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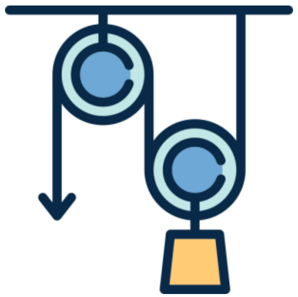


Physics

preparing students for exams

Ana Oliveira | January 2026

Integrated Masters in Medicine
Model Exam | Access for International Students | 2026/2027

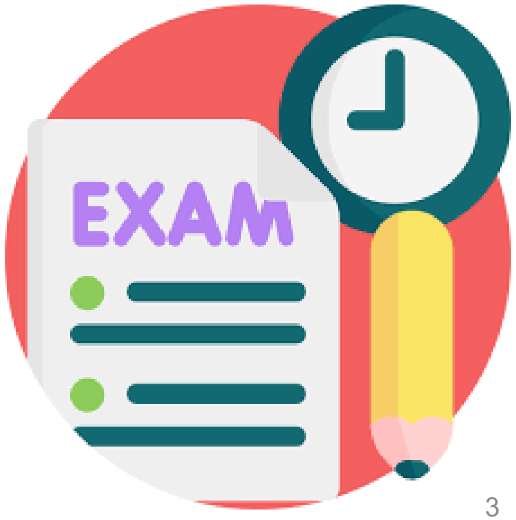
General instructions:

- The exam is evaluated from 0 to 200 points
- The exam is based on 20 questions, 15 multiple-choice and 5 essay questions
- Each multiple-choice question is marked out of 10.0 points and each essay question is also marked out of 10.0 points
- Only a blue or black pen may be used
- The use of a broker is not allowed
- All questions must be answered on the exam sheet
- The use of a scientific calculator is allowed
- The exam lasts 90 minutes

Exam structure:

Type of knowledge and skills		Quote	
Physics	Measurement and measurement units	20.0 points	200.0 points
	Waves and Electromagnetism	30.0 points	
	Optics	10.0 points	
	Sound	20.0 points	
	Energy and its conservation	60.0 points	
	Energy and movement	60.0 points	

Exam date: 04/02/2026 at 10:00 am



Model Exam resolution

Model Exam resolution

Group I

(15 multiple-choice questions)

1. A shopkeeper pours rice into a dish that hangs from a spring balance. He records the reading.

A customer buys some pasta. The shopkeeper notices that the reading on the spring balance, with just pasta in the dish, is the same as it was with just rice in the dish.

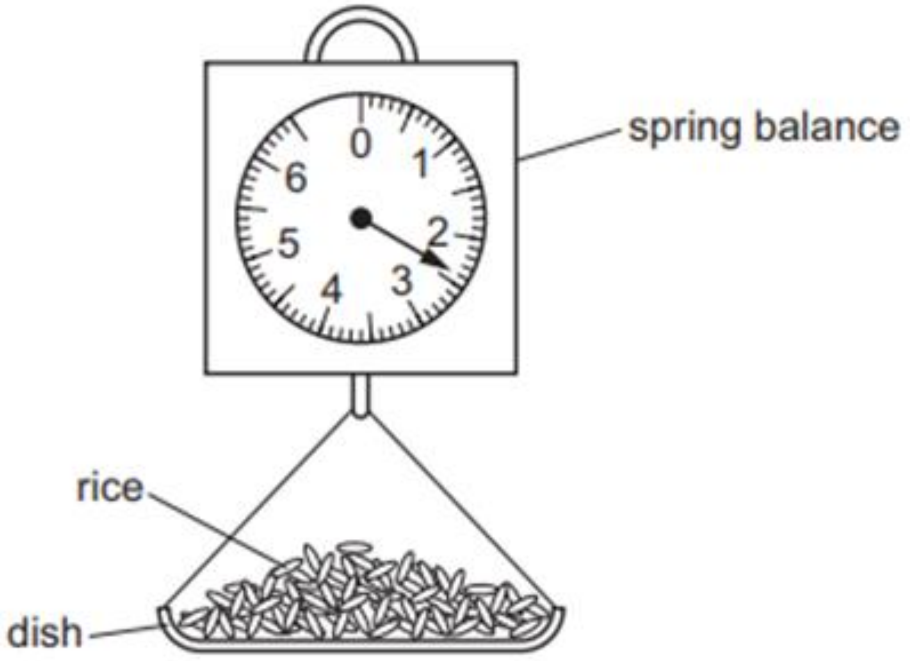
Which quantity must be the same for the rice and for the pasta?

(A) density

(B) temperature

(C) volume

(D) weight



To know

1. **Mass**: Measure with a balance
2. **Volume**:
    - Geometric formula for regular shapes, or
    - Water displacement for irregular objects
3. **Density**: Divide mass by volume

Learn more

[Measuring Density of Irregular Solids]

[Measuring Density of Regular Solids]

To know

The **International System of Units (SI)** is the modern metric system and the global standard for measurement in science, industry, and everyday life. It consists of **seven base units**:

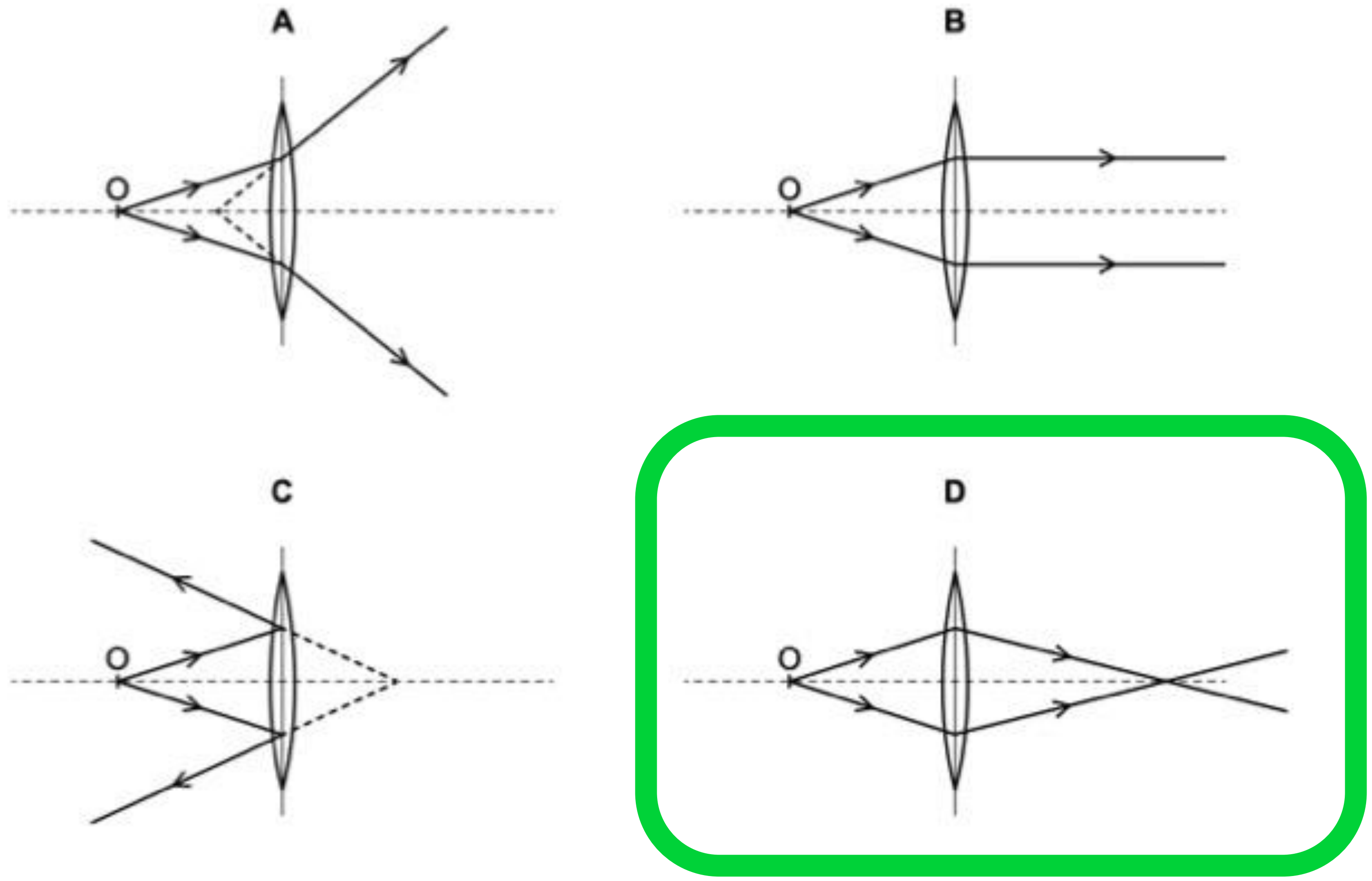
- **Second (s)** – time
- **Metre (m)** – length
- **Kilogram (kg)** – mass
- **Ampere (A)** – electric current
- **Kelvin (K)** – thermodynamic temperature
- **Mole (mol)** – amount of substance
- **Candela (cd)** – luminous intensity

