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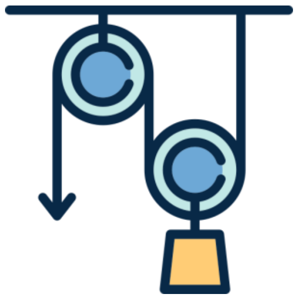


Physics

preparing students for exams

Ana Oliveira | June 2025

Integrated Masters in Medicine
Model Exam | Access for International Students | 2025/2026

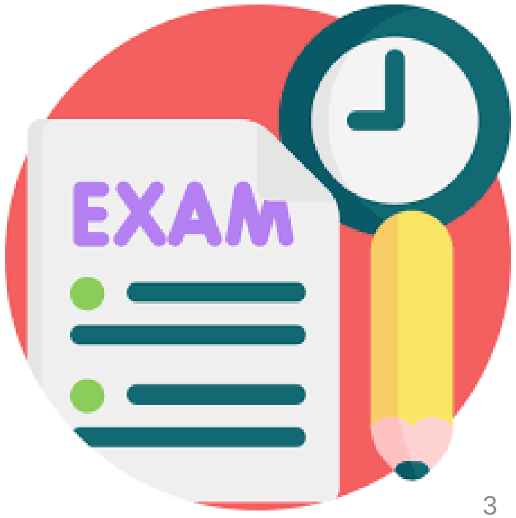
General instructions:

- 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: 20/06/2025 (Friday) at 10:00 am



Model Exam resolution

Model Exam resolution

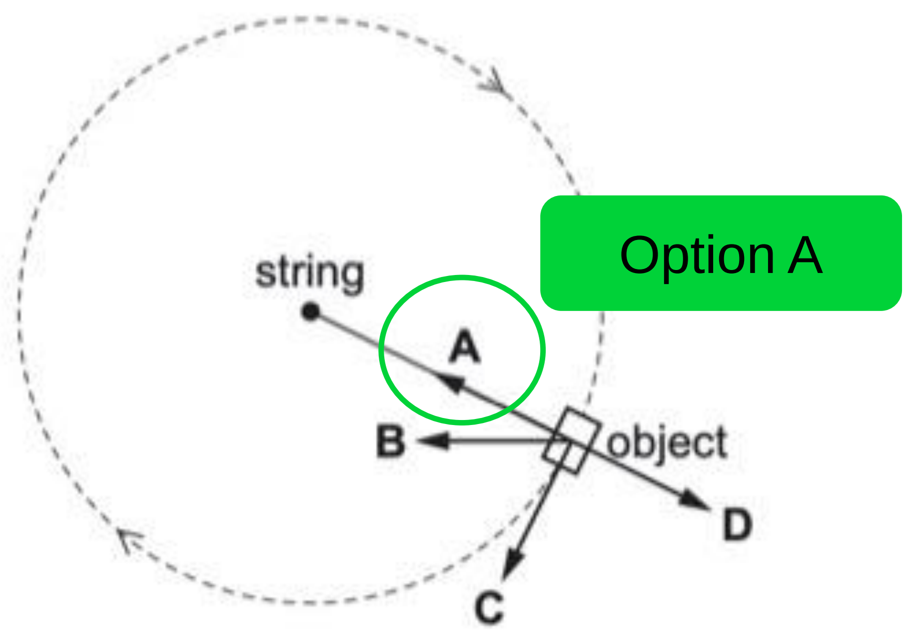
Group I

(15 multiple-choice questions)

1. An object on the end of a string moves in a clockwise circular path at constant speed.

The diagram shows the object as viewed from above.

What is the direction of the resultant force on the object when it is in the position shown?



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

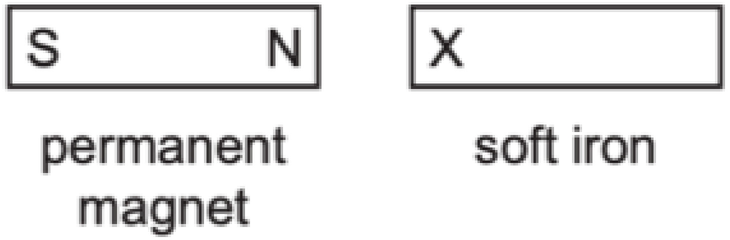
Circular Motion

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

2. An unmagnetised piece of soft iron is placed close to a strong permanent magnet, as shown



What is the induced polarity of end X of the soft iron and in which direction does the magnetic force act on the soft iron?

	polarity of end X	direction of force on the soft iron
(A)	N	to the left
(B)	N	to the right
(C)	S	to the left
(D)	S	to the right

