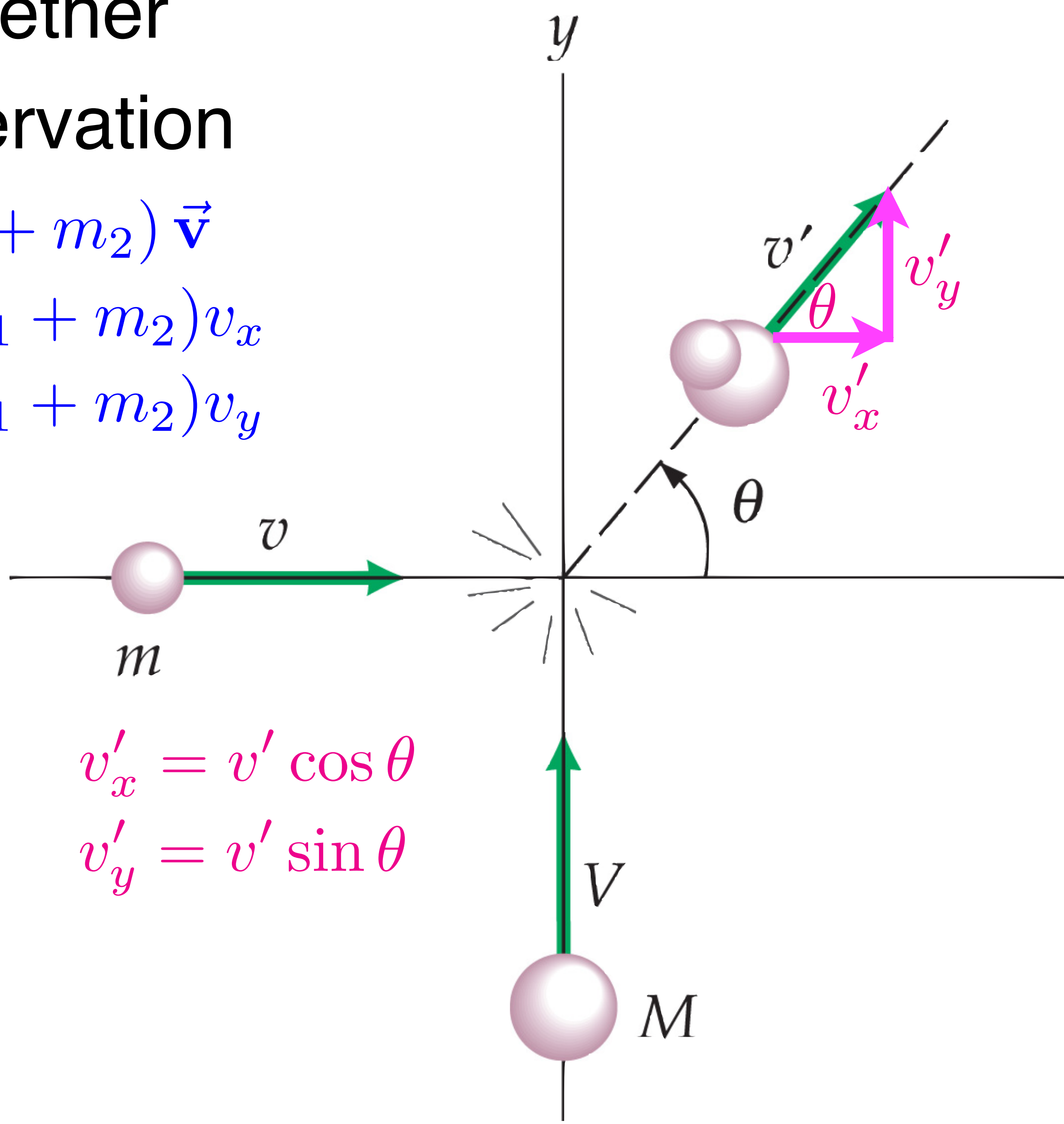
$$m_1 v_{1x} + m_2 v_{2x} = (m_1 + m_2) v_x$$

$$m_1 v_{1y} + m_2 v_{2y} = (m_1 + m_2) v_y$$

- Example

$$mv = (m + M)v'_x$$

$$MV = (m + M)v'_y$$



$$v'_x = v'\cos\theta$$

$$v'_y = v'\sin\theta$$

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Clicker question #82

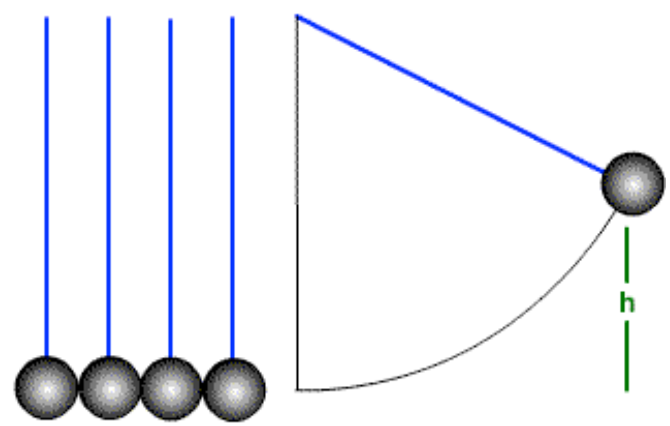
- As the right ball swings down, which of the following best applies to calculate its motion?

A Conservation of momentum

B Conservation of kinetic + potential energy

C Cons. of kinetic energy

D Both A and C



Clicker question #83

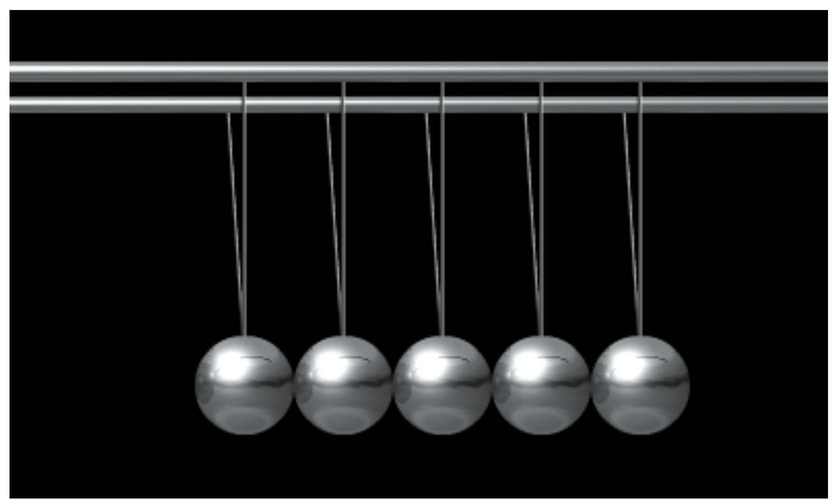
- As the balls collide elastically (from right to left), which principle(s) best describe the collision?