Learn more

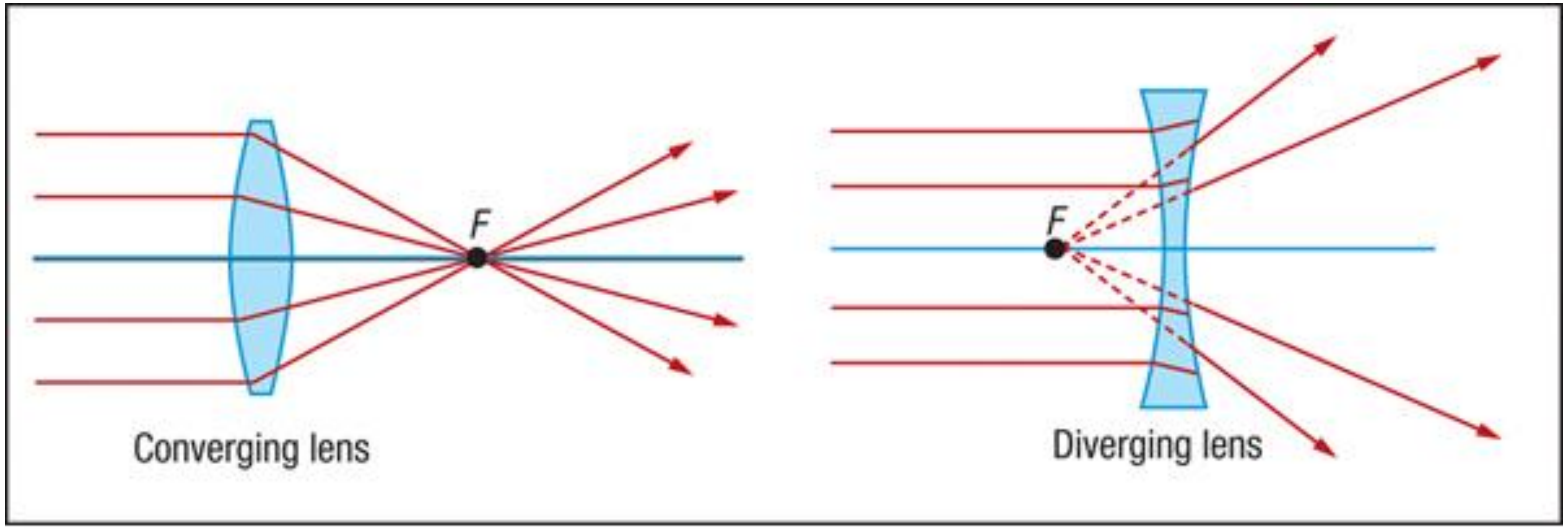
[An introduction to the SI]

[Understanding the SI Units]

2. Which diagram shows the formation of a real image of an object O placed in front of a converging lens?



To know



Learn more [Converging and Diverging Lenses](#)

To know

Speed and Refractive Index

- Light travels fastest in a **vacuum** (~3×10^8 m/s), slightly slower in **air**, and significantly slower in **water** (~2.25×10^8 m/s) because it interacts with the atoms in denser media

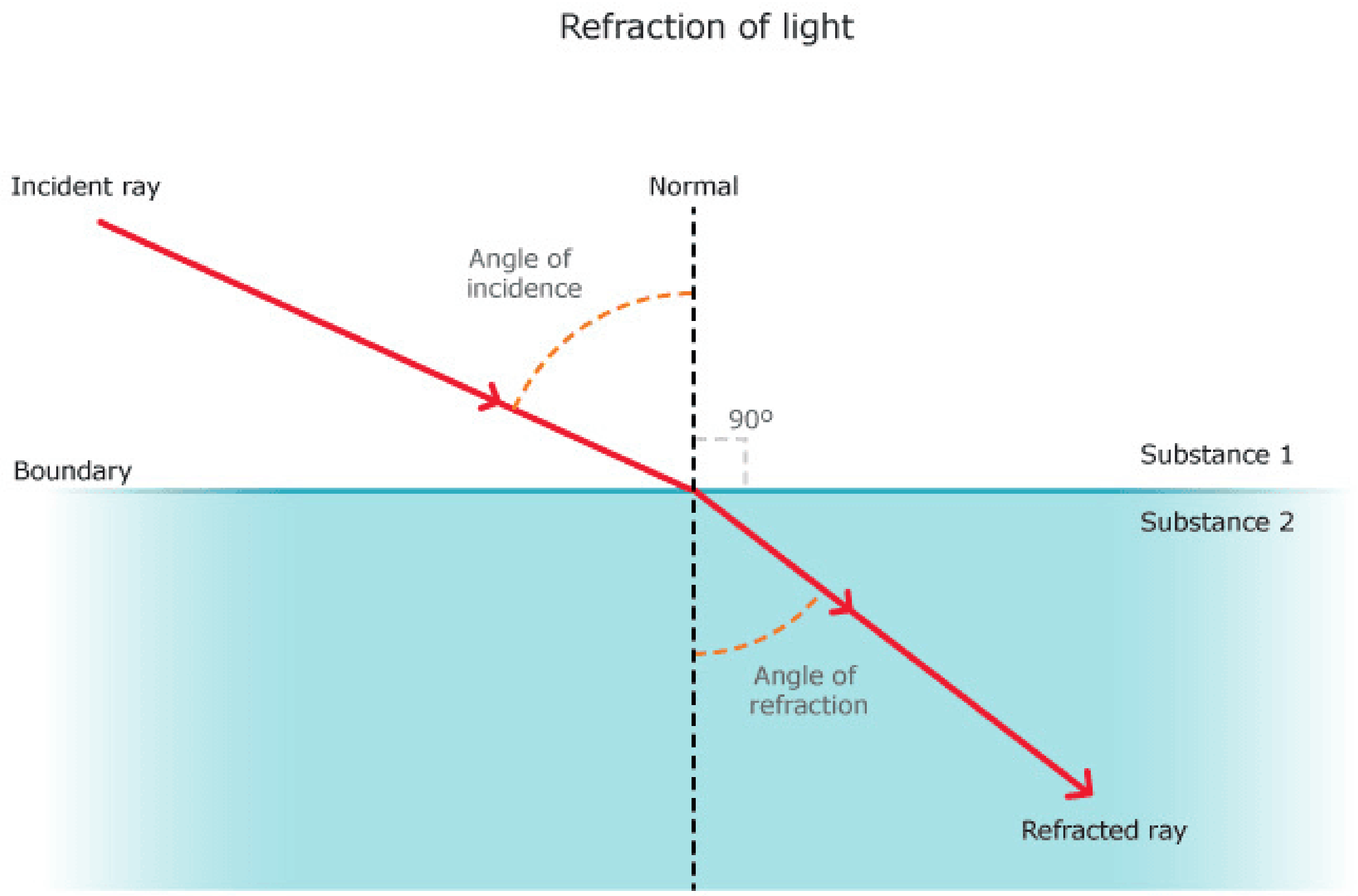
- The **refractive index** (n) reveals this relationship: $n = \frac{c}{v}$

