

Supported Focus Companion

International Baccalaureate · IB Diploma · Physics · HL

Source-supported focus teaching; remaining qualification requirements are held

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Original teaching and practice · exercises.lol

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Kinematics · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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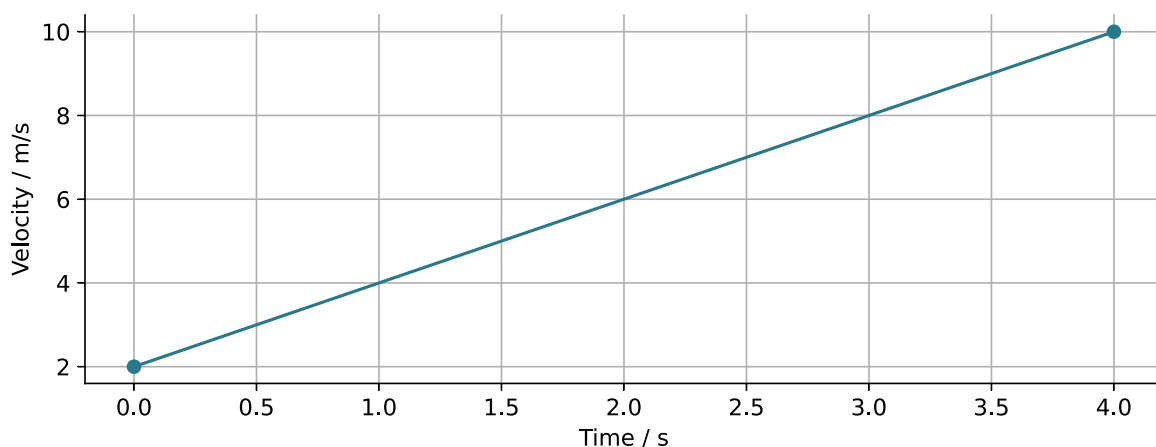
Motion graphs and acceleration

■ What would explain this observation?

- A speedometer gives a reading at one moment. A journey average can hide stops and rapid changes in speed.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- Displacement includes direction; distance counts total path length. **Velocity** is change in displacement per time. **Acceleration** is change in velocity per time.
- velocity: Rate of change of displacement; acceleration: Rate of change of velocity.



■ Choose evidence that can test it

- The gradient of a displacement-time graph is velocity. The area under a velocity-time graph gives displacement. A constant-acceleration formula is valid only when its assumption is justified.
 - Choose a positive direction and state it. Use a light gate or video with a known scale and frame interval for repeatable motion measurements. Avoid assuming hand timing is exact over very short intervals.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: velocity rises uniformly from 2 to 10 metres per second in 4 s. $a = (v-u)/t$.
 $a = (10-2)/4 = 2$ metres per second squared. Displacement is trapezium area: $s = (u+v)t/2 = (2+10) \times 4/2 = 24$ m.

Example:

Velocity changes from 3 to 15 metres per second in 6 s. Find acceleration. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Negative velocity indicates direction under the chosen sign convention; it does not necessarily mean slowing down.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A negative velocity always means the object is slowing down. This claim is false: Negative velocity indicates direction under the chosen sign convention; it does not necessarily mean slowing down.

Key:

Motion graphs and acceleration: The gradient of a displacement-time graph is velocity. The area under a velocity-time graph gives displacement. A constant-acceleration formula is valid only when its assumption is justified.

Forces and momentum · supported focus

International Baccalaureate · IB Diploma · Physics · HL

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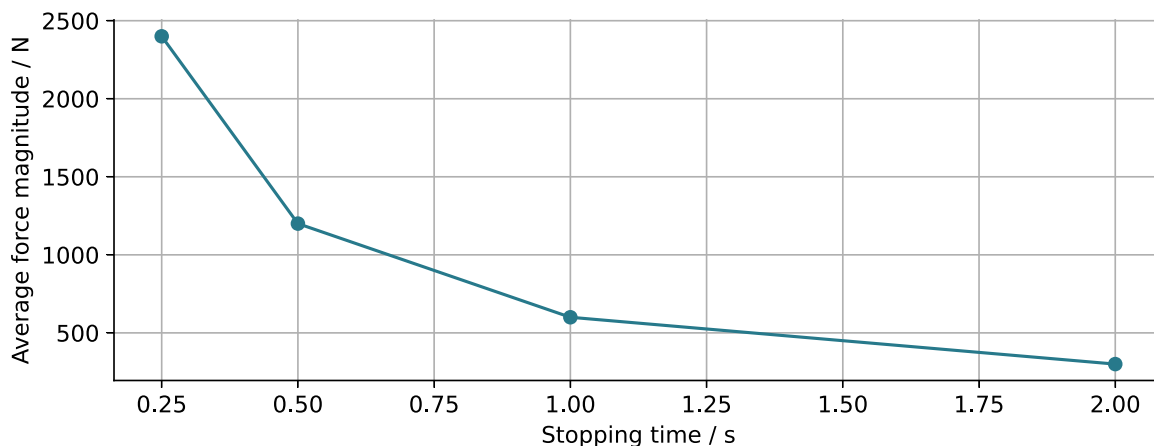
Forces, momentum and safe stopping

■ What would explain this observation?

- A passenger continues moving when a vehicle brakes. The seat belt provides the force needed to change the passenger **momentum**.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **Resultant force** causes acceleration, not motion itself. Momentum is mass multiplied by velocity. For an isolated system, total momentum is conserved even when kinetic energy is not.
- momentum: Mass multiplied by velocity; resultant force: The vector sum of forces on an object.



■ Choose evidence that can test it

- Impulse equals momentum change. Increasing stopping time for the same momentum change reduces average force. Identify external forces before applying momentum conservation.
 - Draw a free-body diagram containing only forces on the selected object. For spring measurements, add loads in steps within the elastic range and measure extension from the unloaded position.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a 60 kg passenger slows from 10 to 0 metres per second in 0.50 s. $\Delta p = m(v-u) = 60(0-10) = -600$ kg metres per second. Average $F = \Delta p / \Delta t = -600 / 0.50 = -1,200$ N. The sign shows the force opposes the initial motion.

Example:

A 2 kg trolley travels at 3 metres per second. Find its momentum. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Balanced forces do not require the object to be at rest. Mass and weight have different units and meanings.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

An object moving at constant velocity must have a nonzero resultant force. This claim is false: Balanced forces do not require the object to be at rest. Mass and weight have different units and meanings.

Key:

Forces, momentum and safe stopping: Impulse equals momentum change. Increasing stopping time for the same momentum change reduces average force. Identify external forces before applying momentum conservation.