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

3. Consider a system that expands, absorbs radiation, and heats up. Knowing that the work, heat, and radiation involved in this process are, respectively, 15 J, 35 J and 46 J, we can state that the internal energy variation of the system is:

(A) – 66 J

(B) 96 J

(C) 66 J

(D) – 96 J

$\Delta U = Q - W = (35 + 46) - 15 = 66$ J

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**:

$$\Delta U = Q + W$$

- 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 PΔV 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

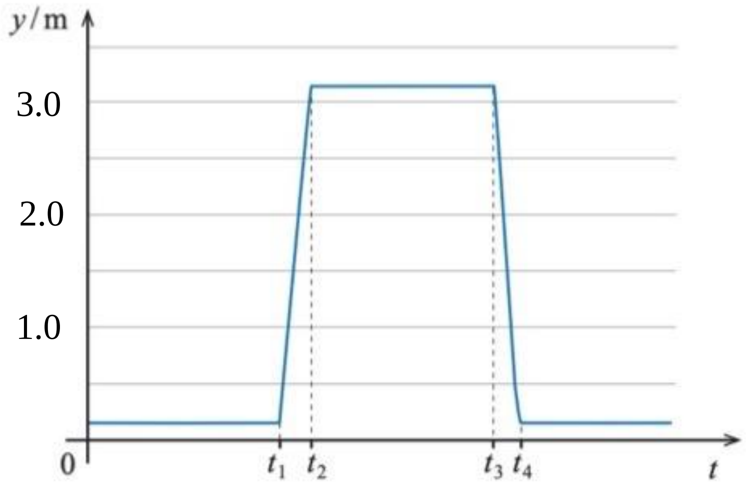
First Law of Thermodynamics
Covers the first law, internal energy, work, and heat in a clear, example-rich format

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

4. In 2020, a space probe was sent to the planet Mars, as part of the Mars 2020 mission. This probe carried, for the first time in the history of space exploration, a small helicopter. Flying a helicopter on Mars was a challenge. Engineers knew that Mars' gravitational acceleration, approximately 1/3 of Earth's, would help with liftoff, but its thin atmosphere would make lift more difficult. Thus, the small helicopter, weighing 1.8 kg, was built with two 1.2 m diameter propellers, which rotate in opposite directions at 2400 revolutions per minute.

Using altimeter data, engineers confirmed the success of the first test flight, in which the helicopter only followed a vertical trajectory. The figure shows the graph of the helicopter's altitude, y, as a function of time, t.

Consider that the helicopter can be represented by its center of mass (material particle model).



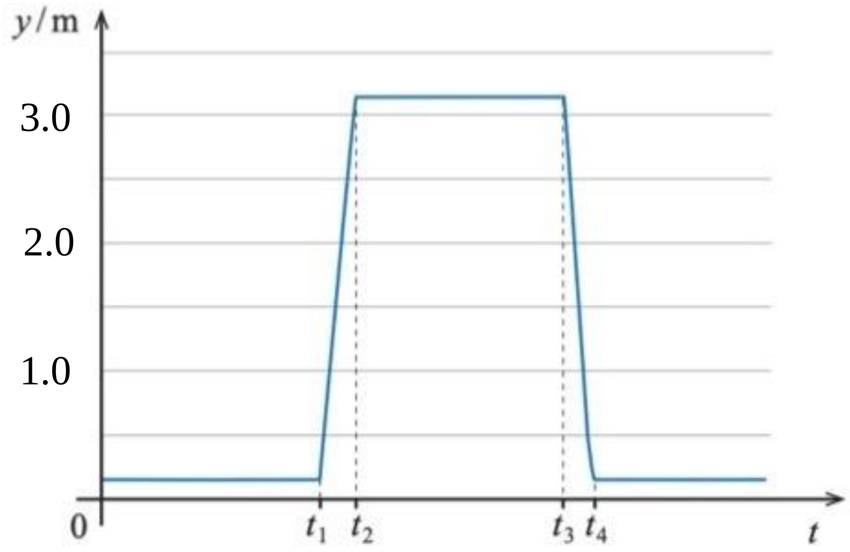
The graph in the figure allows us to conclude that,

(A) between 0 and t_1, the helicopter moved away from the starting point.

(B) between t_1 and t_2, the movement of the helicopter was uniformly accelerated.

(C) between t_2 and t_3, the helicopter described a straight trajectory.

(D) between 0 and t_4, there was a reversal in the direction of the helicopter movement.



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

5. A student determines the density of an irregularly shaped stone. The stone is slowly lowered into a measuring cylinder partly filled with water.