A Conservation of momentum

B Conservation of kinetic + potential energy

C Cons. of kinetic energy

D Both A and C



Clicker question #84

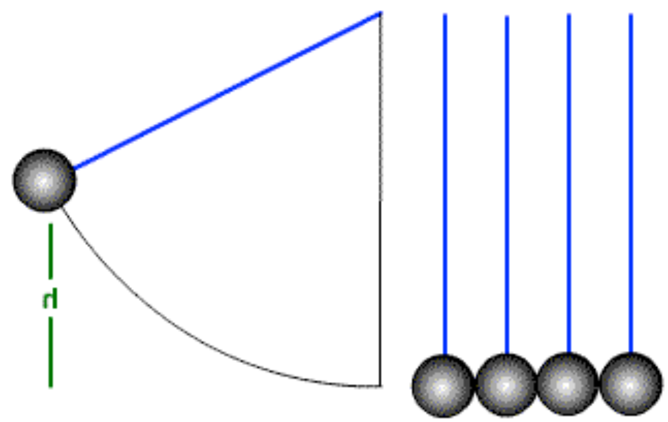
- After the balls collide elastically, which principle(s) best describe the motion after the collision?

A Conservation of momentum

B Conservation of kinetic + potential energy

C Cons. of kinetic energy

D Both A and C



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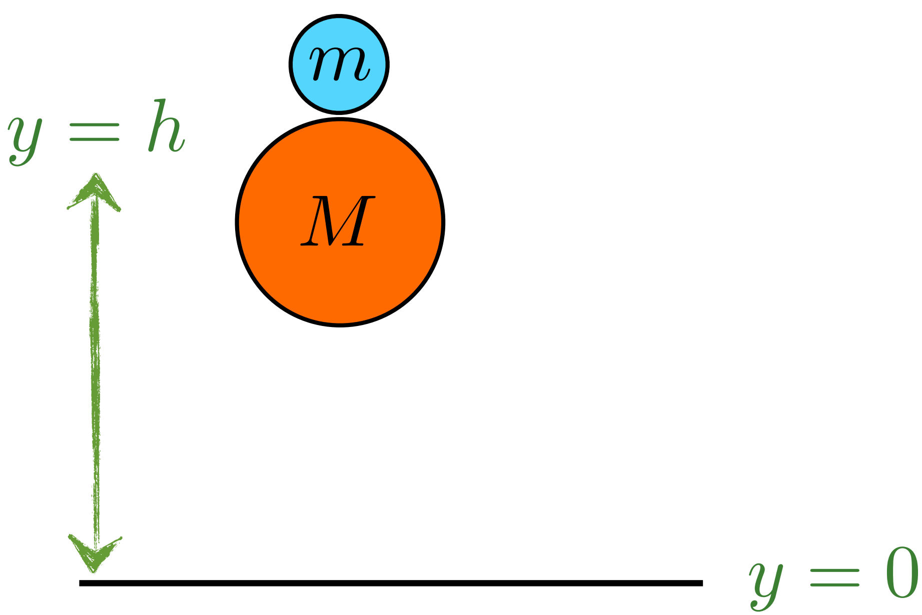
Double-ball-bounce

2 small balls (mass *m << M)* dropped from rest at a height *h*. How high does the small ball bounce? (All collisions are elastic. Small = point particles.)