  → Air n≈1.0003, Water n≈1.33, Glass n≈1.5

- At an interface (e.g., air → water), the change in speed makes light **bend toward the normal** (when slowing down) or **away** (when speeding up)

- This follows **Snell's Law**: $n_1 sin\theta_1 = n_2 sin\theta_2$

where θ are angles relative to the normal



Learn more

[Refraction - How does light refract when it moves from air to water?]

3. The graph represents the motion of a vehicle.

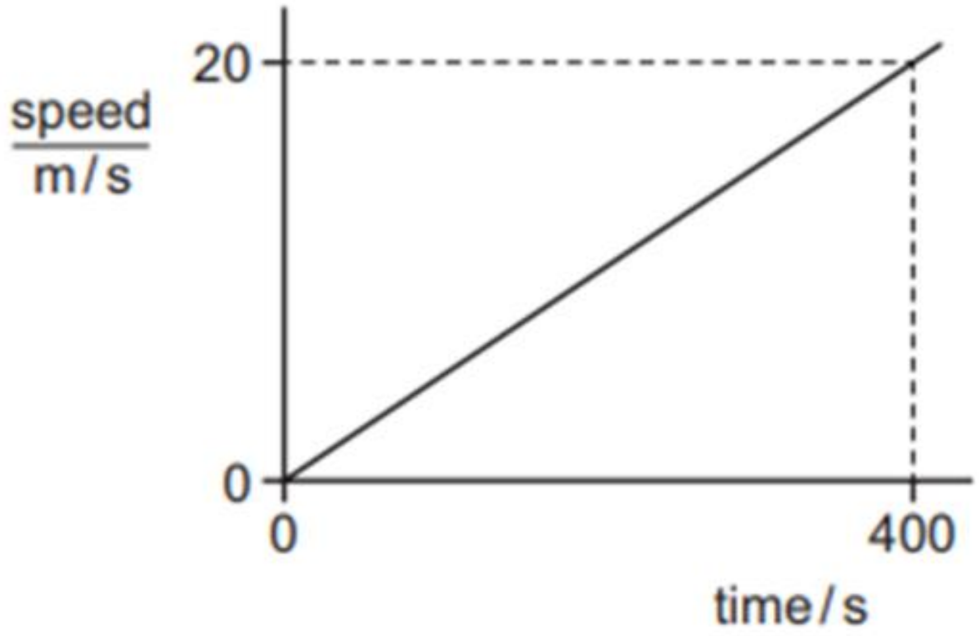
What is the distance travelled by the vehicle in 400 s?

(A) 20 m

(B) 400 m

(C) 4000 m

(D) 8000 m

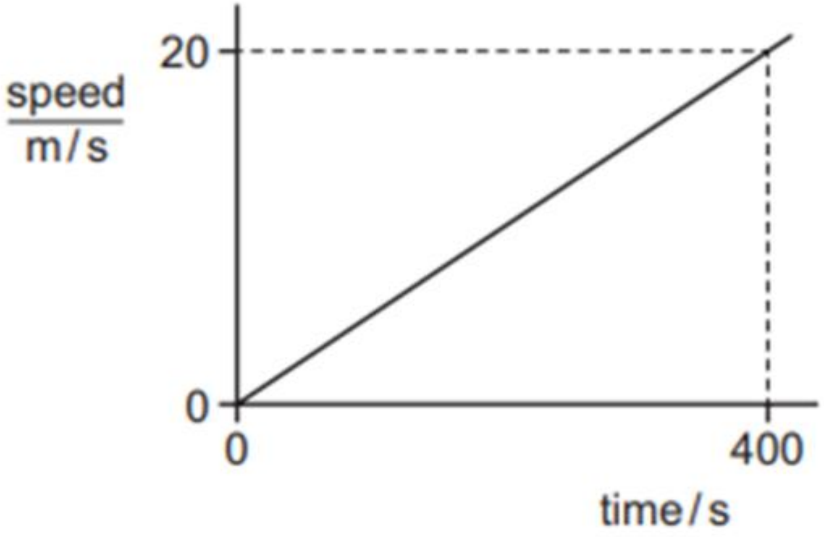


RESOLUTION:

To calculate the distance traveled by the vehicle from a speed vs. time graph, we determine the area under the curve.

In this specific graph, the shape formed between the speed line and the time axis from 0 to 400 s is a right-angled triangle.

$$d = \frac{base \times high}{2} = \frac{400 \times 20}{2} = 4000\ m$$



To know

What is Motion?

- Motion is the **change in position** or orientation of an object relative to a reference frame over time
- It can be **translational** (straight or curved path), **rotational** (spinning around an axis), or **oscillatory** (back-and-forth, like a pendulum)

Key Concepts

- **Uniform motion**: constant velocity (no net force, per Newton's 1st Law)
- **Accelerated motion**: changing velocity due to force (Newton's 2nd Law: F = m a)
- **Types of Motion**:
  - **Linear motion**: straight-line movement
  - **Rotational motion**: around an axis (e.g., wheel turning)
  - **Oscillatory motion**: to-and-fro patterns (e.g., pendulums)

Learn more

Motion and its Types

An engaging overview of motion concepts and categories

Kinematics Review

A kinematics review with real examples and formula breakdowns

To know

- **Definition**: An object moves along a circular path in a **clockwise** direction when viewed from a specific reference point

- **Key properties**:
  - **Tangential velocity** (v): always perpendicular to the radius and directed along the circular path
  - **Centripetal acceleration** ($a_c = v^2 / r$): always points toward the center of the circle, keeping the object on its curved path
  - In **uniform** circular motion (constant speed), velocity magnitude is constant but its direction constantly changes, due to centripetal force
  - In **non-uniform** circular motion, the speed also changes, so there's an additional tangential acceleration component