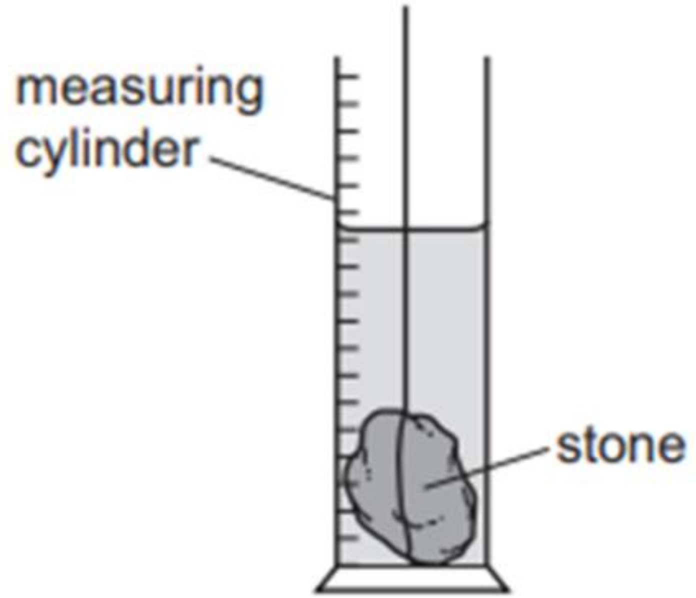
Which other apparatus does the student need to calculate the density of the irregularly shaped stone?

(A) Balance

(B) Thermometer

(C) Metre rule

(D) Stop-watch



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

6. A rectangular conducting coil rotates at a constant angular velocity in a uniform magnetic field.

The rotation axis of the coil is perpendicular to the field.

At one instant the plane of the coil is at an angle q to the direction of the field.

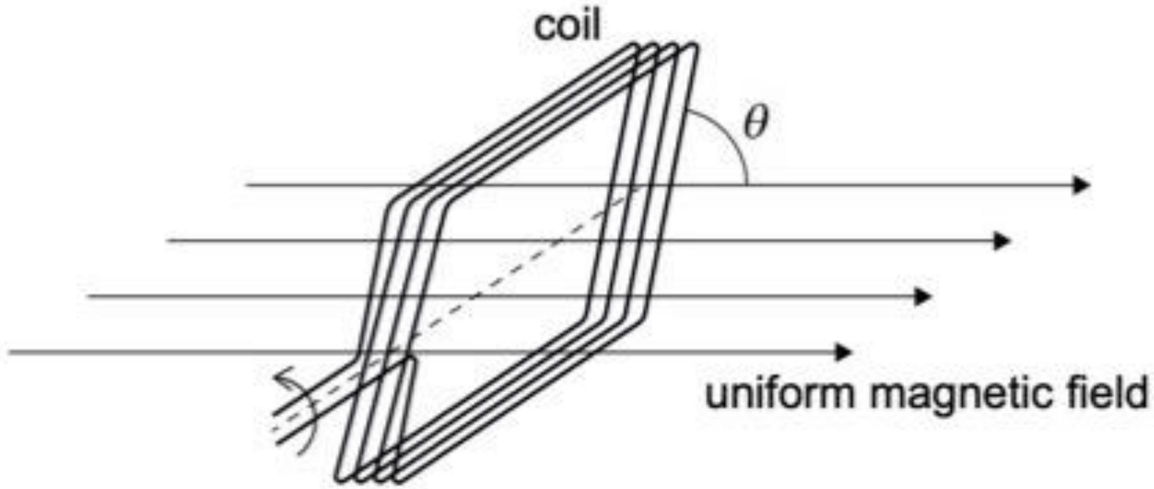
The magnitude of the electromotive force (emf) induced in the coil is

(A) never zero.

(B) at a maximum when q = 0° or 180°.

(C) at a maximum when q = 45° or 225°.

(D) at a maximum when q = 90° or 270°.



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)

7. Which unit is a unit of weight?

(A) kilogram

(B) kilojoule

(C) kilometre

(D) kilonewton

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

8. A ball is thrown vertically upwards. Neglecting air resistance, it is possible to state that:

(A) At the beginning of the movement, when the ball is thrown, all the mechanical energy is in the form of potential energy, since the gravitational potential energy is maximum when the ball is at the launch point (considering that this is the reference point).

(B) At the highest point of the trajectory, where the speed of the ball is zero, all the mechanical energy is converted into kinetic energy.

(C) The gravitational potential energy increases as the ball rises, while the kinetic energy decreases.

(D) The total mechanical energy of the ball decreases along the path, since there is no air resistance to dissipate it.