Given: $y_0 = h$, $m \ll M$

Goal: $y =$ height small ball bounces

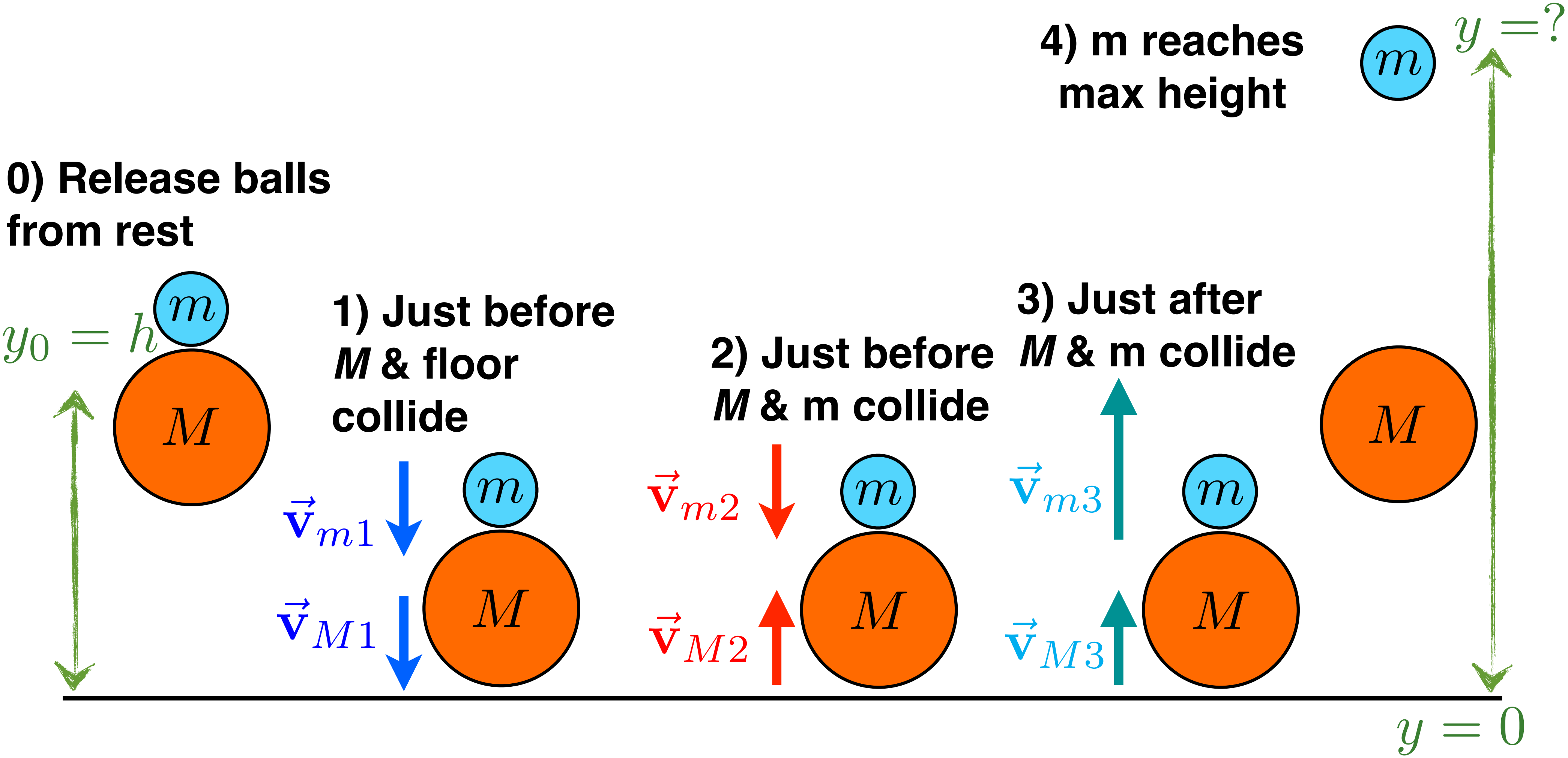


1. Read carefully
2. (Draw a sketch)
3. Given? Goal?
4. Principles & equations?

Double-ball bounce

Given: $y_0 = h$, $m \ll M$

Goal: $y =$ height small ball bounces



Clicker question #78

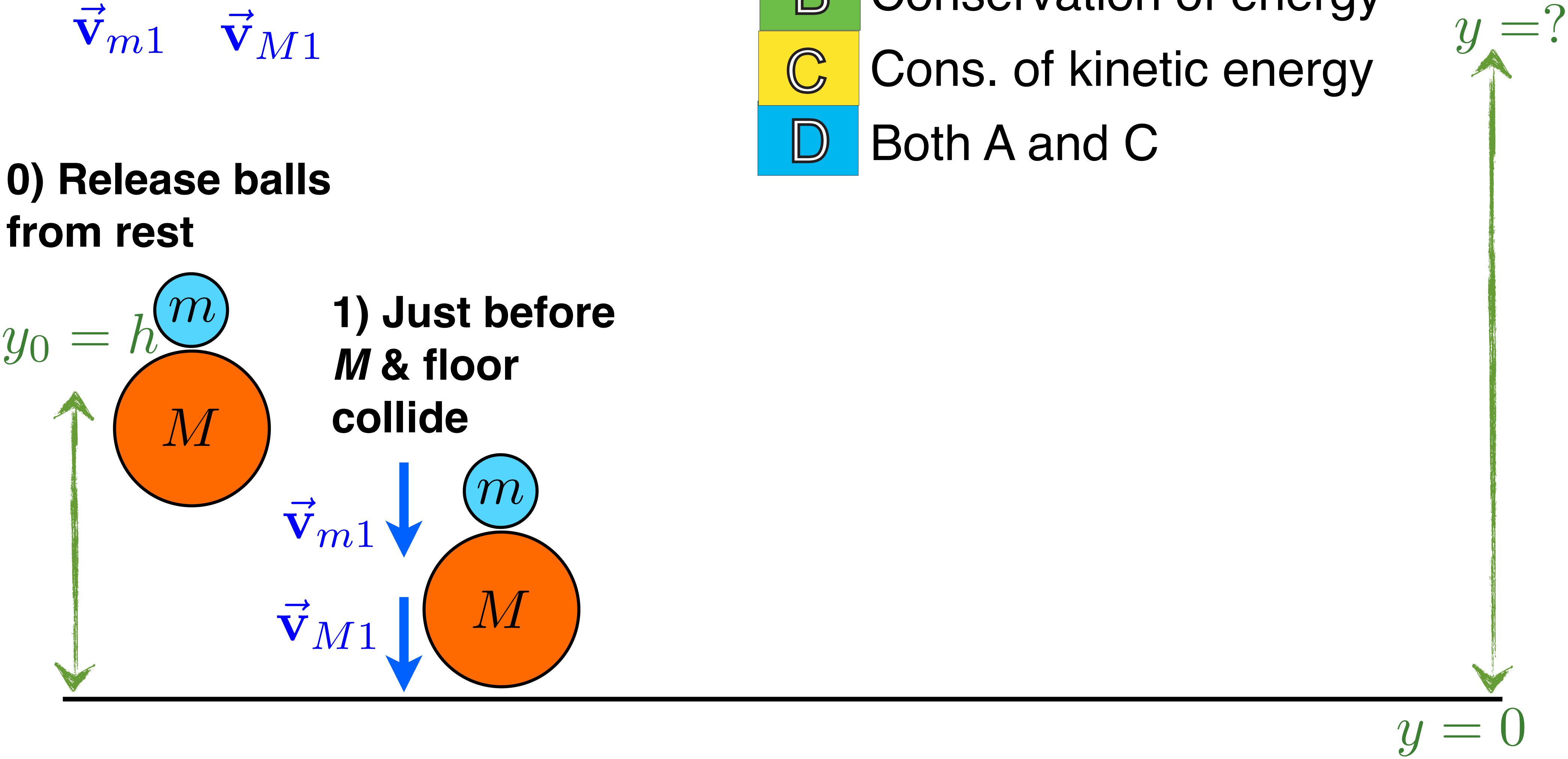
Which principle(s) best can be used to find the following?