Learn more

Circular Motion

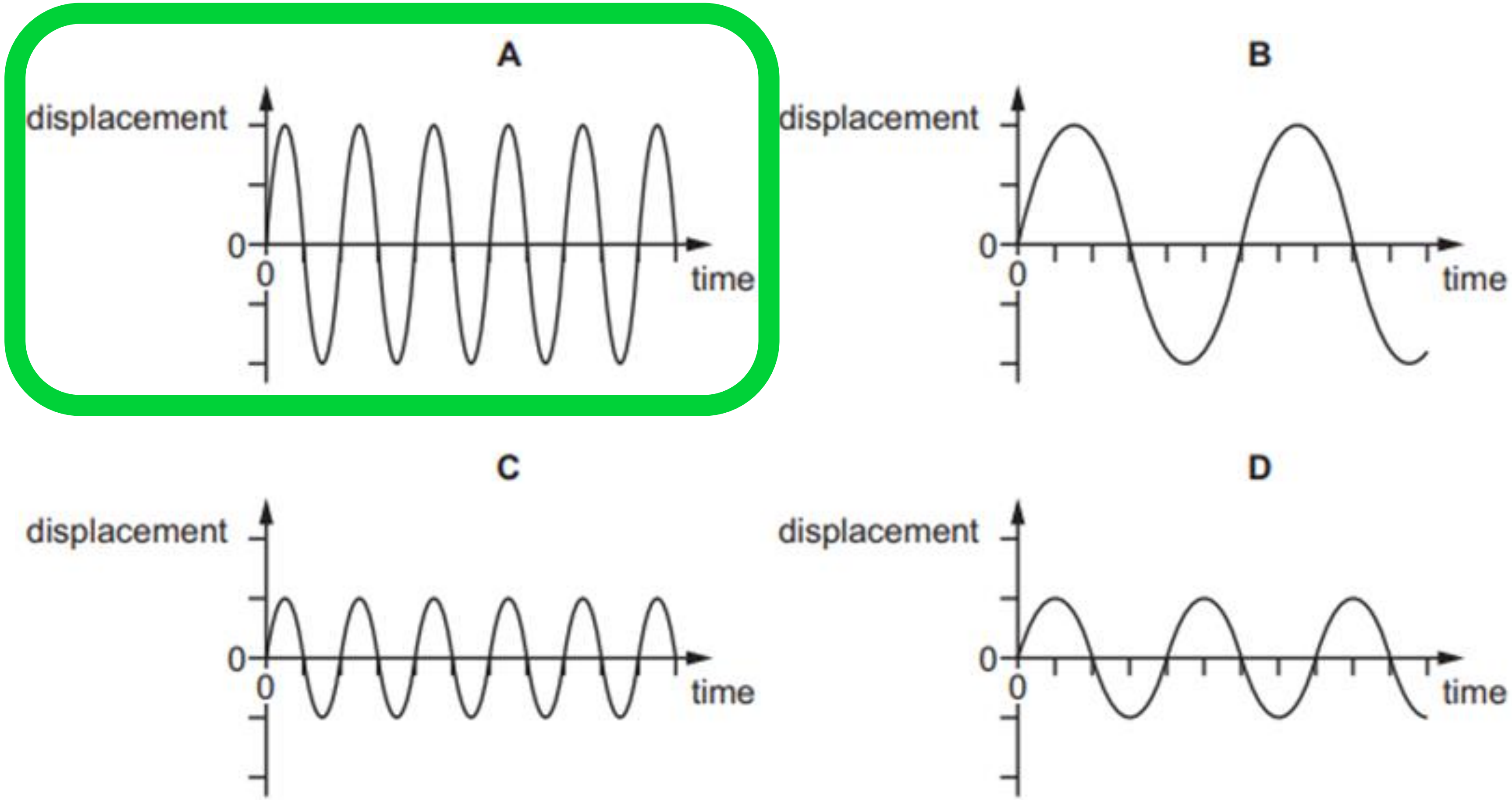
Describes velocity, centripetal acceleration, and formulas; perfect for understanding the mechanics

Uniform Circular Motion

A lively crash-course overview that demystifies centripetal vs. centrifugal forces

4. The diagrams show graphs of displacement against time for four sound waves. All the graphs are drawn to the same scale.

Which wave has the largest amplitude and the highest frequency?



Learn more

[Time and Frequency Domains Explained]

Explains the difference between time-based and frequency-based analysis with visuals

[Time Domain vs. Frequency Domain (Keysight Labs)]

Great technical video showing real signal analysis

[Understanding Sound Frequency and Period]

Clear and basic explanation of frequency, period, and waveform timing

Learn more [Relationship between wavelength and frequency]

5. A ball is at rest at the top of a hill. The ball rolls down the hill. At the bottom of the hill the ball hits a wall and stops.

Which energy changes occur?

(A) gravitational potential energy → internal energy → kinetic energy

(B) gravitational potential energy → kinetic energy → internal energy

(C) kinetic energy → gravitational potential energy → internal energy

(D) kinetic energy → internal energy → gravitational potential energy

To know

Energy Store Changes in Water Pumping

1. Work Done: A pump (electrical or mechanical) does work on the water, adding energy to raise it, this energy goes into the **gravitational potential energy** store

2. Energy Conversion:

- **Input**: Electrical or mechanical energy
- **Output**: Increased potential energy of water plus **losses** to **thermal energy** and **sound** due to inefficiencies

3. Efficiency: Not all input energy is stored in the water due to friction, turbulence, and heat; real systems recover only a part of the energy added

Learn more [Work, Energy, and Power (17 of 37) Pumping Water]

To know

Changing Energy Stores in Systems

1. System definition

A system is any object or group of objects you focus on. Energy changes only count when energy enters or leaves the system

2. Energy isn't destroyed or created

- It is **transferred** between stores (mechanical, thermal, chemical, etc.) or **transformed** from one form to another, following the **conservation of energy** principle

learn more

To know

3. Common energy stores include:

learn more

- Kinetic (motion)
- Gravitational potential (height)
- Elastic (stretched/compressed)
- Thermal (heat)
- Chemical (bonds)
- Magnetic, nuclear, electrical

4. Transfer mechanisms:

- **Mechanical work**: force over distance (e.g., lifting, pushing)
- **Heating**: thermal exchange
- **Electrical**: current moving through circuit
- **Radiation**: energy via waves (light, heat)

learn more

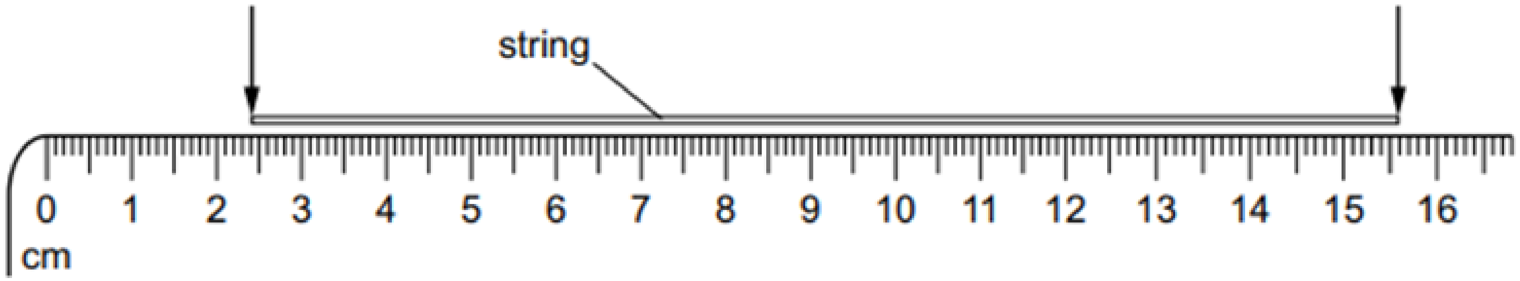
Learn more

Energy Changes in Systems

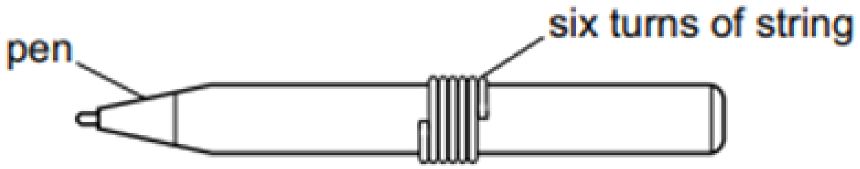
Changes in Energy Stores

Energy Stores, Transferring Energy & Work Done

6. A length of string is measured between two points on a ruler.



When the length of string is wound closely around a pen, it goes round six times.