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

9. A telecommunications technician is setting up a radio transmitter that emits electromagnetic waves with a frequency of 100 MHz. Knowing that the speed of electromagnetic waves in a vacuum is 3.0×10^{8} m s^{-1}, the wavelength of this electromagnetic wave is:

(A) 3 m

(B) 0.3 m

(C) 0.003 m

(D) 0.0003 m

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8}{100 \times 10^6} = 3\ m$$

Learn more [Relationship between wavelength and frequency]

10. Two runners take part in a race.

The graph shows how the speed of each runner changes with time.

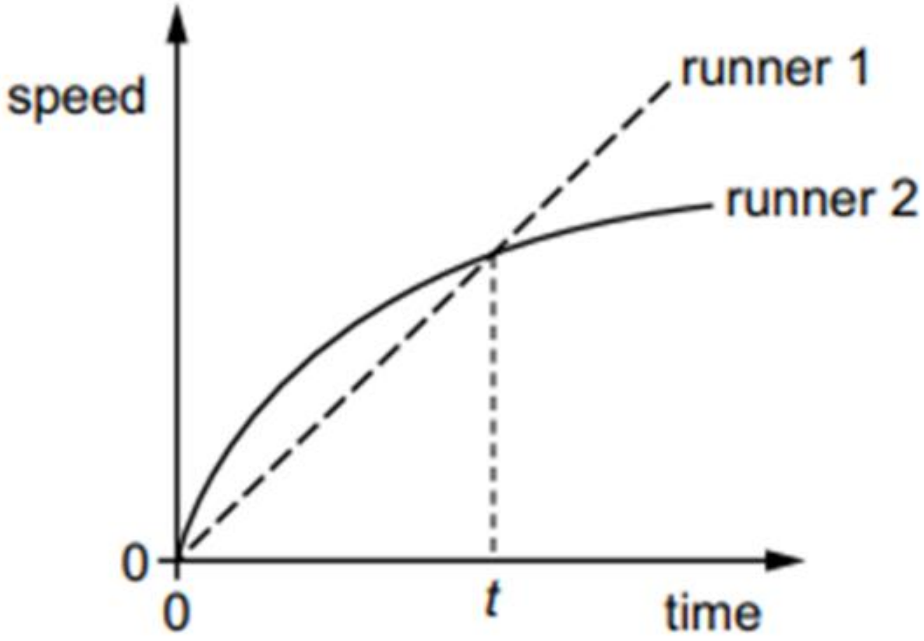
What does the graph show about the runners at time t?

(A) Both runners are moving at the same speed.

(B) Runner 1 has zero acceleration.

(C) Runner 1 runs ahead of runner 2.

(D) Runner 2 is slowing down.



11. According to Newton's Third Law, when a bird flaps its wings to fly:

(A) The air pushes the bird upward with a force less than that exerted by the wings.

(B) The bird exerts no force on the air.

(C) The air exerts a force on the bird equal and opposite to that exerted by the wings.

(D) The force exerted by the air on the bird is greater than the force exerted by the wings on the air.

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]

12. An acoustics technician is analyzing the propagation of sound in an industrial building. The technician emits a sound signal and notices that the echo returns after 1.5 seconds. Knowing that the speed of sound in air is 340 m s^{-1}, the distance between the technician and the wall where the sound reflected is:

(A) 51 m

(B) 255 m

(C) 510 m

(D) 25.5 m

$$d = \frac{v \cdot t}{2} = \frac{340 \times 1.5}{2} = 255\ m$$

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: $d = (v \cdot t / 2)$ (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

13. Some whales emit a sound with a practically constant frequency, called a backbeat. Figure shows the recording of an electrical signal, obtained by a hydrophone, of part of a backbeat. The horizontal axis represents the time in ms.

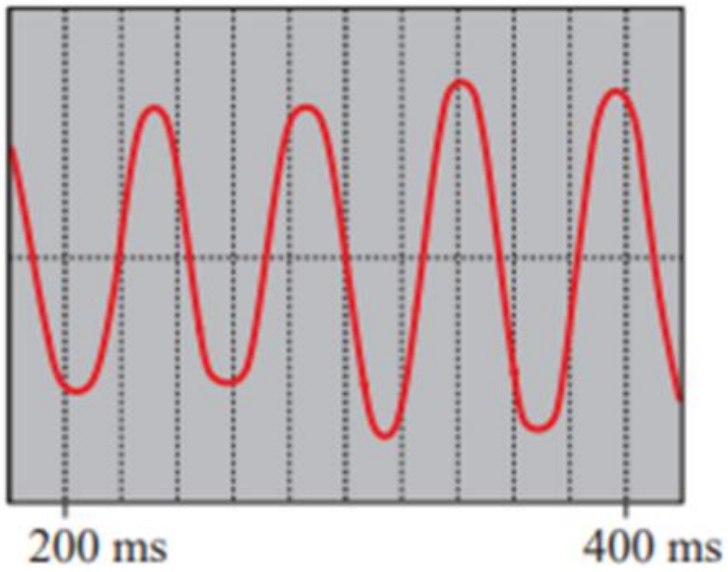
The frequency of this backbeat is contained in the interval