Work, energy and power · supported focus

International Baccalaureate · IB Diploma · Physics · HL

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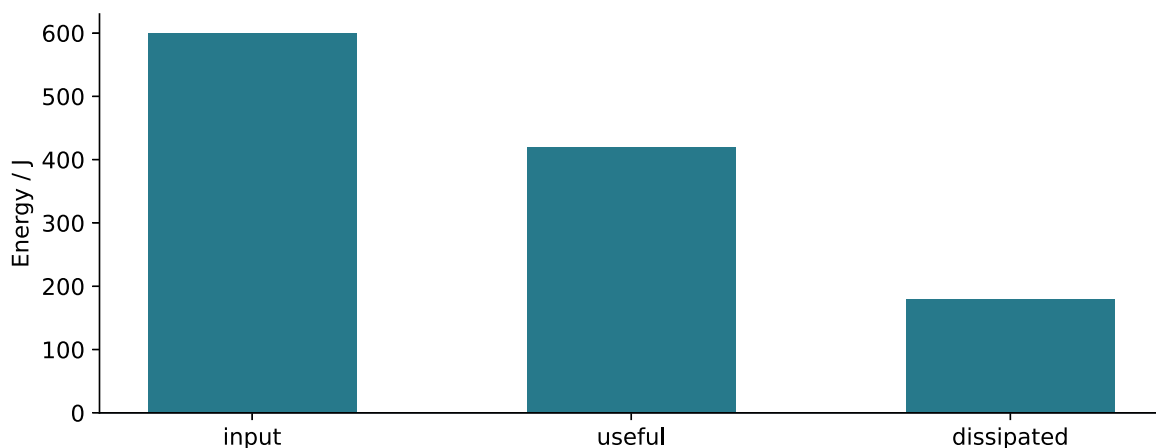
Energy stores, work and efficiency

■ What would explain this observation?

- A motor can transfer some input energy to lifting and the rest to heating. Useful output is part of the total energy transfer.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- Work done by a constant force parallel to displacement is force multiplied by distance. Kinetic energy depends on speed squared. Energy is conserved when all transfers and stores are included.
- **power** : Energy transferred per unit time; **efficiency**: Useful output divided by total input.



■ Choose evidence that can test it

- Define the system and useful output before calculating efficiency. Doubling speed quadruples kinetic energy at constant mass. Power describes transfer per time, not total energy.
 - Measure a lifting height and load, time the lift, and record electrical input with suitable instruments. Repeat trials and account for heating or friction as transfers, not missing energy.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a device receives 600 J and transfers 420 J usefully. Efficiency = useful output / total input. Efficiency = $420/600 = 0.70 = 70\%$. Over 3 s, useful power = useful energy/time = $420/3 = 140$ W.

Example:

A device receives 250 J and gives 150 J useful output. Find efficiency as a percentage. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- Efficiency cannot exceed 100% for a properly defined energy balance. Energy dissipated by heating is still conserved.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Dissipated energy is destroyed. This claim is false: Efficiency cannot exceed 100% for a properly defined energy balance. Energy dissipated by heating is still conserved.

Key:

Energy stores, work and efficiency: Define the system and useful output before calculating efficiency. Doubling speed quadruples kinetic energy at constant mass. Power describes transfer per time, not total energy.

Rigid body mechanics · supported focus

International Baccalaureate · IB Diploma · Physics · HL

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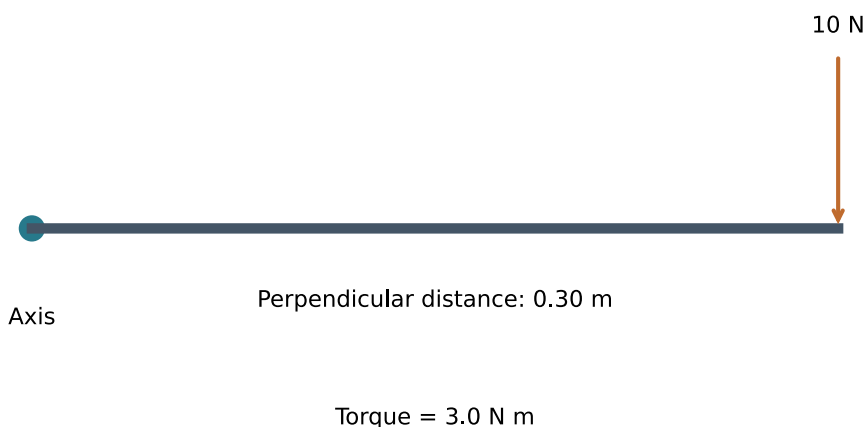
Rigid bodies and rotational dynamics

■ What would explain this observation?

- A door is easier to open when pushed near its outer edge. Force size alone does not determine the turning effect.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- **Torque** depends on force and perpendicular distance from the axis. **Moment of inertia** describes resistance to angular acceleration and depends on mass distribution about a stated axis.
- torque: Turning effect about an axis; moment of inertia: Resistance to angular acceleration about a specified axis.



■ Choose evidence that can test it

- For a rigid body about a fixed axis, net torque equals moment of inertia multiplied by angular acceleration. Rotational kinetic energy depends on angular speed squared. Angular momentum is conserved when net external torque is zero.
 - Draw the pivot, force direction and perpendicular lever arm. Do not use the sloping distance from pivot to force point unless it is perpendicular to the force. For experiments, keep rotating parts guarded and loads secure.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a 10 N perpendicular force acts 0.30 m from an axis. Torque = force $\times$ perpendicular distance = $10 \times 0.30 = 3.0$ N m. If moment of inertia is 0.60 kg square metres, angular acceleration = torque/inertia = $3.0/0.60 = 5.0$ radians per second squared.

Example:

A 12 N force acts perpendicularly 0.25 m from the pivot. Find torque. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Torque has unit N m but is a turning effect, not an energy store. Moment of inertia changes if the same mass moves farther from the axis.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Moment of inertia depends only on total mass, never its distribution. This claim is false: Torque has unit N m but is a turning effect, not an energy store. Moment of inertia changes if the same mass moves farther from the axis.

Key:

Rigid bodies and rotational dynamics: For a rigid body about a fixed axis, net torque equals moment of inertia multiplied by angular acceleration. Rotational kinetic energy depends on angular speed squared. Angular momentum is conserved when net external torque is zero.

Galilean and special relativity · supported focus

International Baccalaureate · IB Diploma · Physics · HL

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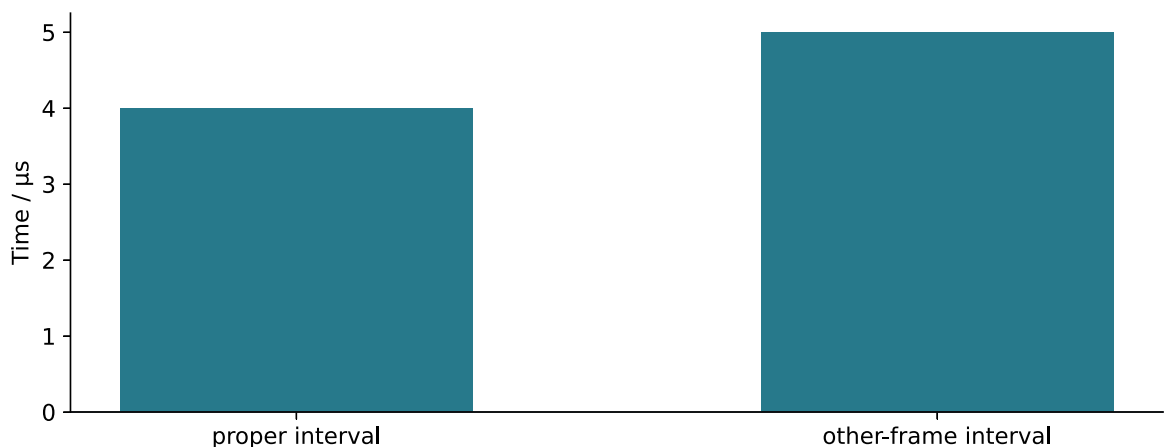
Relativity and measuring events

■ What would explain this observation?