$\vec{\mathbf{v}}_{m1}$ $\vec{\mathbf{v}}_{M1}$

A	Conservation of momentum
B	Conservation of energy
C	Cons. of kinetic energy
D	Both A and C

0) Release balls from rest

1) Just before *M* & floor collide



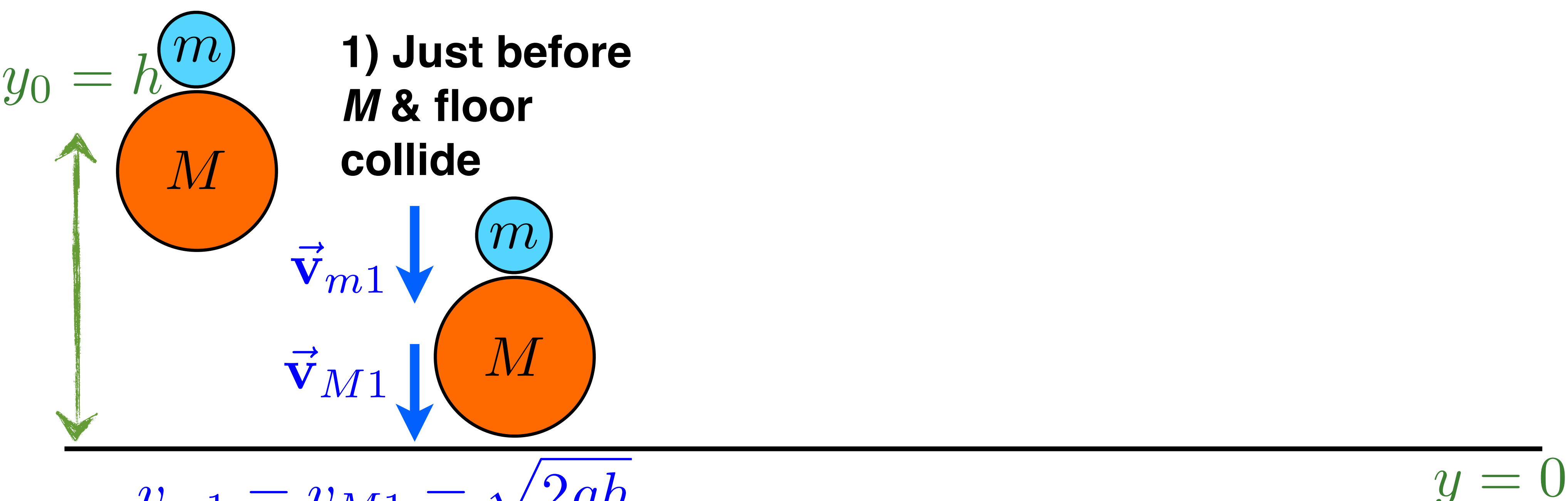
Double-ball bounce

$$mgh = \frac{1}{2} m v_{m1}^2 \qquad Mgh = \frac{1}{2} M v_{M1}^2$$

$$2gh = v_{m1}^2 \qquad 2gh = v_{M1}^2$$

$$v_{m1} = \sqrt{2gh} \qquad v_{M1} = \sqrt{2gh}$$

0) Release balls from rest



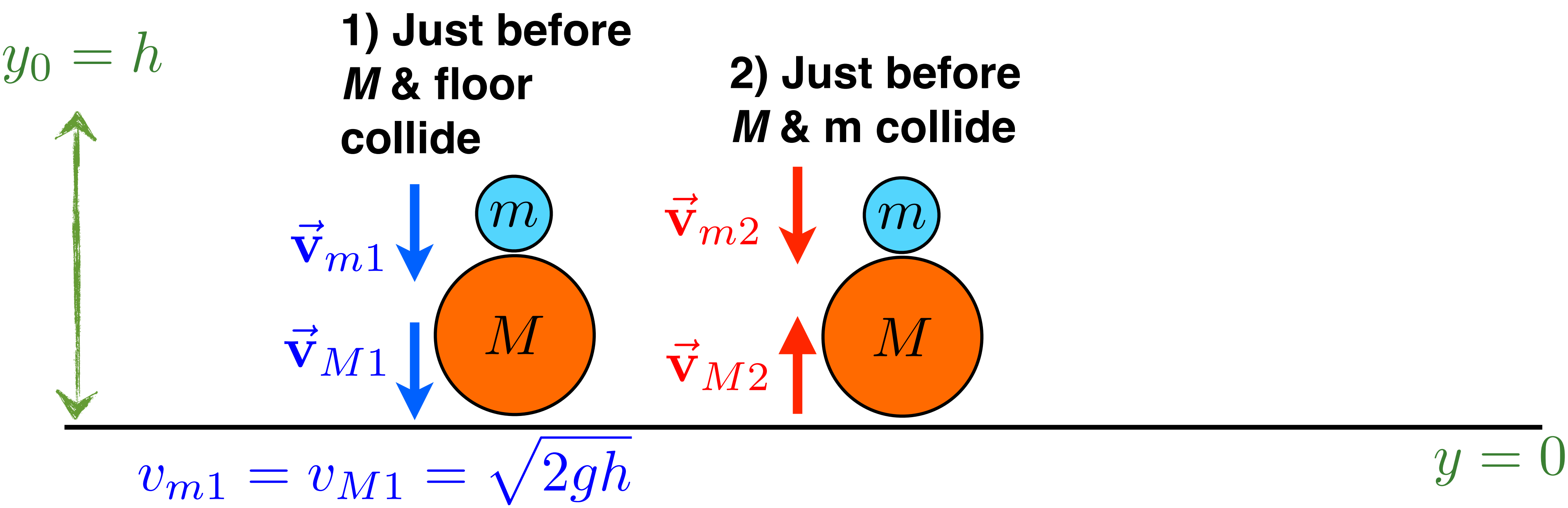
$$v_{m1} = v_{M1} = \sqrt{2gh}$$

Clicker question #79

Which principle(s) best can find the following?

$\vec{\mathbf{v}}_{m2}$ $\vec{\mathbf{v}}_{M2}$

- A Conservation of momentum
- B Cons. of kinetic + pot. energy
- C Cons. of kinetic energy
- D Both A and C