What is the distance once round the pen?

(A) 2.2 cm

(B) 2.6 cm

(C) 13.2 cm

(D) 15.6 cm

15.5 – 2.5 = 13.0 cm

13.0 / 6 = 2.167 ~ 2.2 cm

7. A rocket is launched into space. According to Newton's Third Law, which of the following correctly explains why it rises?

(A) The rocket rises because the air below it pushes it upward.

(B) The rocket rises because its propulsive force is greater than the force of gravity.

(C) The rocket rises because it expels gases downward, and these gases exert an equal and opposite force upward.

(D) The rocket rises because the atmosphere exerts a greater pressure on the base of the rocket than on the top.

To know

Newton’s Third Law

- **Statement**: *“For every action, there is an equal and opposite reaction”*
- When two objects interact, the force exerted by object A on B is **equal in magnitude** and **opposite in direction** to the force exerted by B on A. These are called **action-reaction pairs**
- These forces act on **different bodies**, so they **do not cancel** each other out

Real-World Examples

- **Swimming**: A swimmer pushes water backward; the water pushes the swimmer forward with equal force
- **Rocket propulsion**: Exhaust gases are expelled backward, pushing the rocket forward
- **Walking**: You push back on the ground with your foot, and the ground pushes you forward

Learn more [Newton's third law]

8. The diagram shows a vertical wire carrying a current I placed between the poles of a magnet.

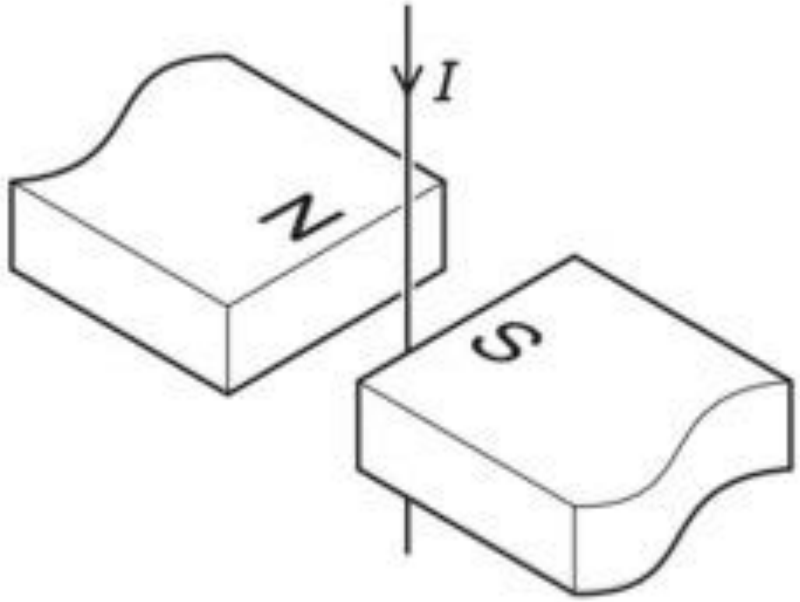
What is the direction of the force on the wire exerted by the magnetic field?

(A) from N to S

(B) from S to N

(C) horizontal and at right angles to the direction from N to S

(D) parallel to the wire



To know

Polarity of Magnetic Field

- Magnets have two poles: north and south. Field lines emerge from the north pole, loop through space, and return to the south pole

- Unlike electric charges, you cannot isolate a single magnetic pole – cutting a magnet always gives two smaller dipoles, each with a north and south pole

To know

Magnetic Force on a Moving Charge (Lorentz Force)

A charged particle (of charge qqq) moving with velocity $\vec{v}$ in a magnetic field $\vec{B}$ experiences a force:

$$\vec{F} = q \cdot \vec{v} \cdot \vec{B}$$

The force's magnitude is F = q v B sinθ, where θ is the angle between the velocity and the field – it's **maximal** when perpendicular and **zero** when parallel

It's always **perpendicular** to both the motion and the field, causing circular or spiral trajectories

To know

Determining the Force Direction: Right-Hand Rule

Use your right hand:

- Point your index finger in the **direction of velocity** ($\vec{v}$)
- Middle finger in the **direction of the magnetic field** ($\vec{B}$)
- Thumb points in the **direction of the force** ($\vec{F}$) for **positive** charges; flip for negatives

Learn more

[Magnetic Force and Right Hand Rule]
A clear demonstration of how a magnetic field exerts force on moving charges with practical visuals

To know

Force on a Current-Carrying Conductor

• When a current flows through a wire in a magnetic field, each charge segment experiences the same type of force

• You can use **Fleming's left-hand rule** to find the direction:

- First finger = Field
- Second finger = Current (conventional)
- Thumb = Force (motion)

Learn more

[Fleming's Left Hand Rule | Magnetism | Physics]
A focused explanation of the rule used for current-bearing conductors in motors

9. In air, sound is a wave

(A) electromagnetic and transverse.

(B) electromagnetic and longitudinal.

(C) mechanical and transverse.

(D) mechanical and longitudinal.

To know

Velocity (v) of sound is defined as how far sound travels per unit time: v = d / t

Measuring Distance with Sound

- Techniques like **echo-ranging** use time delays of reflected sound to compute distance: d = (v . t / 2) (the wave travels to the object and back)
- This principle is used in sonar, bats' echolocation, and ultrasonic sensors

Propagation & Intensity with Distance

- Although **speed** stays constant in a medium (for given conditions), **intensity** decreases with distance, following the **inverse-square law**: intensity -$1/r^2$
- The **sound pressure** and particle velocity decrease approximately -1/r, while energy spreads out -$1/r^2$

Learn more

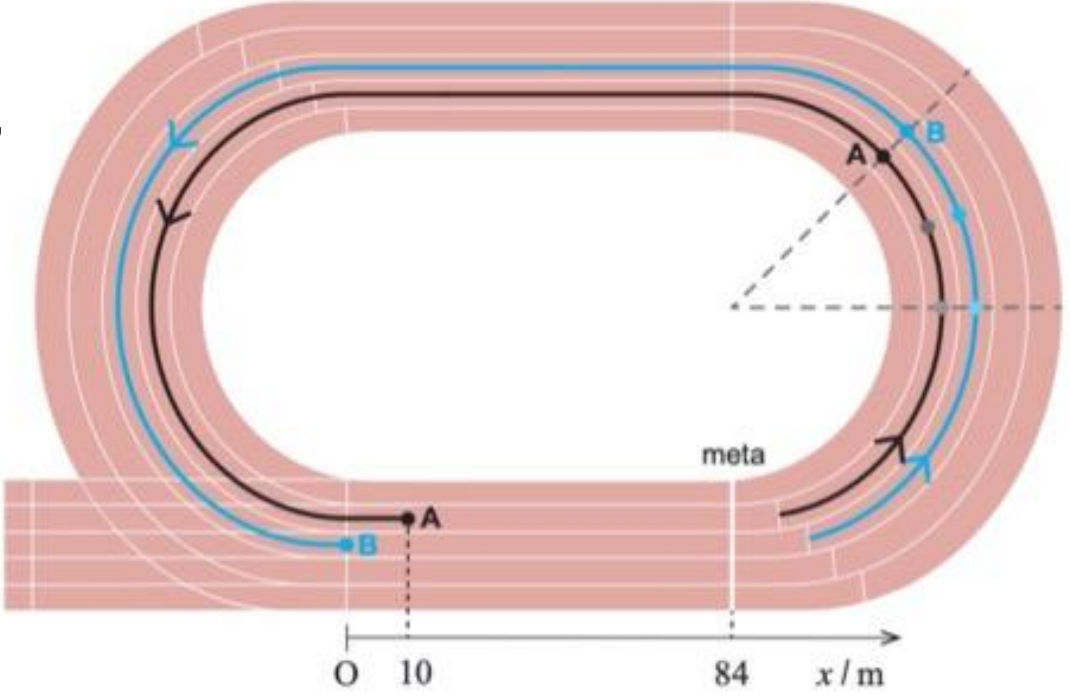
[Measuring speed of sound using distance & time]

Shows a simple experiment tracking time-of-flight to find distance

[Echo ranging and echolocation basics]

Explains how bats and sonar systems calculate distance using sound echoes

10. Consider the curved section of the track highlighted on the right side of the figure, in which the athletes stand side by side, describing circular arcs of different radii with uniform circular motion.



