Momentum and Impulse

I. Momentum and Impulse
- concepts and definition
- relation to force

II. Conservation of Momentum
- internal and external force
- elasticity

	The student will be able to:	HW:
1	Define and calculate momentum using appropriate SI units. ✓	1
2	Define and calculate impulse and solve problems relating impulse, momentum, and force. ✓	2 – 6
3	State and apply the law of conservation of momentum with proper consideration to internal and external forces.	7 – 9
4	Use conservation of momentum to solve related problems.	10 – 19
5	Define elastic and inelastic collisions and use the definitions to solve related problems.	20 – 26

Conservation of Momentum

The total momentum of an isolated system of objects will remain constant over time.

For two objects that interact with one another:

$$\vec{p}_1 + \vec{p}_2 = \vec{p}_1' + \vec{p}_2'$$

$$\underbrace{m_1\vec{v}_1 + m_2\vec{v}_2}_{\text{total momentum } \textit{before} \text{ an interaction}} = \underbrace{m_1\vec{v}_1' + m_2\vec{v}_2'}_{\text{total momentum } \textit{after} \text{ the interaction}}$$

Conservation of Momentum

The total momentum of an isolated system of objects will remain constant over time.

The same reasoning may be extended to interactions of three or more objects…

$$\vec{p}_1 + \vec{p}_2 + \vec{p}_3 = \vec{p}_1' + \vec{p}_2' + \vec{p}_3'$$

Internal and External Forces

In order for the total momentum of a particular system to remain constant there must be **no net external force** on the system.

When an object *outside* the system interacts with an object *inside* the system this is called **external force**.

When objects within a system interact with one another this is called **internal force**. Internal forces *have no effect on the total momentum*!

Elasticity

Characterizing Collisions

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   - **elasticity**

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1	Define and calculate momentum using appropriate SI units.	✓ 1
2	Define and calculate impulse and solve problems relating impulse, momentum, and force.	2 – 6 ✓
3	State and apply the law of conservation of momentum with proper consideration to internal and external forces.	7 – 9 ✓
4	Use conservation of momentum to solve related problems.	10 – 19 ✓
5	Define elastic and inelastic collisions and use the definitions to solve related problems.	20 – 26

Variety in Collisions

- All collisions will illustrate conservation of momentum and conservation of energy.
- However, depending on the nature of the objects involved, only a certain amount of kinetic energy will remain after the collision.
- In certain situations there may be conservation of *kinetic* energy.

Elasticity

In a perfectly **elastic** collision the total kinetic energy of the system remains *constant*.

The total kinetic energy of the system will be *reduced* in an **inelastic** collision.

In a “perfectly inelastic” collision the objects stick together and the reduction in kinetic energy is maximized.