- Two observers can assign different times between the same events. A clock reading has meaning only when the frame and events are specified.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- In special relativity, inertial observers measure the same vacuum light speed. Time dilation compares **proper time** measured where two events occur at one place with the interval in another **inertial frame**.
- proper time: Time between events measured at one location in a frame; inertial frame: A frame in which a free body moves at constant velocity.



■ Choose evidence that can test it

- The Lorentz factor is 1 divided by the square root of 1 minus speed squared over light speed squared. Galilean velocity addition is an approximation for speeds much smaller than light speed.
 - Label which frame measures proper time or proper length before substituting. Use event coordinates consistently. Do not combine lengths from one frame with time intervals from another without transformation.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: $v = 0.60c$ and proper time is 4.0 microseconds. $\gamma = 1/\sqrt{1-v^2/c^2} = 1/\sqrt{1-0.60^2} = 1.25$. $\Delta t = \gamma \Delta t_0 = 1.25 \times 4.0 = 5.0$ microseconds in the stated second frame.

Example:

A proper interval is 8 microseconds and gamma is 1.25. Find the other-frame interval. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Time dilation is not an instrument fault. Proper length is measured in the object rest frame; a contracted length is measured in a frame where it moves.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

All inertial observers must measure the same time interval between any two events. This claim is false: Time dilation is not an instrument fault. Proper length is measured in the object rest frame; a contracted length is measured in a frame where it moves.

Key:

Relativity and measuring events: The Lorentz factor is 1 divided by the square root of 1 minus speed squared over light speed squared. Galilean velocity addition is an approximation for speeds much smaller than light speed.

Thermal energy transfers · supported focus

International Baccalaureate · IB Diploma · Physics · HL

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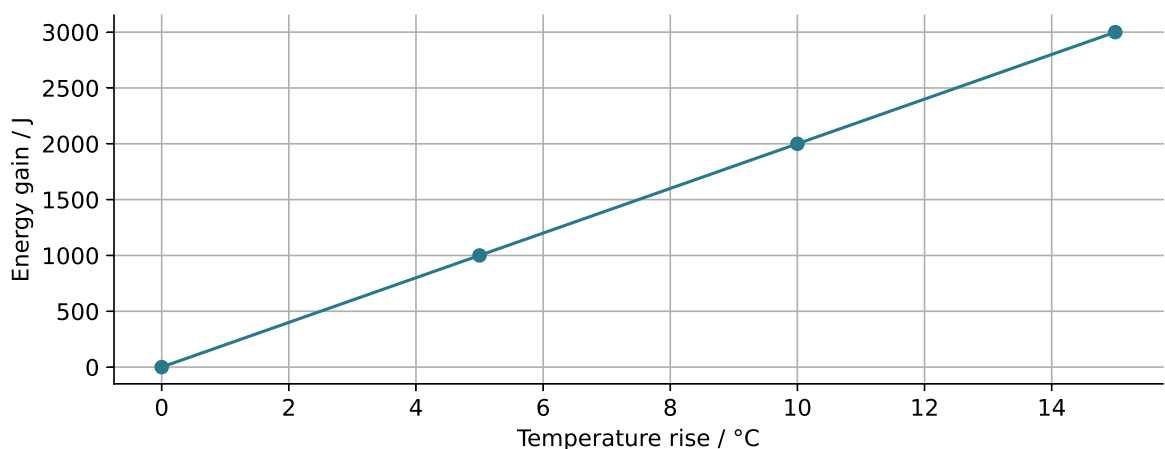
Thermal measurements and particle models

■ What would explain this observation?

- Two equal masses receive the same energy but show different temperature rises. Material properties determine how energy transfer changes temperature.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **Specific heat capacity** is energy needed to raise the temperature of unit mass by one degree. **Specific latent heat** relates energy to change of state without temperature change for the idealized process.
- specific heat capacity: Energy per mass per temperature rise; latent heat: Energy associated with a change of state.



■ Choose evidence that can test it

- Temperature relates to particle motion in a model; internal energy includes kinetic and potential contributions. During a change of state, energy can change particle arrangements rather than temperature.
- Measure mass, electrical input and temperature change for an insulated block. Ensure the temperature sensor has good contact, allow time for equilibration, and consider energy transferred to the surroundings.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a 0.50 kg block gains 2,000 J and rises 10 °C. Use $E = mc\Delta T$. Rearranging gives $c = E/(m\Delta T)$. $c = 2,000/(0.50 \times 10) = 400$ J per kilogram per degree. Heat loss would make the value inferred from electrical input too large.

Example:

A 2 kg sample with $c=500$ J per kilogram per degree warms by 3 °C. Find energy gain. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- A flat section of a heating curve can show a phase change, not absence of energy transfer. Do not substitute temperature for a temperature difference in $E = mc\Delta T$.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A temperature plateau always means zero energy transfer. This claim is false: A flat section of a heating curve can show a phase change, not absence of energy transfer. Do not substitute temperature for a temperature difference in $E = mc\Delta T$.

Key:

Thermal measurements and particle models: Temperature relates to particle motion in a model; internal energy includes kinetic and potential contributions. During a change of state, energy can change particle arrangements rather than temperature.

Greenhouse effect · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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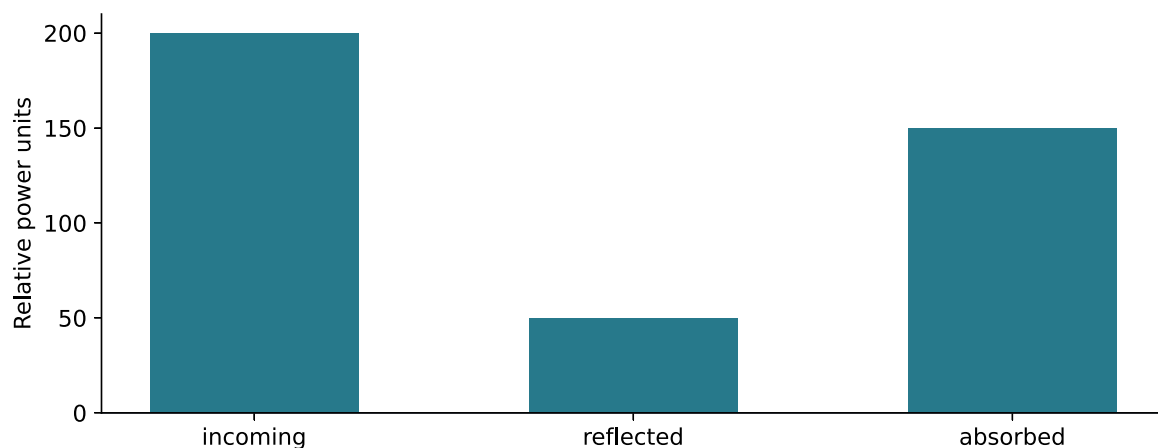
Climate evidence, energy budgets and policy

■ What would explain this observation?

- One cold day does not disprove a warming climate. Weather describes short-term conditions; climate describes distributions over longer times and regions.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- The Earth energy balance includes incoming solar radiation, reflection, absorption and outgoing infrared radiation. Greenhouse gases absorb and emit infrared radiation. Feedback can alter the response to an initial forcing.
- **mitigation** : Actions addressing causes of environmental change; **adaptation** : Actions reducing harm from environmental impacts.