(A) [36, 39] Hz

(B) [8, 11] Hz

(C) [53, 56] Hz

(D) [1.7, 20] Hz



$$frequency\ (f)\ and\ \text{period (T) are inversely related:}\ f = \frac{1}{T}$$

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)]

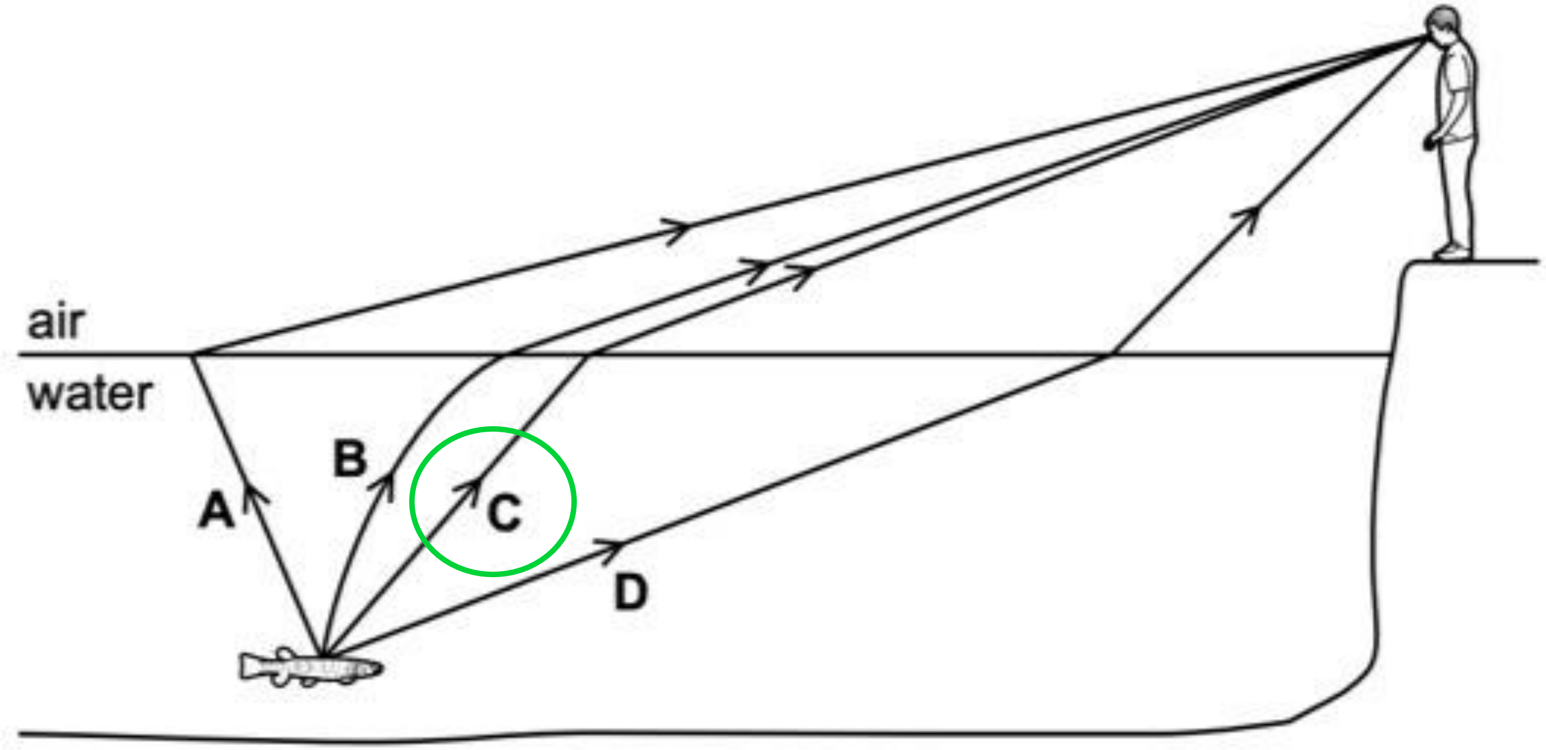
Great technical video showing real signal analysis

[Understanding Sound Frequency and Period]

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

14. A boy sees a fish in a lake.

Which labelled path is taken by the light travelling from the fish to the boy's eye?