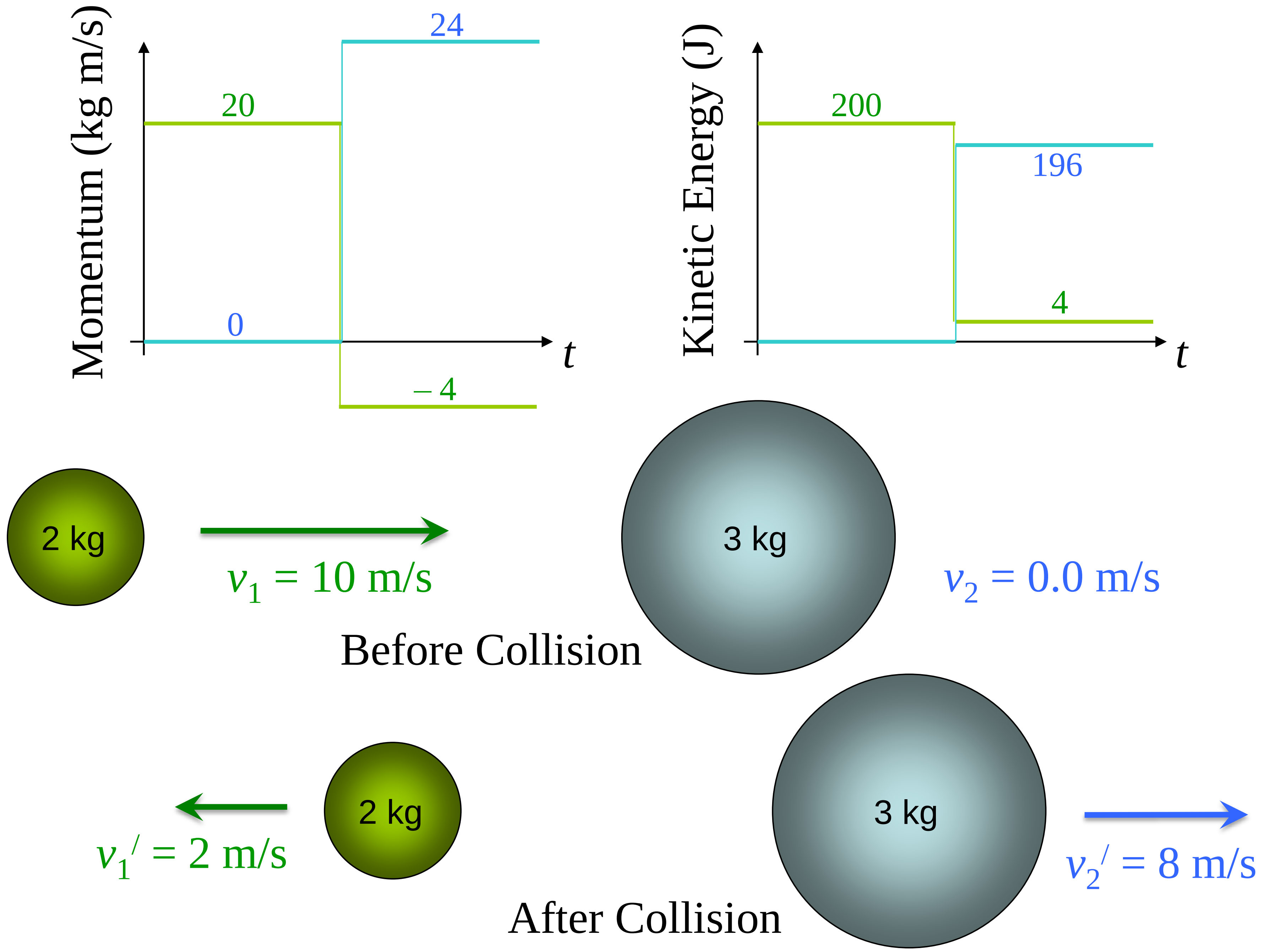
Quantifying Elasticity

For two objects in a perfectly **elastic** collision:

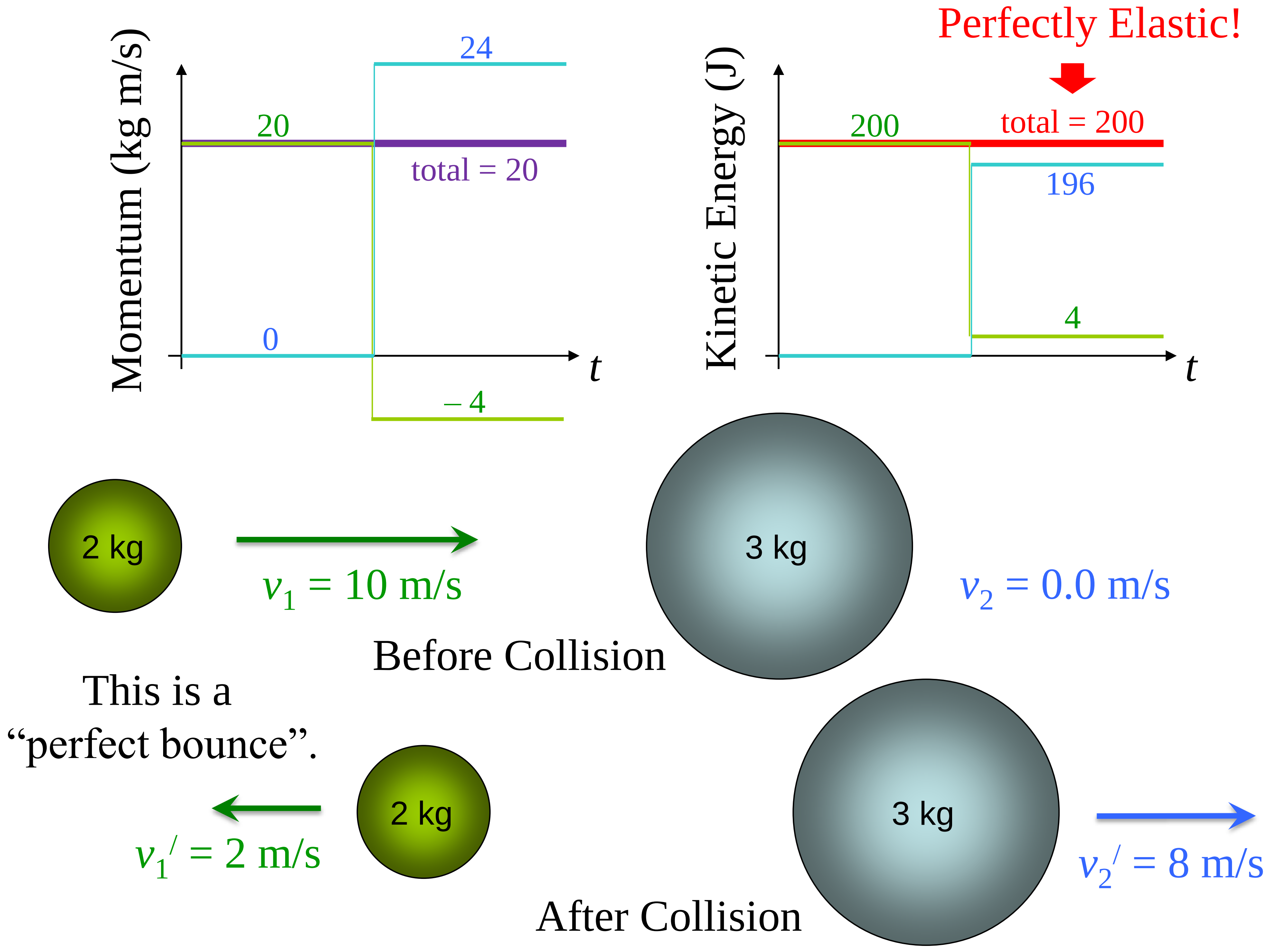
$$KE_1 + KE_2 = KE_1' + KE_2'$$

For two objects in an **inelastic** collision:

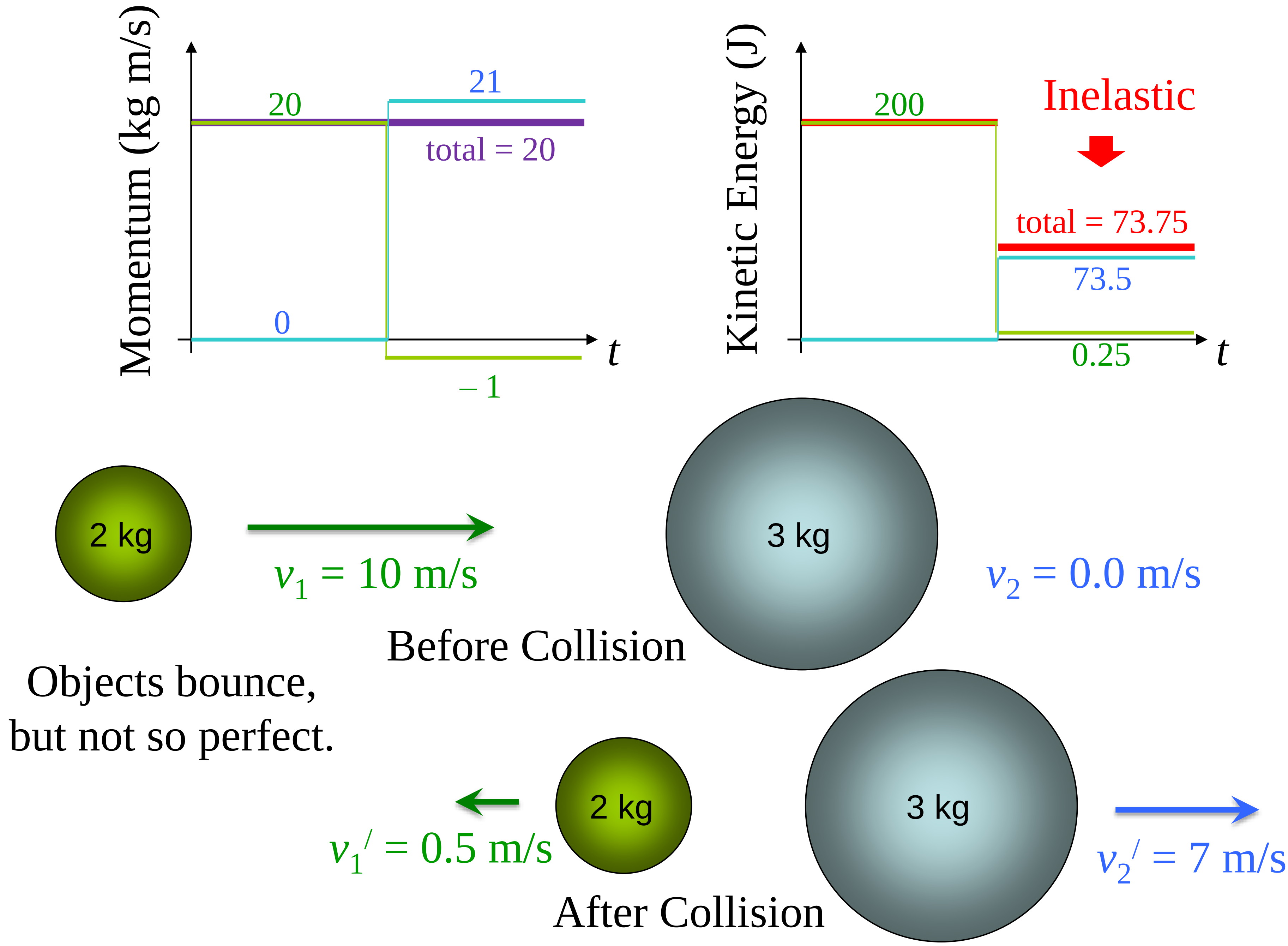
$$KE_1 + KE_2 > KE_1' + KE_2'$$



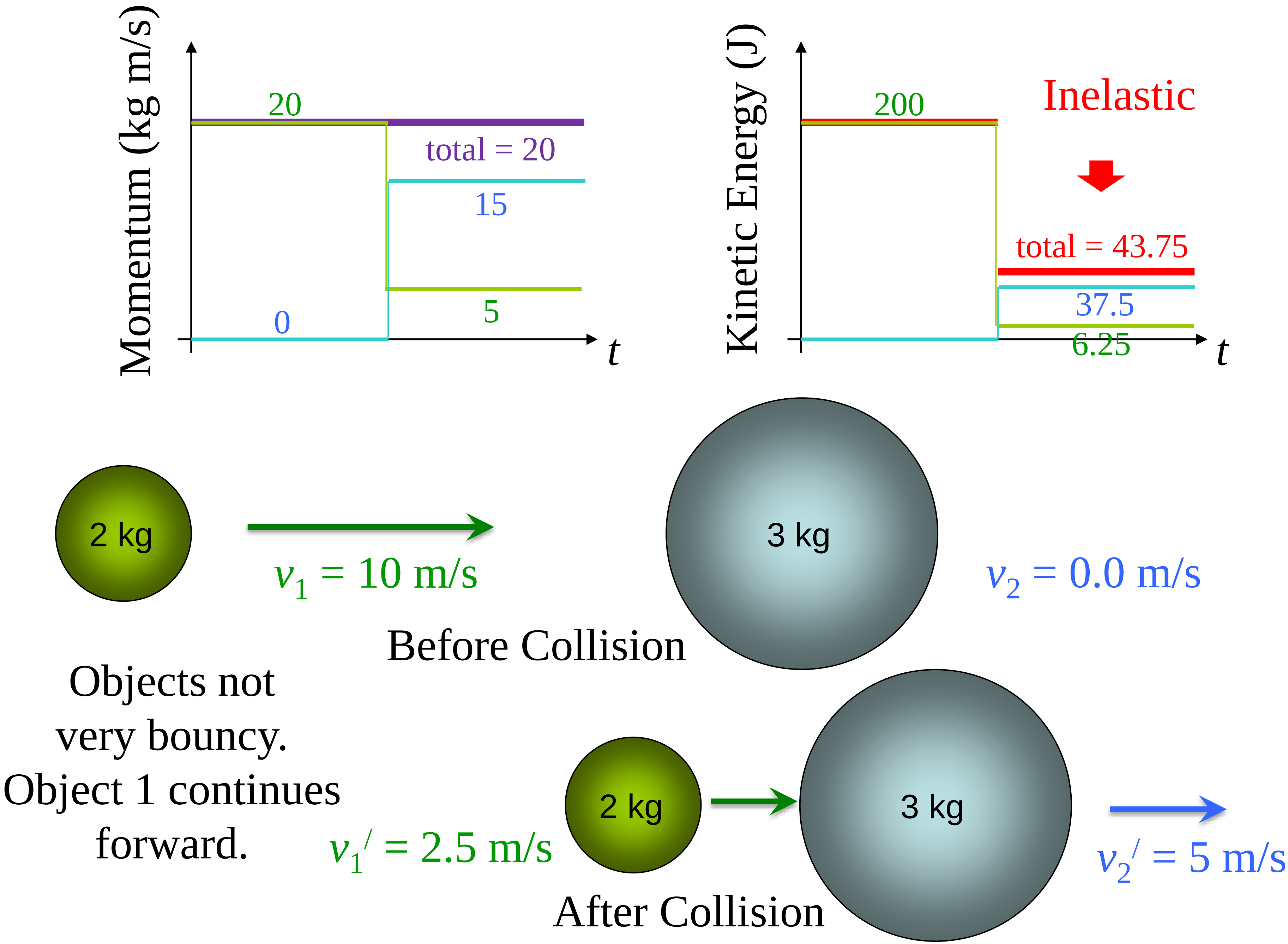
Momentum (kg m/s)
24
20
0
– 4
t
Kinetic Energy (J)
200
196
4
t
2 kg
v_1 = 10 m/s
3 kg
v_2 = 0.0 m/s
Before Collision
2 kg
v_1' = 2 m/s
3 kg
v_2' = 8 m/s
After Collision