■ Choose evidence that can test it

- Distinguish mitigation, which addresses drivers, from adaptation, which reduces harm from impacts. A policy assessment needs evidence about effectiveness, cost, equity and uncertainty; one criterion is not the entire decision.
 - Compare multi-year data using consistent baselines. State the region, timescale and uncertainty. At HL, connect a management decision to law, economics and ethics rather than treating these lenses as extra definitions only.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a surface receives 200 power units and reflects 50. Absorbed input = incoming-reflected = $200 - 50 = 150$. Reflected fraction = $50/200 = 0.25 = 25\%$. A change in reflectivity alters the absorbed budget under this model.

Example:

Incoming energy is 240 units and reflected energy 72. Find reflected percentage. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- The greenhouse effect is not the same process as ozone depletion. A carbon footprint estimate depends on its system boundary.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

One local weather observation establishes a global climate trend. This claim is false: The greenhouse effect is not the same process as ozone depletion. A carbon footprint estimate depends on its system boundary.

Key:

Climate evidence, energy budgets and policy: Distinguish mitigation, which addresses drivers, from adaptation, which reduces harm from impacts. A policy assessment needs evidence about effectiveness, cost, equity and uncertainty; one criterion is not the entire decision.

Gas laws · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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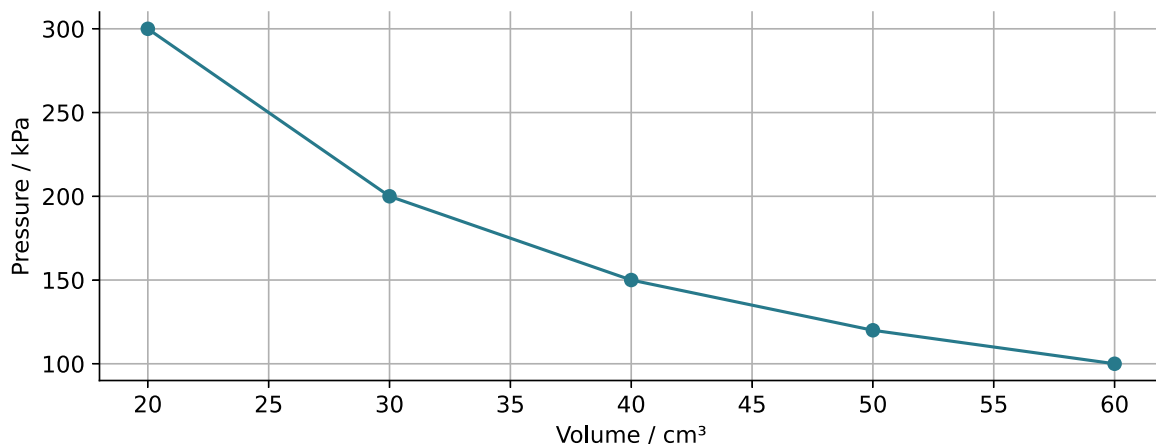
Gas models and absolute temperature

■ What would explain this observation?

- A sealed gas container changes pressure when heated. Celsius ratios cannot predict the pressure change because the gas model uses **absolute temperature**.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- In a gas model, particles move randomly and pressure results from momentum transfer at walls. The **ideal gas** equation connects pressure, volume, amount and absolute temperature.
- absolute temperature: Temperature on the kelvin scale; ideal gas: A gas model with specified simplifying assumptions.



■ Choose evidence that can test it

- At fixed amount and volume, pressure is proportional to kelvin temperature. At fixed temperature and amount, pressure is inversely proportional to volume. State which quantities are fixed before choosing a relationship.
 - Use approved apparatus with a temperature range and pressure limit set by the teacher. Allow thermal equilibrium and record pressure against kelvin temperature. Never heat an improvised sealed vessel.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: pressure is 100 kPa at 300 K, with fixed volume and amount. At 330 K, $p_2/p_1 = T_2/T_1$. $p_2 = p_1 T_2/T_1 = 100 \times 330/300 = 110$ kPa. A 30 °C rise is a 30 K change, but the temperature ratio must use kelvin.

Example:

At fixed volume, pressure is 120 kPa at 300 K. Find pressure at 350 K. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- An ideal gas is a model with conditions of validity. Celsius zero is not zero molecular motion, and internal energy is not determined by pressure alone.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A gas pressure ratio can always use Celsius temperatures. This claim is false: An ideal gas is a model with conditions of validity. Celsius zero is not zero molecular motion, and internal energy is not determined by pressure alone.

Key:

Gas models and absolute temperature: At fixed amount and volume, pressure is proportional to kelvin temperature. At fixed temperature and amount, pressure is inversely proportional to volume. State which quantities are fixed before choosing a relationship.

Thermodynamics · supported focus

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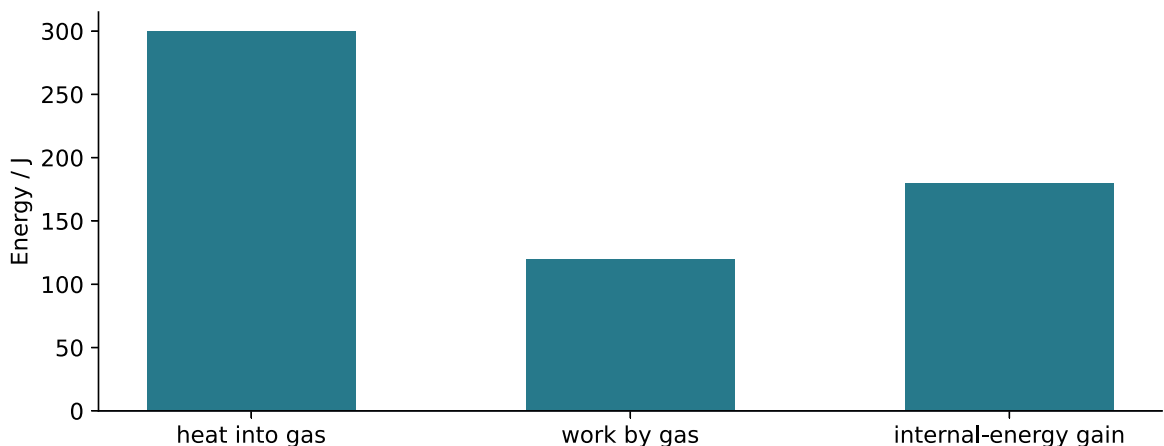
Thermodynamic systems and energy accounts

■ What would explain this observation?

- Compressing a gas can warm it even without a heater. Work is another path for energy transfer into the system.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **Internal energy** is a property of the chosen system. Heat and work describe energy transfer across its boundary. For an ideal monatomic gas, internal energy depends on temperature and amount.
- **adiabatic** : A process with no heat transfer; internal energy: Total microscopic kinetic and potential energy of a system.



■ Choose evidence that can test it

- State a sign convention before using the first law. Here change in internal energy equals heat into the system minus work done by the system. Expansion work can reduce internal energy when no heat enters.
 - Identify whether a process is isothermal, adiabatic or at constant volume. On a pressure-volume graph, area under the process curve gives work done by the gas. The path matters for work even when endpoints match.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: gas gains 300 J by heating and does 120 J of work. With $\Delta U = Q - W$, $\Delta U = 300 - 120 = 180$ J. For adiabatic compression, $Q = 0$ and work done by the gas is negative, so ΔU is positive.