10.1. In this excerpt, the intensity of the resultant of the forces acting on each of the athletes is

(A) zero, and the speed modules of both are equal.

(B) zero, and the angular speed modules of both are equal.

(C) nonzero, and the speed modules of both are equal.

(D) nonzero, and the angular speed modules of both are equal.

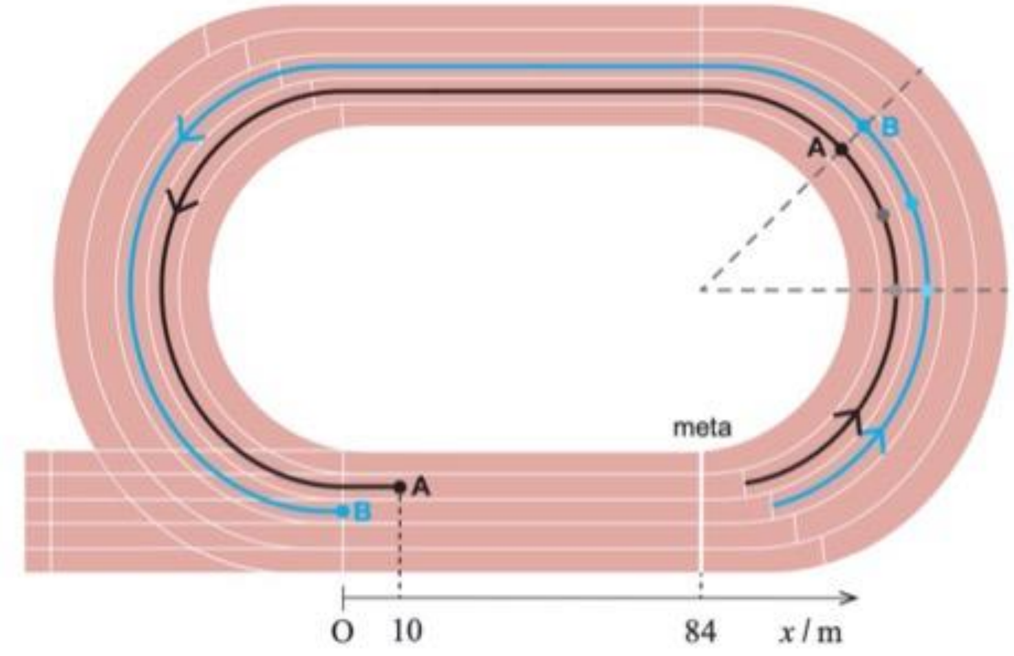
10.2. When athlete B enters the finish line, 84 m away, athlete A is 10 m ahead of him, as shown in the figure. Consider that, at this instant, the speed modules of both athletes are 6.5 m s^{-1} and that, until reaching the finish line, athlete A maintains a rectilinear and uniform motion, while athlete B moves in a rectilinear direction with a constant acceleration of module 0.10 m s^{-2}. Considering the reference frame Ox represented in the figure, the equations of motion of the two athletes are:

(A) $x_A = 10 + 6.5t$ and $x_B = 6.5t + \frac{1}{2} \times 0.10t^2$

(B) $x_A = 6.5t + \frac{1}{2} \times 0.10t^2$ and $x_B = 10 + 6.5t$

(C) $x_A = 10 + 0.10t$ and $x_B = 6.5t + \frac{1}{2} \times 10t^2$

(D) $x_A = 0.10 + \frac{1}{2} \times 6.5t^2$ and $x_B = 6.5 + 10t$



To know

Vertical motion refers to how an object's position changes in the up and down direction, for instance, a ball thrown upward or dropped downward

In ideal cases (neglecting air resistance), such motion is **constant acceleration motion** due to gravity

Key Concepts

1. **Initial velocity (v_i)**: Upward if thrown up; zero if dropped
2. **Acceleration ($a = -9.8\ m/s^2$)**: Downward, constant near Earth's surface
3. **Velocity changes over time**:
   - **Upward → slows down**, stops at peak
   - **Downward → speeds up** until impact
4. **Free fall**: Any object under only gravity follows the same vertical acceleration

To know

Direction Conventions and Gravity

- Typically, **upward** is considered **positive**, while **downward** is **negative**, making acceleration a = –9.8 m/s²
- This leads to kinematic equations such as:

$$v_f = v_i + at$$

$$y = y_i + v_i t + \frac{1}{2}at^2$$

$$v_f^2 = v_i^2 + 2a\Delta y$$

These apply to objects thrown up or dropped down

Learn more

Vertical Motion

A concise overview of vertical movement (motion in the up–down direction), mainly influenced by gravity

Vertical Motion – Calculus

A worked example using calculus for deeper insight

Projectile Motion Overview (with vertical component)

Breaks down vertical aspects as part of projectile motion

11. A circular loop near a fixed magnet rotates in the same horizontal plane, around a vertical axis, z, which passes through the center of the loop, C, as shown in the figure.

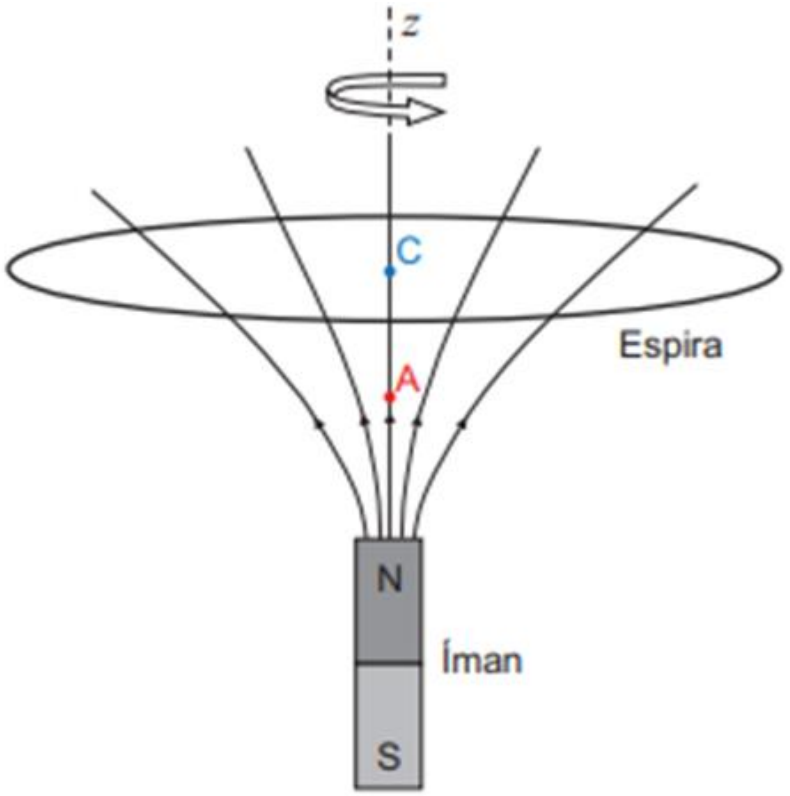
11.1. In the situation described, the magnetic flux through the flat surface bounded by the loop _____, and the electromotive force induced in the loop _____ zero.