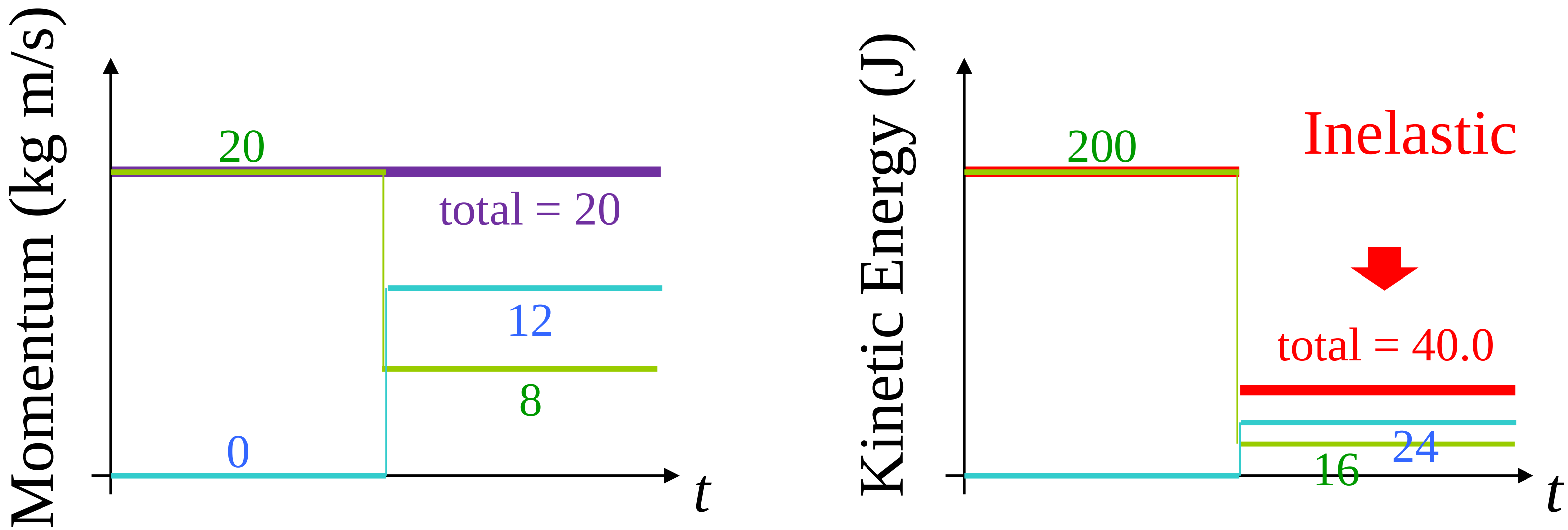


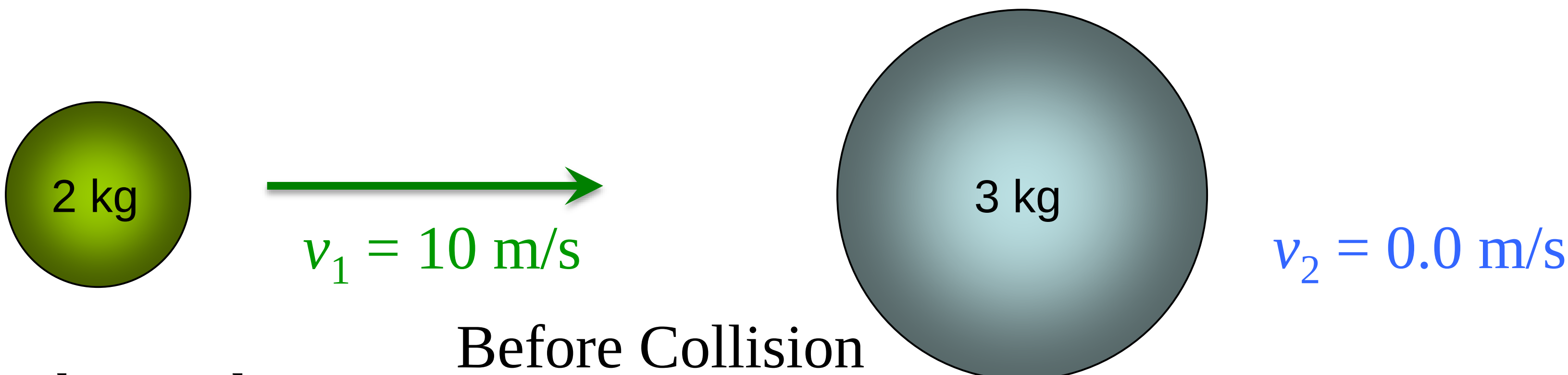
Perfectly Elastic!
Momentum (kg m/s)
24
20
total = 20
0
– 4
t
Kinetic Energy (J)
200
total = 200
196
4
t
2 kg
$v_1 = 10$ m/s
3 kg
$v_2 = 0.0$ m/s
Before Collision
This is a "perfect bounce".
2 kg
$v_1' = 2$ m/s
3 kg
$v_2' = 8$ m/s
After Collision



Momentum (kg m/s)
20
21
total = 20
0
– 1
t
Kinetic Energy (J)
200
Inelastic
total = 73.75
73.5
0.25
t
2 kg
v_1 = 10 m/s
3 kg
v_2 = 0.0 m/s
Before Collision
Objects bounce,
but not so perfect.
2 kg
v_1' = 0.5 m/s
3 kg
v_2' = 7 m/s
After Collision


Momentum (kg m/s)
20
total = 20
15
0
5
t
Kinetic Energy (J)
200
Inelastic
total = 43.75
37.5
6.25
t
2 kg
v_1 = 10 m/s
3 kg
v_2 = 0.0 m/s
Before Collision
Objects not very bouncy. Object 1 continues forward.
v_1' = 2.5 m/s
2 kg
3 kg
v_2' = 5 m/s
After Collision





Objects do not bounce at all, but rather stick together. This is said to be "perfectly inelastic".