Example:

A gas gains 500 J of heat and does 200 J work. Find internal-energy change. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Adiabatic does not mean constant temperature. Use the stated sign convention; some courses write work done on the gas with the opposite sign.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every adiabatic process has constant temperature. This claim is false: Adiabatic does not mean constant temperature. Use the stated sign convention; some courses write work done on the gas with the opposite sign.

Key:

Thermodynamic systems and energy accounts: State a sign convention before using the first law. Here change in internal energy equals heat into the system minus work done by the system. Expansion work can reduce internal energy when no heat enters.

Current and circuits · supported focus

International Baccalaureate · IB Diploma · Physics · HL

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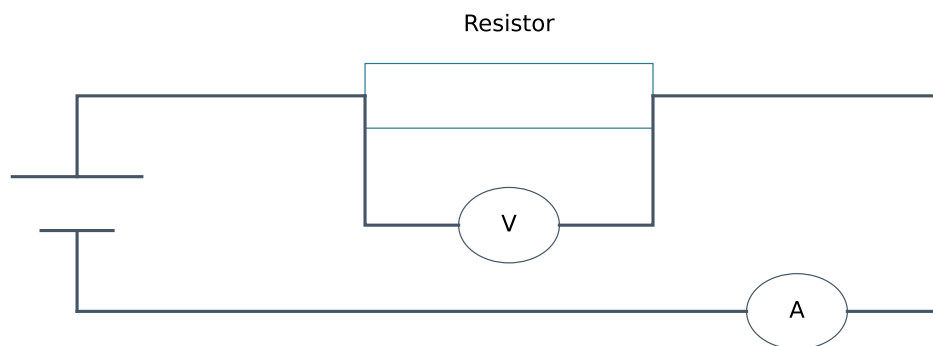
Current, potential difference and resistance

■ What would explain this observation?

- A lamp becomes dimmer when another is added in series. **Current** and energy transfer depend on the whole circuit, not only one lamp.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- Current is charge passing per time. **Potential difference** is energy transferred per charge. Resistance is potential difference divided by current for a stated operating point.
- current: Rate of flow of charge; potential difference: Energy transferred per unit charge.



DC supply in series

Ammeter in series; voltmeter across resistor

■ Choose evidence that can test it

- Current is the same through components in series. Potential differences add around the series path. In parallel, branches share the same potential difference, while branch currents sum at a junction.
 - Place an ammeter in series and a voltmeter in parallel. For an I-V investigation, change voltage in steps, reverse polarity when appropriate and limit current to reduce heating.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a resistor has 6.0 V across it and carries 0.30 A. Use $R = V/I$. $R = 6.0/0.30 = 20$ ohms. Power = VI. Power = $6.0 \times 0.30 = 1.8$ W. These quantities describe the same operating point.

Example:

A component has 12 V across it and carries 0.40 A. Find resistance. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Current is not used up by a lamp. A filament heats up, so its resistance need not remain constant as voltage changes.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A lamp uses up electric current as charge passes through it. This claim is false: Current is not used up by a lamp. A filament heats up, so its resistance need not remain constant as voltage changes.

Key:

Current, potential difference and resistance: Current is the same through components in series. Potential differences add around the series path. In parallel, branches share the same potential difference, while branch currents sum at a junction.

Simple harmonic motion · supported focus

International Baccalaureate · IB Diploma · Physics · HL

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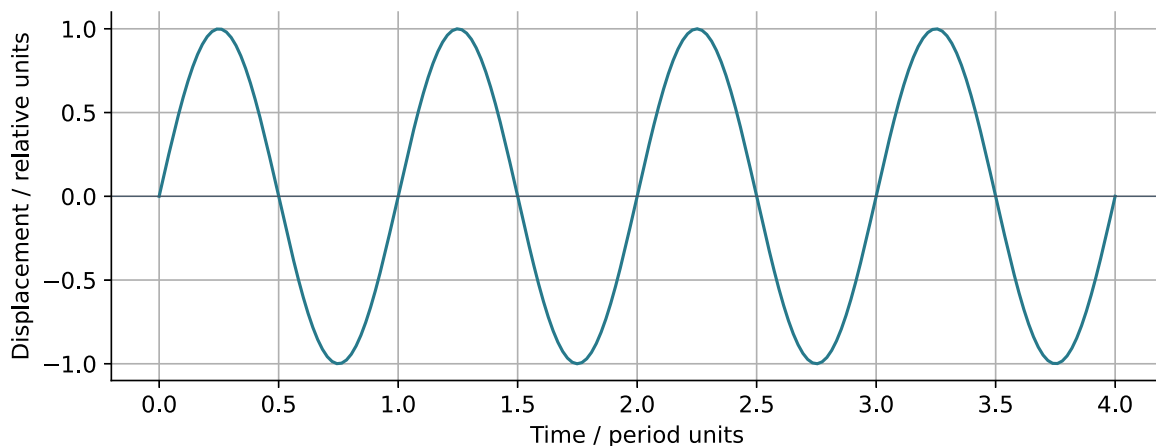
Oscillation, resonance and phase

■ What would explain this observation?

- A swing gains a large amplitude when pushes arrive with the right timing. The forcing frequency and **damping** help determine the response.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- Simple harmonic motion has acceleration proportional to displacement and directed toward equilibrium. Period is time per cycle; frequency is its reciprocal. Damping transfers energy away from the oscillating system.
- **resonance**: A large response to periodic forcing near a natural frequency; damping: Energy transfer out of an oscillating system.



■ Choose evidence that can test it

- Velocity is greatest near equilibrium for ideal SHM, while acceleration magnitude is greatest at extreme displacement. Resonance can occur near the natural frequency under periodic driving, with amplitude limited by damping.
 - Measure time for several complete oscillations and divide. Define a cycle consistently and use a small displacement when the model requires it. Keep pendulum paths clear and record damping effects rather than assuming perfect motion.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: 20 cycles take 32 s. $T = \text{total time} / \text{cycles} = 32 / 20 = 1.6 \text{ s}$. Frequency $= 1/T = 1/1.6 = 0.625 \text{ Hz}$. A shorter total timing interval would make reaction-time error a larger fraction of the measurement.

Example:

30 cycles take 45 s. Find period. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Not every repeated motion is SHM. A force proportional to displacement but directed away from equilibrium does not produce SHM.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every periodic motion satisfies the condition for simple harmonic motion. This claim is false: Not every repeated motion is SHM. A force proportional to displacement but directed away from equilibrium does not produce SHM.

Key:

Oscillation, resonance and phase: Velocity is greatest near equilibrium for ideal SHM, while acceleration magnitude is greatest at extreme displacement. Resonance can occur near the natural frequency under periodic driving, with amplitude limited by damping.

Wave model · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; full Physics guide acquired (84 PDF pages). Remaining guide, assessment and practical requirements retain their recorded holds.