Option C

To know

Speed and Refractive Index

- Light travels fastest in a **vacuum** (~3×10⁸ m/s), slightly slower in **air**, and significantly slower in **water** (~2.25×10⁸ m/s) because it interacts with the atoms in denser media

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

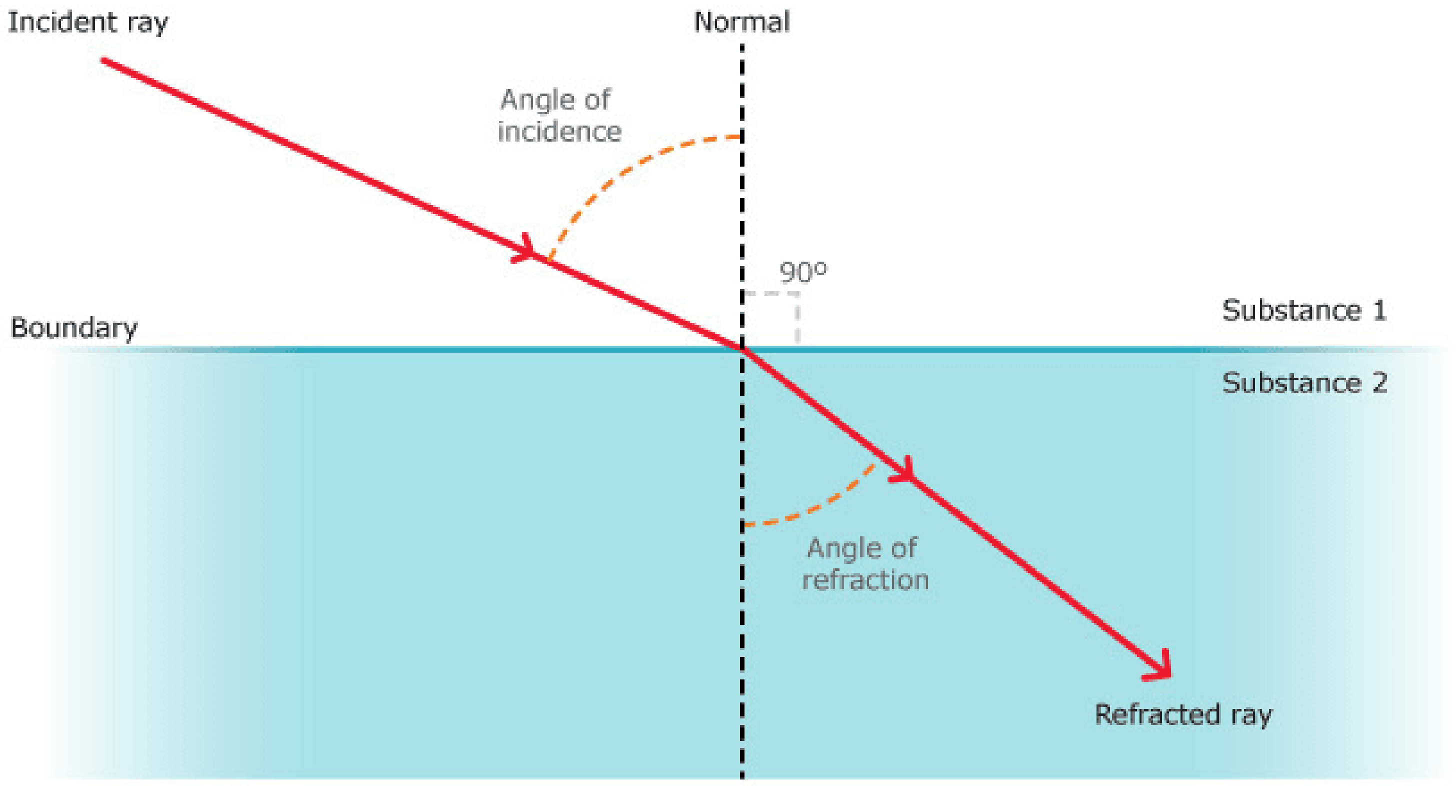
  → Air n≈1.0003, Water n≈1.33, Glass n≈1.5

- 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

Refraction of light



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

15. Which row about the change of energy in the energy store must be correct?

	Process	Energy store	Change of energy in store
(A)	water pumped up to a high-altitude dam	gravitational potential energy of water	increases
(B)	water pumped up to a high-altitude dam	kinetic energy of water	decreases
(C)	air passes through a wind turbine	gravitational potential energy of air	increases
(D)	air passes through a wind turbine	kinetic energy of air	increases