Double ball drop

- Kinetic energy conserved (elastic collision)
- Earth accelerates negligibly

$$\frac{1}{2}Mv_{M1}^2 = \frac{1}{2}Mv_{M2}^2$$

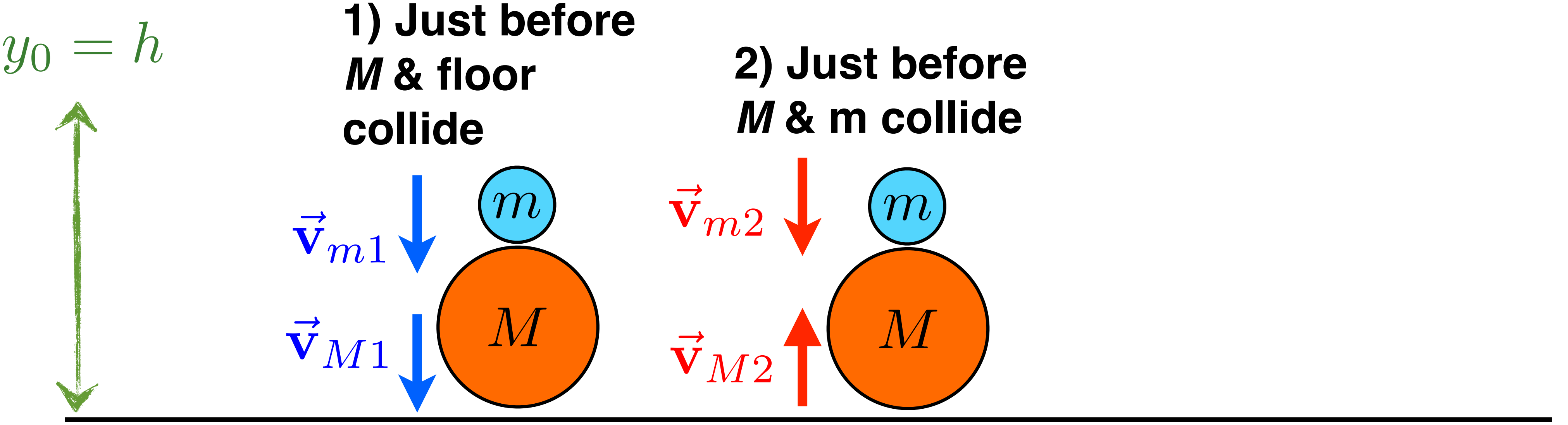
$$v_{M1} = v_{M2} \quad \text{so } \vec{\mathbf{v}}_{M2} = -\vec{\mathbf{v}}_{M1}$$

- Second ball: still just about to collide

$$\text{so } \vec{\mathbf{v}}_{m2} = \vec{\mathbf{v}}_{m1}$$

1) Just before *M* & floor collide

2) Just before *M* & m collide



$$v_{m1} = v_{M1} = \sqrt{2gh}$$

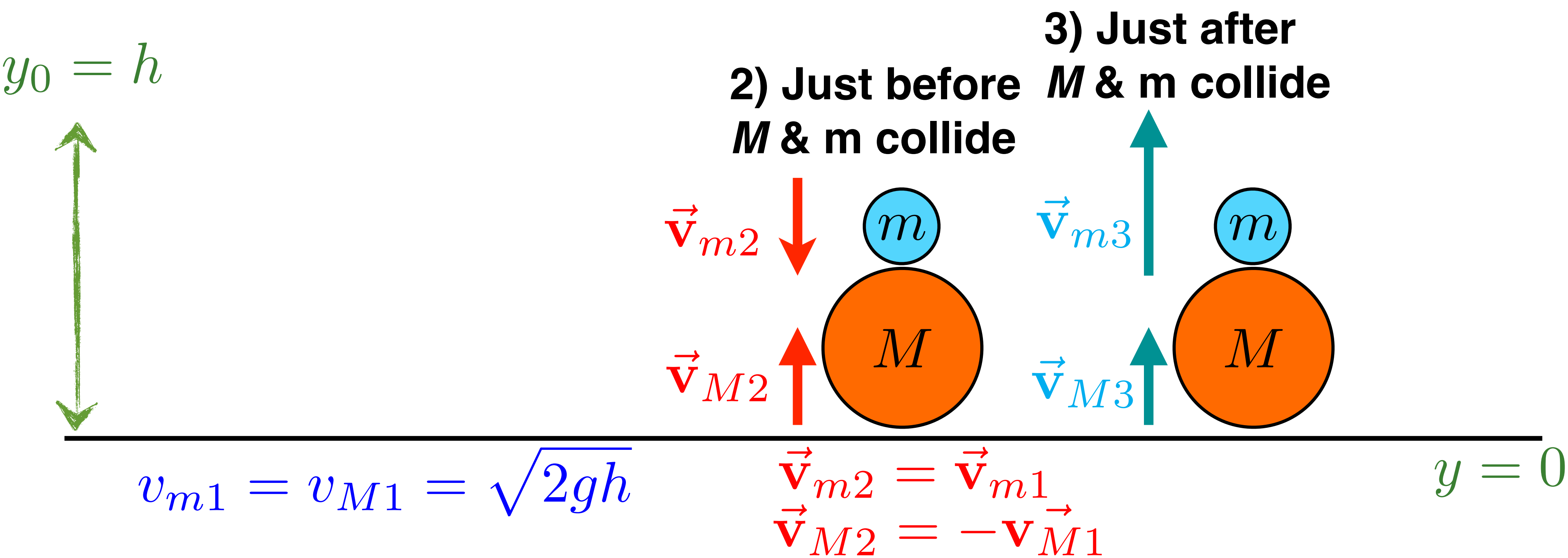
$$\vec{\mathbf{v}}_{m2} = \vec{\mathbf{v}}_{m1}$$
$$\vec{\mathbf{v}}_{M2} = -\vec{\mathbf{v}}_{M1}$$

Clicker question #80

Which principle(s) best can be used to find the following?

$\vec{\mathbf{v}}_{m3}$ $\vec{\mathbf{v}}_{M3}$

- A Cons. of momentum
- B Cons. of kinetic + pot. energy
- C Cons. of kinetic energy
- D Both A and C