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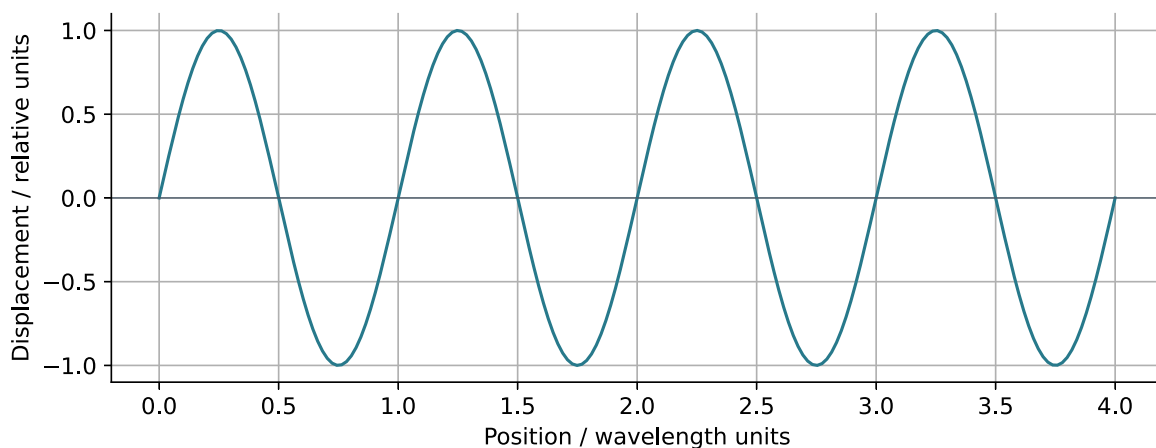
Waves, measurement and refraction

■ What would explain this observation?

- A wave can carry energy across water while a floating marker mainly oscillates. Energy transfer and bulk transfer of matter are different.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- **Frequency** is oscillations per time; **wavelength** is distance between successive points in phase. Wave speed equals frequency multiplied by wavelength. Transverse oscillations are perpendicular to propagation.
- wavelength: Distance between successive points in phase; frequency: Number of oscillations per unit time.



■ Choose evidence that can test it

- At a boundary, frequency stays fixed by the source. A change of speed changes wavelength. Refraction follows from speed differences; angles are measured from the normal.
 - Measure several wavelengths and divide to reduce fractional reading uncertainty. Use a ray box with a normal drawn at the boundary. Keep the beam away from eyes and record incident and refracted angles clearly.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: frequency 5 Hz and wavelength 0.40 m. Use $v = f\lambda$. $v = 5 \times 0.40 = 2.0$ metres per second. If speed falls to 1.5 metres per second at the same frequency, wavelength = $v/f = 1.5/5 = 0.30$ m.

Example:

Frequency is 8 Hz and wavelength is 0.25 m. Find wave speed. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- The wave frequency does not change simply because the medium changes. A longitudinal wave has oscillations parallel to propagation.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Wave frequency always changes when a wave enters a new medium. This claim is false: The wave frequency does not change simply because the medium changes. A longitudinal wave has oscillations parallel to propagation.

Key:

Waves, measurement and refraction: At a boundary, frequency stays fixed by the source. A change of speed changes wavelength. Refraction follows from speed differences; angles are measured from the normal.

Doppler effect · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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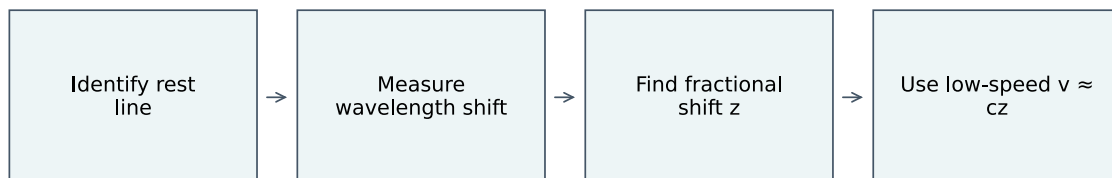
Spectral shifts: a low-speed astronomical estimate

■ What would explain this observation?

- A recognizable spectral line appears at a longer wavelength in a distant source. Its shift can provide evidence of recession along the line of sight.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- Relative source-observer motion changes observed frequency or wavelength. For light at a relative speed much smaller than c , the magnitude of the fractional wavelength shift is approximately v/c . Recession corresponds to longer wavelength, and approach to shorter wavelength.
- **redshift** : Shift of an identified line toward longer wavelength; **rest wavelength** : Wavelength of the line measured with no relative source motion.



■ Choose evidence that can test it

- Compare a identified line with its laboratory rest wavelength. Use $z = (\text{observed} - \text{rest})/\text{rest}$, then v approximately cz in the stated low-speed model. Do not apply this approximation without checking the regime or treating a cosmological redshift as a simple exact velocity.
 - Use attributed spectra with calibration and line identification. Compare several lines for a consistent shift. State uncertainty and distinguish relative line-of-sight motion from an unmeasured transverse component.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a 500 nm rest line is observed at 501 nm. $z = (501 - 500)/500 = 0.002$. With $c = 3.0 \times 10^8$ m/s, v approximately 6.0×10^5 m/s away. The sound-source denominator formula is not the required SL light approximation.

Example:

A 600 nm rest line is observed at 601.2 nm. Find $z = (\text{observed} - \text{rest})/\text{rest}$. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- The approximate shift relation does not show that light travels faster from an approaching source. A single unidentified line cannot safely establish a redshift.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

An observed redshift means light speed increased. This claim is false: The approximate shift relation does not show that light travels faster from an approaching source. A single unidentified line cannot safely establish a redshift.

Key:

Spectral shifts: a low-speed astronomical estimate: Compare a identified line with its laboratory rest wavelength. Use $z = (\text{observed} - \text{rest})/\text{rest}$, then v approximately cz in the stated low-speed model. Do not apply this approximation without checking the regime or treating a cosmological redshift as a simple exact velocity.

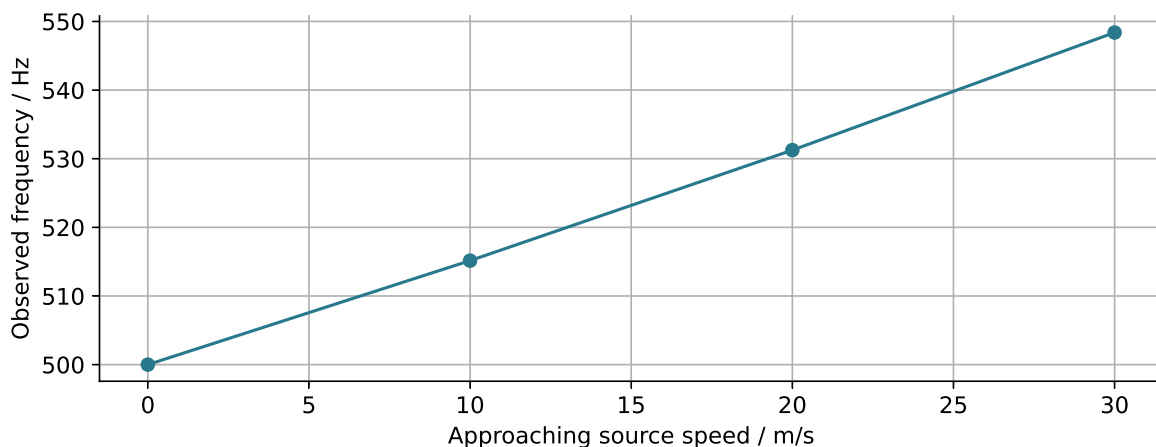
Doppler effect: separate source motion from wave speed

■ What would explain this observation?