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]

Model Exam resolution

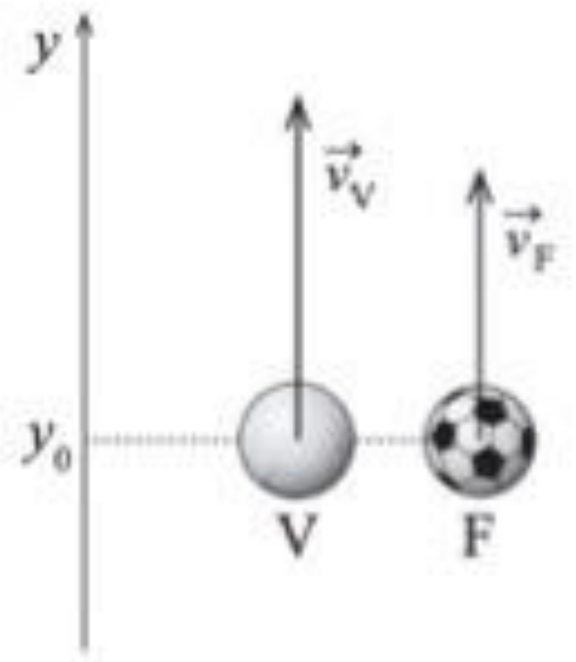
Group II

(5 essay questions)

16. A volleyball, V, and a soccer ball, F, were thrown vertically, from bottom to top, from the same position, y_0, with initial velocities of magnitudes 5.0 m s^{-1} and 4.0 m s^{-1}, respectively, according to the figure.

Admit that:

- y_0 is the reference level of gravitational potential energy;
- air resistance is negligible;
- balls can be represented by their center of mass (material particle model).



16.1. Determine, using energy considerations, the ratio between the maximum height reached by the volleyball ball, y_{max}, V, and the maximum height reached by the soccer ball, y_{max}, F.

RESOLUTION:

16.1.

- For ball V, at maximum height (y_{max}):

$$\Delta E_p = \Delta E_c \Leftrightarrow m \cdot g \cdot h = \frac{1}{2} \cdot m \cdot v^2 \Leftrightarrow h_V = \frac{\frac{1}{2} \cdot m \cdot v^2}{m \cdot g} = \frac{\frac{1}{2} \times 5^2}{9.8} = 1.276\, m$$

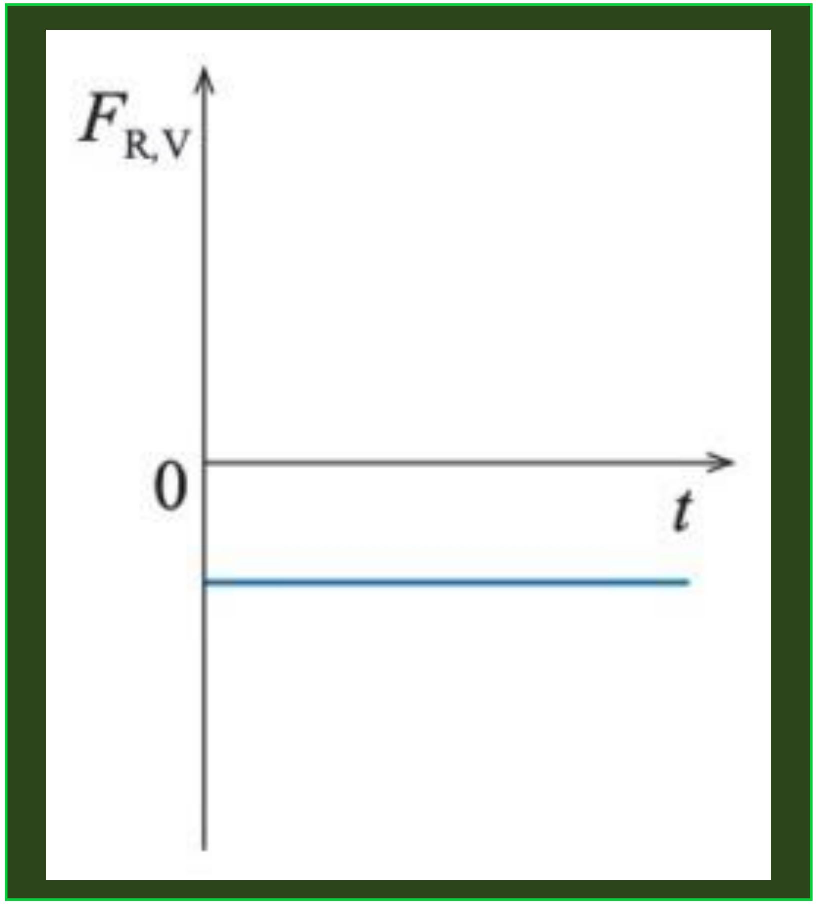
- For ball F, at maximum height (y_{max}):