(A) varies ... is

(B) varies ... is not

(C) does not vary ... is

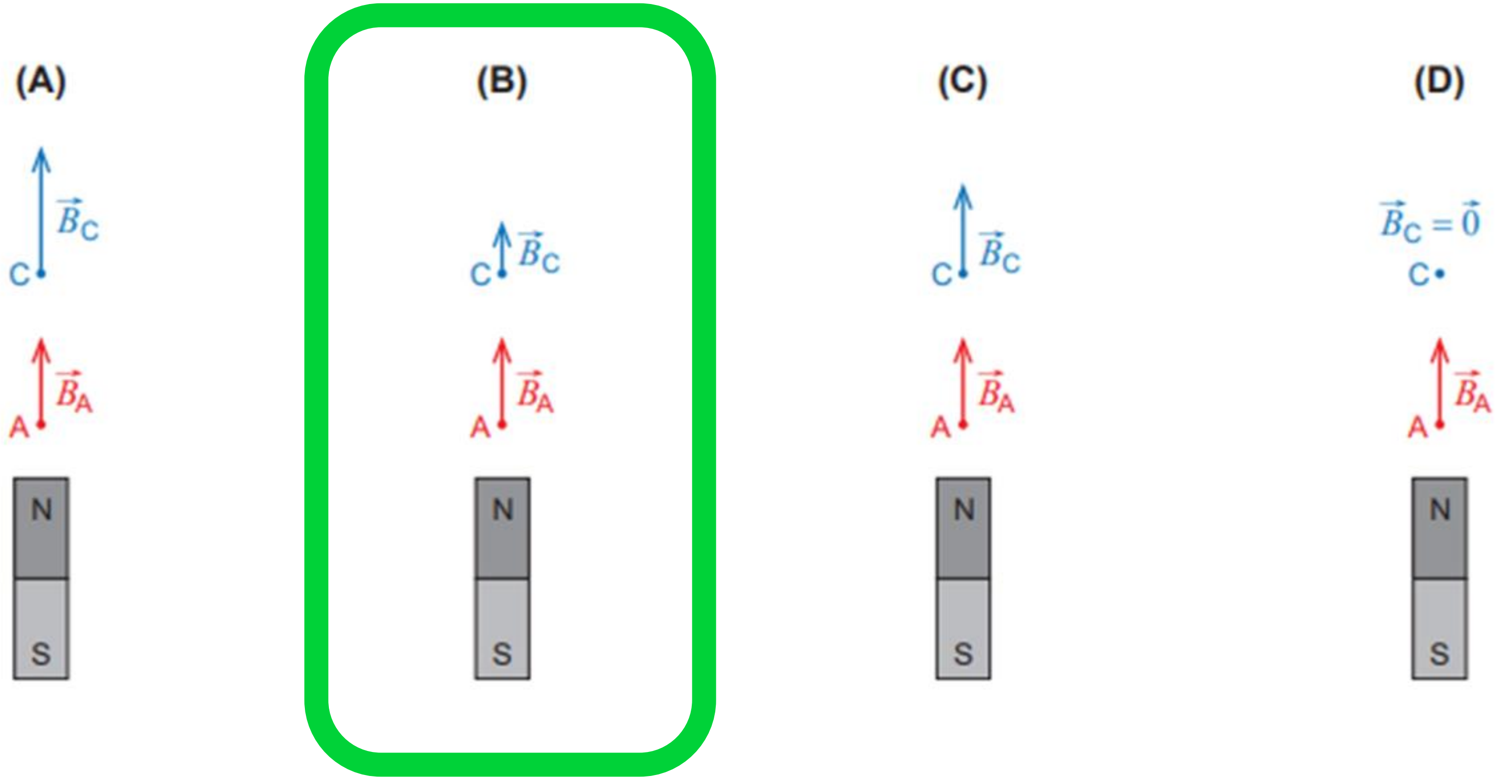
(D) does not vary ... is not



11.2. Points A and C belong to the same magnetic field line.

The following figures represent the magnetic field created by the magnet at point A, $\overrightarrow{B_A}$.

In which of the figures can the magnetic field created by the magnet at point C, $\overrightarrow{B_C}$, be represented?



To know

The magnitude of the induced electromotive force (EMF) is directly proportional to the rate of change of the magnetic flux through a circuit. This relationship is expressed by Faraday's Law:

$$|\varepsilon| = N \cdot \left|\frac{\Delta\Phi_B}{\Delta t}\right|$$

Where:

- N = number of turns in the coil
- $\Delta\Phi_B$ = change in magnetic flux ($\Phi_B = B \cdot A \cdot \cos\theta$)
- Δt = time interval

Thus:

- More coil turns → higher EMF
- Faster flux change → stronger EMF
- Larger area or magnetic field → more flux change

Learn more

Faraday's Law

A clear, step-by-step review of Faraday's Law, including factors affecting EMF magnitude

Faraday's Law - Induced EMF

Explains the full equation, with emphasis on the magnitude (without the negative sign)

12. A rock of weight 50 N falls a vertical distance of 7.0 m from rest.

What is the change in the gravitational potential energy store of the rock?

(A) decrease of 7.1 J

(B) decrease of 350 J

(C) increase of 7.1 J

(D) increase of 350 J

RESOLUTION:

The change in gravitational potential energy (ΔE_p) is calculated using the following formula:

$$\Delta E_p = m \cdot g \cdot h$$

In physics, Weight is the product of mass and gravity ($W = m \cdot g$). Therefore, the formula can be simplified to:

$$\Delta E_p = \text{Weight} \times \text{Vertical distance}$$

ΔE_p = Weight x Vertical distance = 50 x 7.0 = 350 J

The change in the gravitational potential energy store of the rock is 350 J. Since the rock is falling, this store is decreasing by 350 J as it is converted into kinetic energy.

13. Copper is a type of metal. A block of copper has a mass of 2.0 kg. The block of copper absorbs 12000 J of thermal energy. The specific heat capacity of copper is 385 J / (kg°C).

What is the temperature rise of the copper?

(A) 15.6°C

(B) 31.2°C

(C) 46.8°C

(D) 62.4°C

$$Q = m \cdot C \cdot \Delta T$$

$$12000 = 2.0 \times 385 \times \Delta T$$

$$\Delta T = 15.58 \approx 15.6^{\circ}C$$

To know

First Law of Thermodynamics

The internal energy change of the system, **ΔU**, equals the heat added **Q** plus the work done on the system **W**:

$$\Delta \mathrm{U} = Q + W$$

- Heat **absorbed** (e.g. radiation) → **Q > 0**
- Work **done by the system during expansion** → **W < 0** (it loses some internal energy performing work)

To know

What Happens in This Scenario?