- An approaching sound source is heard at a higher pitch even when the source produces a constant frequency.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- **Doppler shift** arises from relative source-observer motion. A moving source compresses **wavefront** spacing ahead and increases it behind. For sound in a stationary medium, the wave speed relative to that medium need not change.
- Doppler shift: Change of observed frequency due to relative motion; wavefront: A surface joining points with the same wave phase.



■ Choose evidence that can test it

- For a source approaching a stationary observer along the line of sight, $f_{\text{observed}} = f_{\text{source}} \times v / (v - v_{\text{source}})$. Recession uses $v + v_{\text{source}}$ in the denominator. These are sound-wave models; light requires its appropriate relation.
 - Use a simulation or recorded data with stated source and observer directions. Draw wavefronts before choosing signs. Avoid demonstrations near moving traffic or unsafe high-volume sources.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: source frequency 500 Hz, sound speed 340 m/s, source approaches at 20 m/s. Observed frequency = $500 \times 340 / (340 - 20) = 531.25$ Hz. The increase is 31.25 Hz; it is not the source frequency changing.

Example:

A 600 Hz source approaches a stationary observer at 20 m/s. Use $v = 340$ m/s. Find observed frequency. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- A stationary source and moving observer require the observer-motion relation. Do not use the same denominator formula for every arrangement or import a sound formula into relativity.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

The Doppler effect always means the wave speed in the medium changed. This claim is false: A stationary source and moving observer require the observer-motion relation. Do not use the same denominator formula for every arrangement or import a sound formula into relativity.

Key:

Doppler effect: separate source motion from wave speed: For a source approaching a stationary observer along the line of sight, $f_{\text{observed}} = f_{\text{source}} \times v / (v - v_{\text{source}})$. Recession uses $v + v_{\text{source}}$ in the denominator. These are sound-wave models; light requires its appropriate relation.

Gravitational fields · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; full Physics guide acquired (84 PDF pages). Remaining guide, assessment and practical requirements retain their recorded holds.

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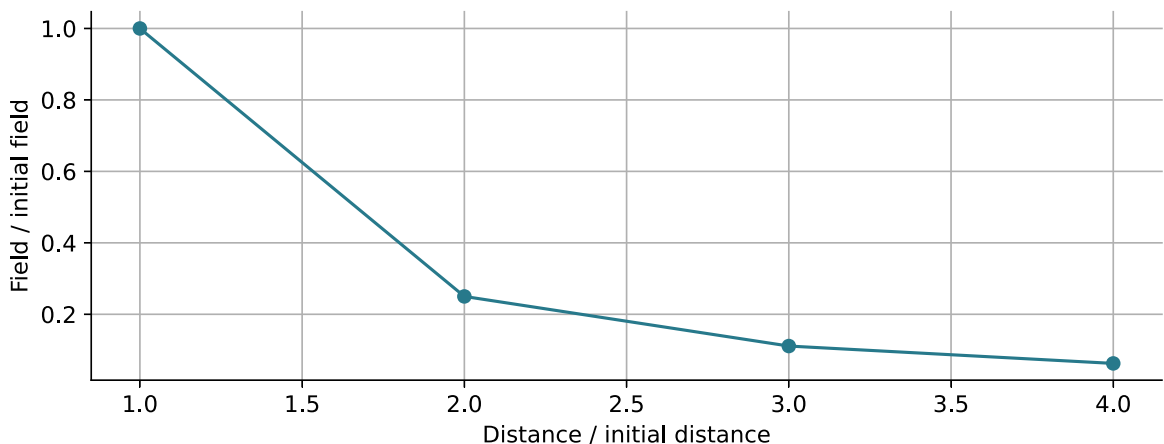
Gravitational fields and orbital motion

■ What would explain this observation?

- An orbiting satellite is continuously falling while moving sideways. Being in orbit does not require gravity to vanish.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **Gravitational field** strength is force per unit mass. A gravitational force can provide the **centripetal force** for a circular orbit. Field and potential describe different quantities.
- gravitational field: A description of gravitational force per unit mass; centripetal force: Net force toward the centre of a curved path.



■ Choose evidence that can test it

- For a point mass or outside a spherical mass, field strength follows an inverse-square distance dependence. Use distance from the centre, not height above the surface alone.
 - State the circular-orbit approximation and ignore atmospheric drag only when justified. Draw the force toward the central body and velocity tangential to the orbit. Do not add an outward force merely because the path is circular.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: field strength is 8 units at distance r from a spherical source. At $2r$, $g_2/g_1 = (r/2r)^2 = 1/4$. $g_2 = 8/4 = 2$ units. The gravitational force on a fixed test mass decreases in the same ratio.

Example:

Field strength is 18 units at r . Find it at $3r$ for an inverse-square field. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Weightlessness in an orbiting spacecraft means apparent weight is small in free fall, not that there is no gravitational field.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Gravity is zero everywhere a spacecraft experiences apparent weightlessness. This claim is false: Weightlessness in an orbiting spacecraft means apparent weight is small in free fall, not that there is no gravitational field.

Key:

Gravitational fields and orbital motion: For a point mass or outside a spherical mass, field strength follows an inverse-square distance dependence. Use distance from the centre, not height above the surface alone.

Electric and magnetic fields · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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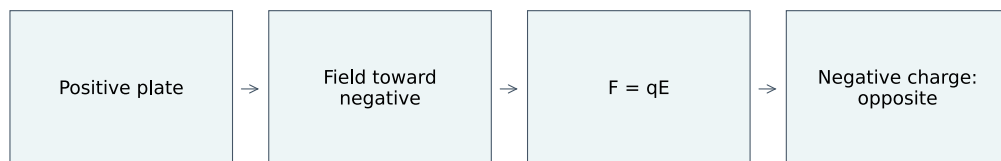
Electric fields: force and a positive test charge

■ What would explain this observation?

- A negatively charged particle moves opposite to the direction of the electric field. Field direction is defined using a positive **test charge**.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- **Electric field strength** is force per unit positive test charge. Like charges repel and unlike charges attract. Field lines point away from positive charges and toward negative charges. Closely spaced lines represent a stronger field within a consistently drawn diagram.
- electric field strength: Electric force per unit positive test charge; test charge: A small charge used to probe an electric field.



■ Choose evidence that can test it

- In a uniform field between ideal parallel plates, $E = V/d$ away from edge effects. The force is $F = qE$, so its direction reverses for a negative charge. Coulomb force between ideal point charges decreases with separation squared.
 - Sketch labelled plate polarities, field arrows and the charge before calculating. Convert separation to metres. In school, use simulations or approved low-voltage electrostatic models rather than exposed high-voltage equipment.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: plate potential difference is 120 V and separation is 0.020 m. $E = V/d = 6,000 \text{ V/m}$. A +2.0 microcoulomb charge experiences $F = qE = 0.012 \text{ N}$ along the field; a -2.0 microcoulomb charge experiences the same magnitude opposite to it.

Example:

Use $E = V/d$. Find E for 100 V across 0.025 m. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Field strength is a vector. Potential difference is energy per charge and is not the same quantity. A field-line drawing is a model, not a set of physical threads.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every charged particle experiences a force along the electric field direction. This claim is false: Field strength is a vector. Potential difference is energy per charge and is not the same quantity. A field-line drawing is a model, not a set of physical threads.