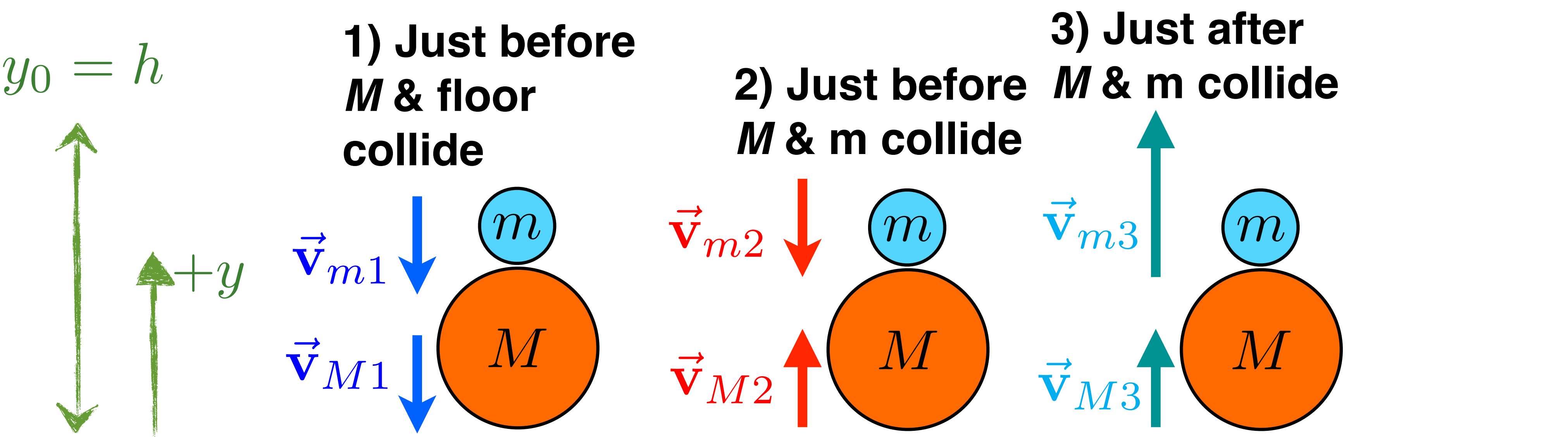
Double-ball drop

$$\vec{\mathbf{v}}_{AB} + \vec{\mathbf{v}}_{BC} = \vec{\mathbf{v}}_{AC}$$
$$\vec{\mathbf{v}}_{AB} = -\vec{\mathbf{v}}_{BA}$$

- Just like earth much heavier than *M*, *M* >> *m*.
- We know what happens if *M* were at rest…
- Trick: relative velocities!

$$\vec{\mathbf{v}}_{(m2)E} + \vec{\mathbf{v}}_{E(M2)} = \vec{\mathbf{v}}_{(m2)(M2)}$$
$$\vec{\mathbf{v}}_{(m2)E} - \vec{\mathbf{v}}_{(M2)E} = \vec{\mathbf{v}}_{(m2)(M2)}$$
$$\vec{\mathbf{v}}_{(m1)E} + \vec{\mathbf{v}}_{(M1)E} = \vec{\mathbf{v}}_{(m2)(M2)}$$

$$2\vec{\mathbf{v}}_{(m1)E} = \vec{\mathbf{v}}_{(m2)(M2)}$$
$$= -\vec{\mathbf{v}}_{(m3)(M3)}$$



$$v_{m1} = v_{M1} = \sqrt{2gh}$$

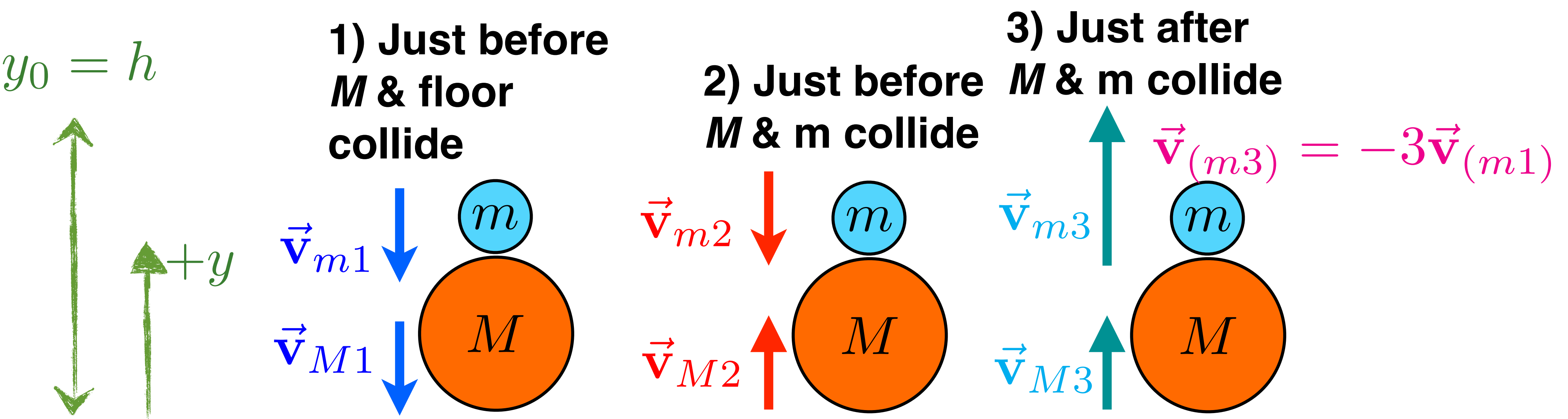
$$\vec{\mathbf{v}}_{m2} = \vec{\mathbf{v}}_{m1}$$
$$\vec{\mathbf{v}}_{M2} = -\vec{\mathbf{v}}_{M1}$$

Double-ball drop

$$\vec{\mathbf{v}}_{AB} + \vec{\mathbf{v}}_{BC} = \vec{\mathbf{v}}_{AC}$$
$$\vec{\mathbf{v}}_{AB} = -\vec{\mathbf{v}}_{BA}$$

$$\vec{\mathbf{v}}_{(m3)E} + \vec{\mathbf{v}}_{E(M3)} = \vec{\mathbf{v}}_{(m3)(M3)}$$
$$\vec{\mathbf{v}}_{(m3)E} - \vec{\mathbf{v}}_{(M3)E} = \vec{\mathbf{v}}_{(m3)(M3)}$$
$$\vec{\mathbf{v}}_{(m3)E} = \vec{\mathbf{v}}_{(m3)(M3)} + \vec{\mathbf{v}}_{(M3)E}$$
$$\vec{\mathbf{v}}_{(m3)E} = -2\vec{\mathbf{v}}_{(m1)E} - \vec{\mathbf{v}}_{(M1)E}$$
$$\vec{\mathbf{v}}_{(m3)E} = -3\vec{\mathbf{v}}_{(m1)E}$$

$$2\vec{\mathbf{v}}_{(m1)E} = \vec{\mathbf{v}}_{(m2)(M2)} = -\vec{\mathbf{v}}_{(m3)(M3)}$$



$$v_{m1} = v_{M1} = \sqrt{2gh}$$

$$\vec{\mathbf{v}}_{m2} = \vec{\mathbf{v}}_{m1}$$
$$\vec{\mathbf{v}}_{M2} = -\vec{\mathbf{v}}_{M1}$$