1. Radiation absorbed raises the system's energy → increases ΔU
2. Expansion (e.g., gas pushing outward) does $P\Delta V$ work on the surroundings, so subtracts from ΔU
3. If absorbed heat exceeds expansion work, temperature rises, meaning internal energy increases, since internal energy links to temperature

In short:

- **System absorbs energy** via radiation → adds to internal energy
- **Does work** pushing out → subtracts from internal energy
- **Net change** → $\Delta U = Q_{rad} - W_{expansion}$
- If $Q_{rad} > W$, **ΔU positive** → system internal energy and temperature **increase**

To know

As the system **absorbs radiation**, Q increases → internal energy → **ΔU rises**

During **expansion**, the system expends energy doing work → subtracts from ΔU

The net result depends on which effect is dominant, if heat input is stronger, the internal energy goes up, causing heating

Learn more

First Law of Thermodynamics
Covers the first law, internal energy, work, and heat in a clear, example-rich format

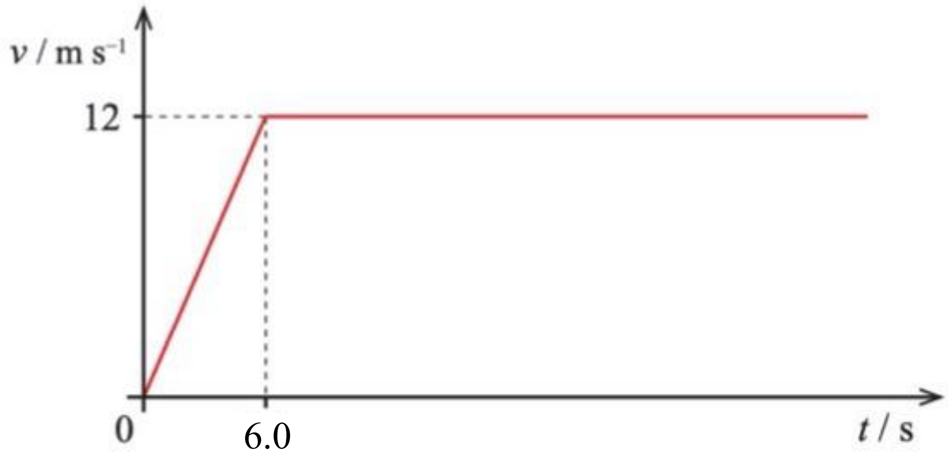
Internal Energy of a System
Demonstrates how expansion work and heat absorption influence internal energy

Model Exam resolution

Group II

(5 essay questions)

14. A car with a mass of 1000 kg is stopped near a traffic light. At the moment the car starts moving, it is overtaken by a motorcycle with a mass of 150 kg, which is moving in the same direction and sense, at a constant speed of 10 m s^{-1}, which it maintains throughout the entire route under analysis. Consider that the trajectory described by both vehicles is rectilinear and horizontal and that they can be represented by their center of mass, according to the material particle model. The figure below shows the graph of the car's speed as a function of time.



14.1. Suppose that, in the first 6.0 s of movement, the car transformed 90% of the energy supplied to it into translational kinetic energy, dissipating the rest. Determine the energy supplied to the car in this time interval. Present all calculations performed.

RESOLUTION:

14.1.

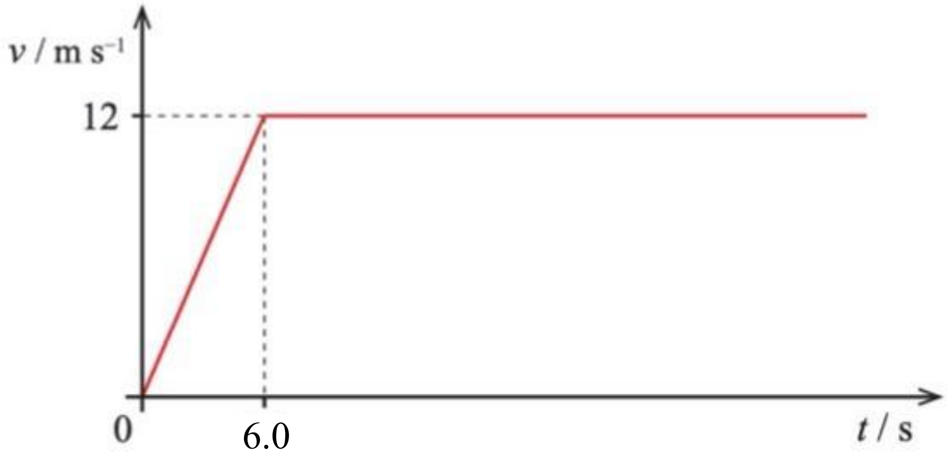
The kinetic energy of the car at the 6.0 s mark is calculated using the following formula:

$$E_k = \frac{1}{2} \cdot m \cdot v^2 \Leftrightarrow E_k = \frac{1}{2} \times 1000 \times 12^2 \Leftrightarrow E_k = 7.20 \times 10^4\ J$$

90% of the energy supplied was transformed into kinetic energy (E_k), while the remaining 10% was dissipated. Therefore, E_k represents the "useful energy”. The relationship between useful energy and total energy is:

$$E_k = E_{total} \cdot \eta \Leftrightarrow E_{total} = \frac{7.2 \times 10^4}{0.90} = 8.00 \times 10^4\ J$$

14.2. Determine the distance traveled by the two vehicles before they met again. Present all calculations performed.



RESOLUTION:

$$\Delta x = d = \frac{base \times high}{2} = \frac{6 \times 12}{2} = 36\ m$$

i) Calculate the Meeting Point (t > 6.0 s)

Let t be the total time from the start. The motorcycle's position: Δx_m = 10t.The car's position (Initial 36 m + distance traveled at 12 m s^{-1}} after 6.0 s): $\Delta x_c = 36 + 12 \cdot (t - 6.0)$

ii) Set the displacements equal to each other ($\Delta x_m = \Delta x_c$):

$$\Delta x_m = \Delta x_c \Leftrightarrow 10t = 36 + 12 \cdot (t - 6.0) \Leftrightarrow t = 18\ s$$

iii) Determine the final distance by substitute t = 18 s into either displacement equation:

$$\Delta x_m = 10t = 10 \times 18 = 180\ m$$

The two vehicles traveled 180 m before meeting again.

15. A simple pendulum with a mass of 0.8 kg and a length of 2 m describes a trajectory that corresponds to an angle of 30º in relation to the vertical. Neglecting air resistance, determine:

15.1. The gravitational potential energy of the pendulum at the highest point of its trajectory.

15.2. The kinetic energy of the pendulum when it passes through the lowest point of its trajectory.

15.3. The speed of the pendulum at the lowest point.

RESOLUTION:

15.1.

When the pendulum swings to an angle θ, the vertical distance from the pivot to the mass is given by L cos(θ).

The height (h) it has risen from the bottom of the arc is the total length minus this vertical distance:

$h = L - L\cos(\theta)$

$h = L \times (1 - \cos(30º))$

$h = 2 \times (1 - 0.866)$

$h = 0.268\ m$

The potential energy is:

$E_p = m \cdot g \cdot h = 0.8 \times 9.8 \times 0.268 = 2.1\ J$

RESOLUTION:

15.2.

To find the kinetic energy at the lowest point, we use the **Law of Conservation of Energy**. In an ideal system (neglecting air resistance), the total mechanical energy remains constant.

According to the **Principles of Energy Conservation** at the **highest point**, the pendulum is momentarily at rest, meaning its kinetic energy is zero and all its energy is **Gravitational Potential Energy (E_p)**. Also, at the **lowest point**, the pendulum has reached its maximum speed. Its height (h) is zero relative to our reference point, meaning its potential energy has been entirely converted into **Kinetic Energy (E_k)**.

Therefore, all the potential energy has been converted to kinetic energy ($E_p = E_k$), so the kinetic energy at the lowest point is also 2.1 J.

RESOLUTION:

15.3.

$$E_k = \frac{1}{2} \cdot m \cdot v^2 \Leftrightarrow 2.1 = \frac{1}{2} \times 0.8 \times v^2 \Leftrightarrow v = 2.29\ ms^{-1}$$

Physics Exam

QUESTIONS?