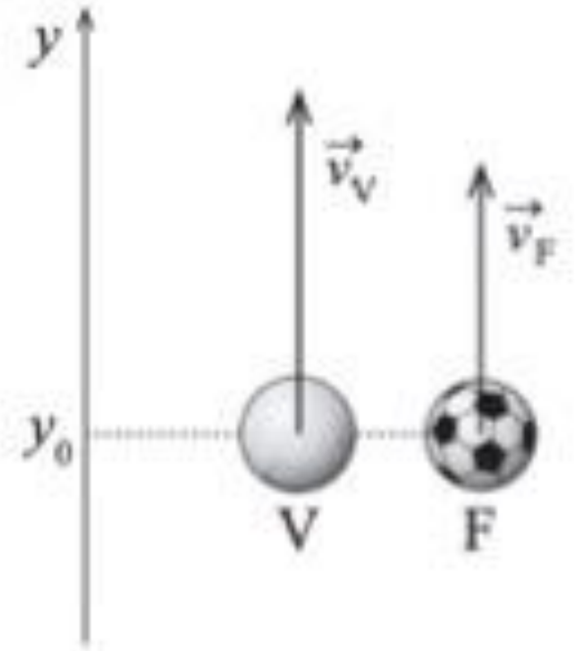
$$\Delta E_p = \Delta E_c \Leftrightarrow m \cdot g \cdot h = \frac{1}{2} \cdot m \cdot v^2 \Leftrightarrow h_F = \frac{\frac{1}{2} \cdot m \cdot v^2}{m \cdot g} = \frac{\frac{1}{2} \times 4^2}{9.8} = 0.816\, m$$

- Calculate $\frac{y_{máx,V}}{y_{máx,F}}$:

$$\frac{y_{\max V}}{y_{\max F}} = \frac{h_V}{h_F} = \frac{1.276}{0.816} = 1.563\, m$$

16.2. Consider that the volleyball was thrown at time t = 0 s, and that the soccer ball was thrown 3 s later. Sketch a graph that represents the scalar component of the resultant force acting on the volleyball ball, $F_{R,V}$, as a function of time, t, from the instant the ball is thrown until the instant it reaches its maximum height.





17. In Antarctica, a 12 kg meteorite, at a temperature of 3100ºC, buries itself in a large block of ice with a speed of 10 km s^{-1}, in module. Admit that:

- the ice block is at a temperature of 0ºC;
- all the meteorite's kinetic energy is used to melt the block's ice;
- the mass thermal capacity of the material that makes up the meteorite is 830 J kg^{-1} K^{-1};
- the melting temperature of ice is 0ºC;
- the change in enthalpy (mass) of ice melting is 3.34×10^5 J kg^{-1}.

Determine the mass of ice that melts, considering that, in the end, the meteorite + ice block system is at 0ºC.

Resolution:

17.

- Calculate the energy transferred to the ice in the form of heat

$$Q = m \cdot C \cdot \Delta T = 12 \times 830 \times [(3100 + 273.15) - (0 + 273.15)] = 3.1 \times 10^7\ J$$

- Calculate the energy transferred to the ice from the kinetic energy of the meteorite

$$E_c = \frac{1}{2} m \cdot v^2 = \frac{1}{2} \times 12 \times (10 \times 10^3)^2 = 6.0 \times 10^8\ J$$

- Calculate the mass of ice that melts ($2 \text{x} 10^3$ kg)

18. A roller coaster car with a mass of 500 kg starts from rest at the top of a slope, 20 m above sea level. Assume that there is no friction or air resistance and assume that the acceleration due to gravity is 9.8 m s^{-2}.

18.1. Calculate the gravitational potential energy of the car halfway down the slope.

18.2. Find the speed of the car halfway down the slope.

Show all solution steps.

RESOLUTION:

18.1.

$$E_p = m \cdot g \cdot h = 500 \times 9.8 \times 20 = 49000\ J$$

18.2 Kinetic energy (E_c) halfway equals the potencial energyy, thus, E_c = 49000 J

$$E_c = \frac{1}{2} m \cdot v^2 \Leftrightarrow 49000 = \frac{1}{2} \times 500 \times v^2 \Leftrightarrow v = 14\ m\ s^{-1}$$

Physics Exam

QUESTIONS?