Clicker question #81

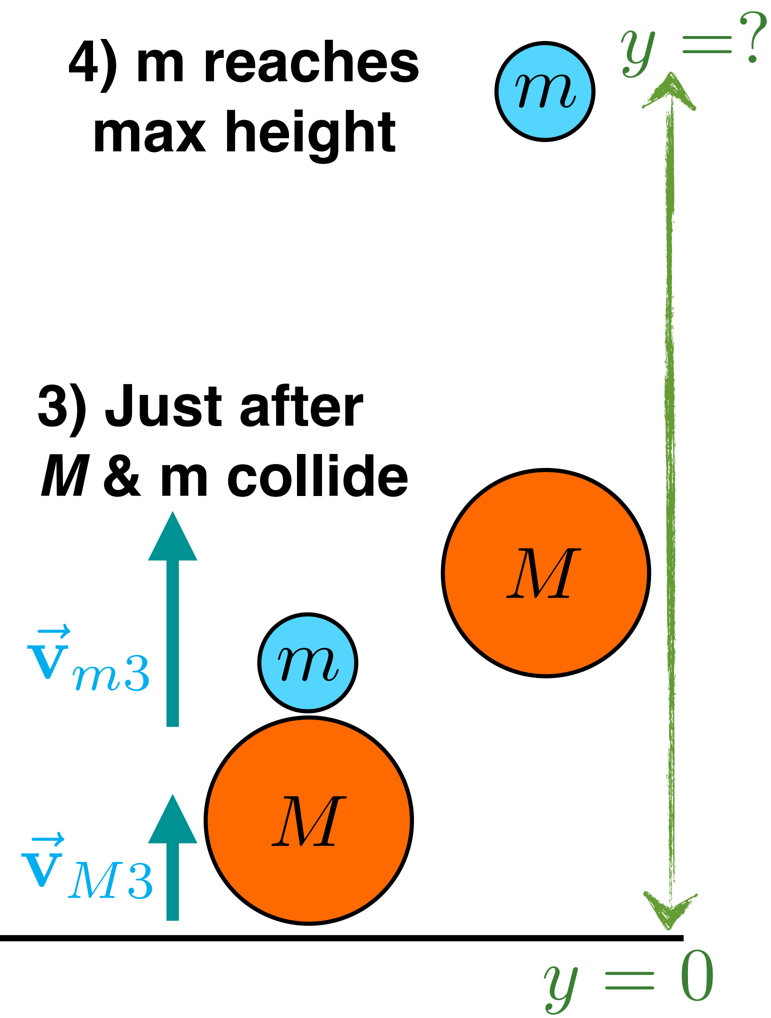
Which principle best can be used to find the following?

y

A	Conservation of momentum
B	Cons. of kinetic + pot. energy
C	Cons. of kinetic energy
D	Both A and C

$$\vec{\mathbf{v}}_{(m3)} = -3\vec{\mathbf{v}}_{(m1)}$$

$$v_{m1} = v_{M1} = \sqrt{2gh}$$

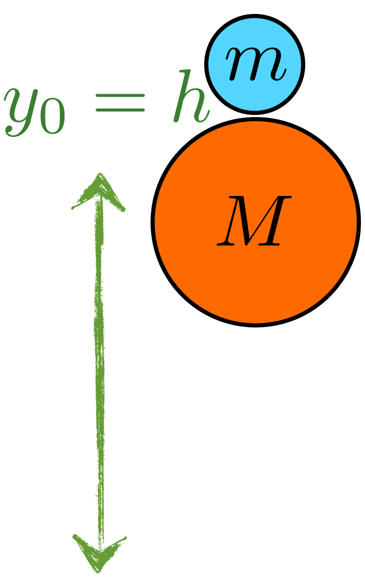


Double ball drop

$$\frac{1}{2}mv_{m3}^2 = mgy \qquad \frac{1}{2g}v_{m3}^2 = y$$

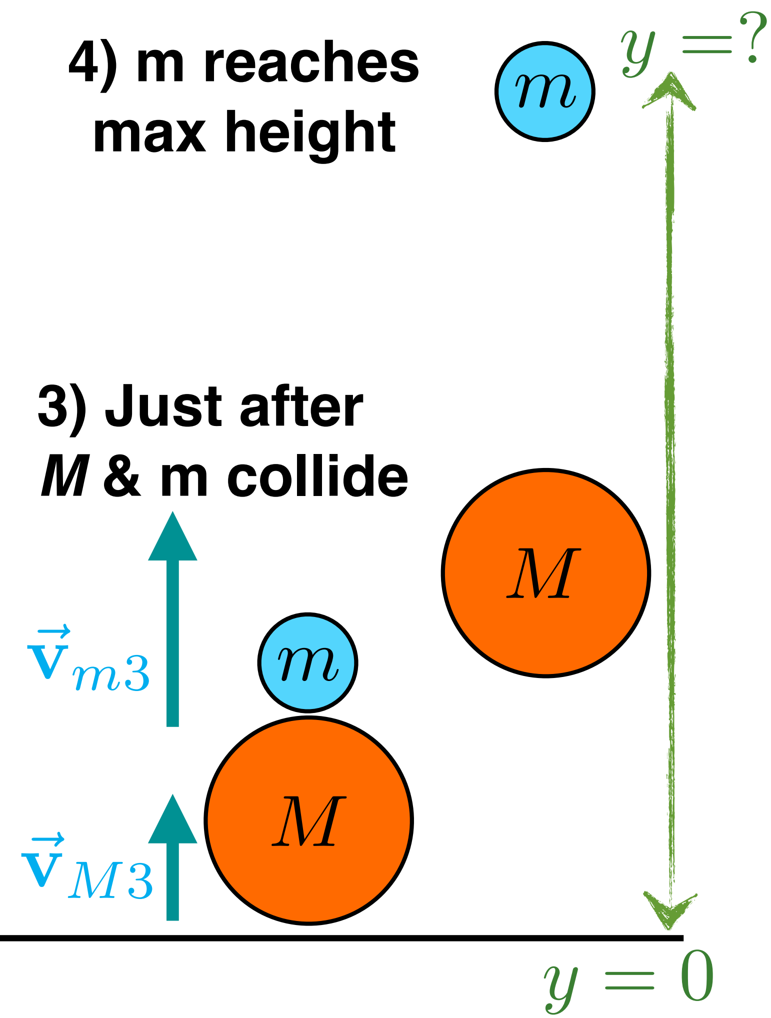
$$\frac{1}{2g}(9)(2gh) = y$$

$$y = 9h$$



$$\vec{\mathbf{v}}_{(m3)} = -3\vec{\mathbf{v}}_{(m1)}$$

$$v_{m1} = v_{M1} = \sqrt{2gh}$$



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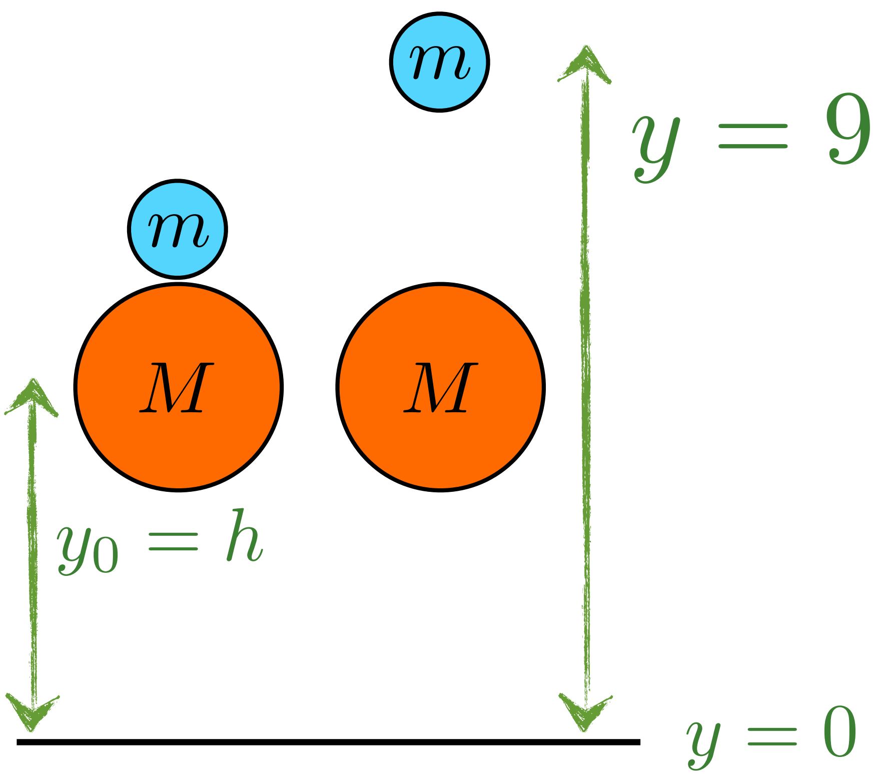
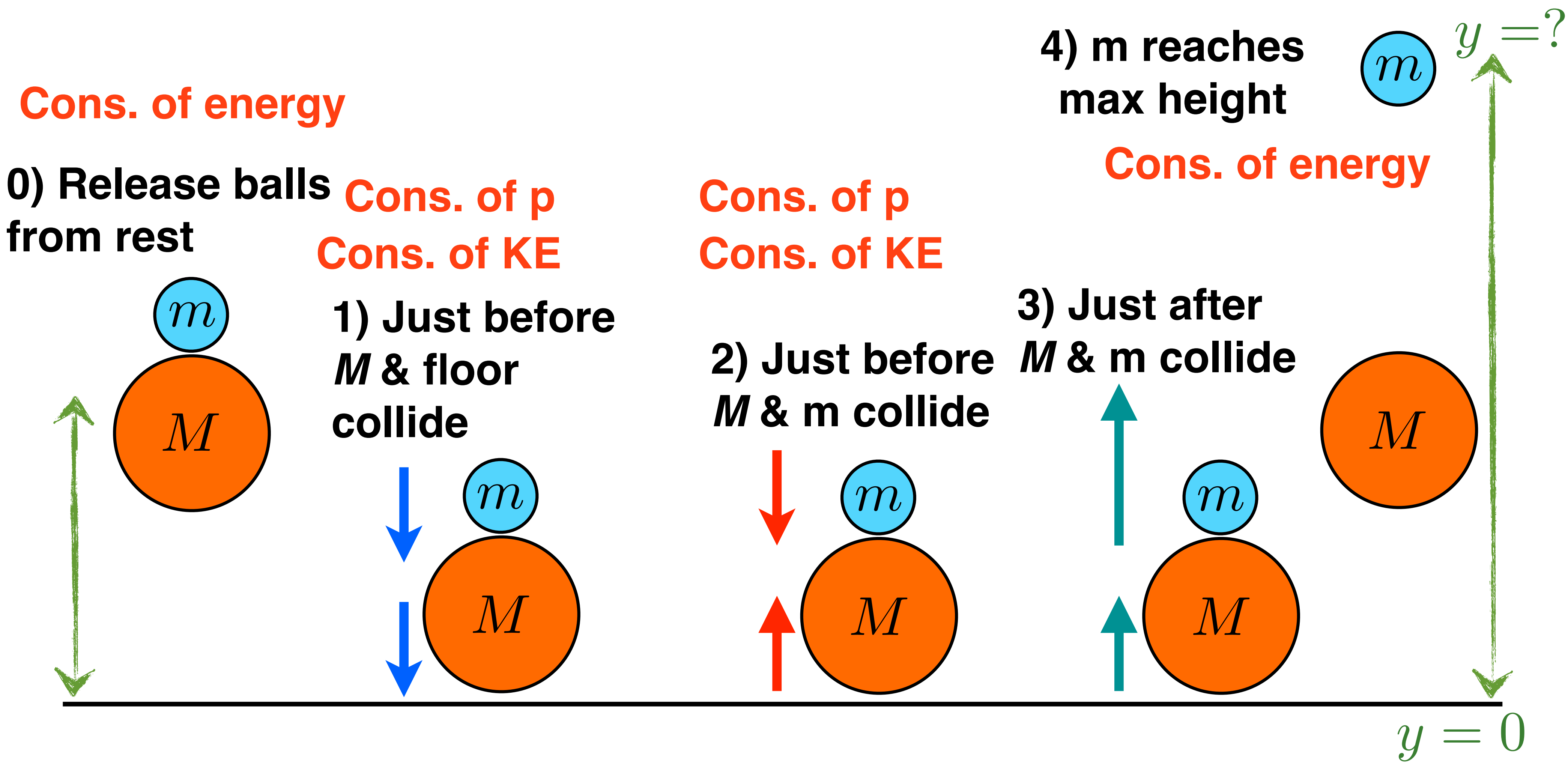


1. Read carefully
2. (Draw a sketch)
3. Given? Goal?
4. Principles & equations?
5. Calculate
6. Plug in numbers
7. Is answer reasonable?

Double-ball bounce



Class participation

- Complete worksheet: conservation of momentum