Key:

Electric fields: force and a positive test charge: In a uniform field between ideal parallel plates, $E = V/d$ away from edge effects. The force is $F = qE$, so its direction reverses for a negative charge. Coulomb force between ideal point charges decreases with separation squared.

Motion in electromagnetic fields · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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Magnetic forces: turn velocity without increasing speed

■ What would explain this observation?

- A charged particle curves in a uniform magnetic field. Its direction changes although the **magnetic force** alone does not increase its kinetic energy.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- The magnetic force magnitude is $F = |q|vB \sin\theta$. It is perpendicular to velocity and magnetic field, with direction determined by charge sign. For perpendicular entry into a uniform field, it can provide the centripetal force for circular motion.
- magnetic force: Force due to a magnetic field on a moving charge or current;
momentum : Mass multiplied by velocity in the classical model.



■ Choose evidence that can test it

- Equate magnetic force with mv^2/r to obtain $r = mv/(|q|B)$ for perpendicular motion. A stronger field makes a smaller radius at fixed momentum. Parallel entry gives zero magnetic force in this model.
 - Draw velocity, field and force as separate arrows using stated into/out-of-page conventions. Use supplied beam data or a simulation. Do not treat a current-carrying wire direction as identical to electron-motion direction.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a particle has $m = 2.0 \times 10^{-27}$ kg, $v = 3.0 \times 10^6$ m/s, $|q| = 1.0 \times 10^{-19}$ C and $B = 0.20$ T. $r = mv/(|q|B) = 0.30$ m. The calculation assumes non-relativistic motion and perpendicular entry.

Example:

Use $r = mv/(|q|B)$. For $m = 2 \times 10^{-27}$ kg, $v = 3 \times 10^6$ m/s, $|q| = 1 \times 10^{-19}$ C and $B = 0.20$ T, find r . Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- A magnetic force can change momentum direction without doing work. Adding an electric field can change the energy, so conclusions about a magnetic field alone do not cover every combined-field apparatus.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A magnetic force alone continuously increases the kinetic energy of a charged particle. This claim is false: A magnetic force can change momentum direction without doing work. Adding an electric field can change the energy, so conclusions about a magnetic field alone do not cover every combined-field apparatus.

Key:

Magnetic forces: turn velocity without increasing speed: Equate magnetic force with mv^2/r to obtain $r = mv/(|q|B)$ for perpendicular motion. A stronger field makes a smaller radius at fixed momentum. Parallel entry gives zero magnetic force in this model.

Induction · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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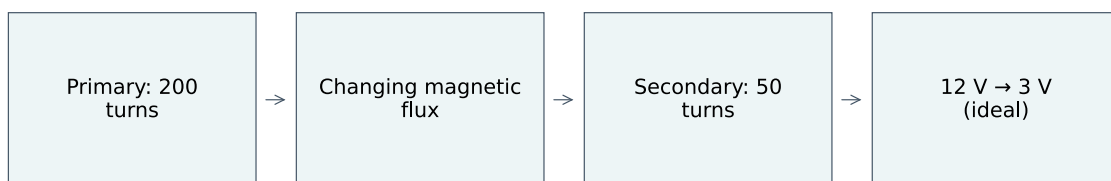
Fields, motors and induction

■ What would explain this observation?

- A magnet beside a wire does not always produce a current. An induced electromotive force depends on changing magnetic flux linkage.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- A field describes a force effect at positions in space. A current-carrying conductor in a magnetic field can experience a force. Electromagnetic **induction** occurs when magnetic flux linkage changes.
- induction: Creation of emf by changing flux linkage; **transformer** : A device transferring energy between coils through changing flux.



■ Choose evidence that can test it

- Changing field strength, coil area, orientation or relative motion can change flux linkage. Lenz law describes an induced effect opposing the change producing it, consistent with energy conservation.
 - Use a coil and sensitive meter to compare magnet motion in each direction. Record that a stationary arrangement gives no induced signal. Use approved low-voltage supplies for motor demonstrations.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a transformer has 200 primary turns, 50 secondary turns and 12 V primary voltage. For an ideal transformer, $V_s/V_p = N_s/N_p$. $V_s = V_p N_s/N_p = 12 \times 50/200 = 3.0$ V. Real transformers also dissipate energy.

Example:

An ideal transformer has $N_p=400$, $N_s=100$ and $V_p=20$ V. Find V_s . Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- A transformer needs changing magnetic flux; a steady DC input does not provide continuous transformer action. Magnetic field direction is not automatically the direction of force.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A steady DC input produces continuous ideal transformer action. This claim is false: A transformer needs changing magnetic flux; a steady DC input does not provide continuous transformer action. Magnetic field direction is not automatically the direction of force.

Key:

Fields, motors and induction: Changing field strength, coil area, orientation or relative motion can change flux linkage. Lenz law describes an induced effect opposing the change producing it, consistent with energy conservation.

Structure of the atom · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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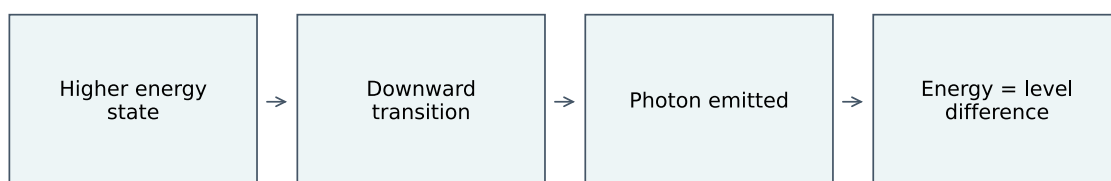
Atomic models and line spectra

■ What would explain this observation?

- An excited gas produces separate coloured lines rather than every wavelength. The pattern is evidence for discrete atomic energy differences.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- Atoms have a small positive nucleus and electrons. Emission and absorption spectra arise from transitions between discrete **energy levels**. A photon energy equals the level difference and obeys $E = hf$.
- **emission spectrum** : Wavelength pattern of radiation emitted by a source; energy level : An allowed energy state in a model.



■ Choose evidence that can test it

- An emitted photon corresponds to a transition to a lower energy level. Absorption requires a compatible energy difference. Rutherford scattering supported a small dense nucleus, but that experiment alone did not establish the complete quantum model.
 - Read a labelled energy-level diagram before calculating. Keep joules and electronvolts distinct and use the given constants. Compare attributed spectra at a common wavelength scale and avoid looking at unsafe light sources.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: energy levels are -6.0 and -2.0 eV. A downward transition releases 4.0 eV $= 6.4 \times 10^{-19}$ J using $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$. With $h = 6.4 \times 10^{-34} \text{ J s}$ for this rounded exercise, frequency is $1.0 \times 10^{15} \text{ Hz}$.

Example:

Levels are -7.0 and -2.0 eV. Find the energy emitted in the downward transition. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Negative bound-state energies are relative to a chosen zero; they do not mean a negative photon energy is emitted. A larger downward energy difference gives higher frequency.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A negative bound-state energy means an emitted photon has negative energy. This claim is false: Negative bound-state energies are relative to a chosen zero; they do not mean a negative photon energy is emitted. A larger downward energy difference gives higher frequency.

Key:

Atomic models and line spectra: An emitted photon corresponds to a transition to a lower energy level. Absorption requires a compatible energy difference. Rutherford scattering supported a small dense nucleus, but that experiment alone did not establish the complete quantum model.

Quantum physics · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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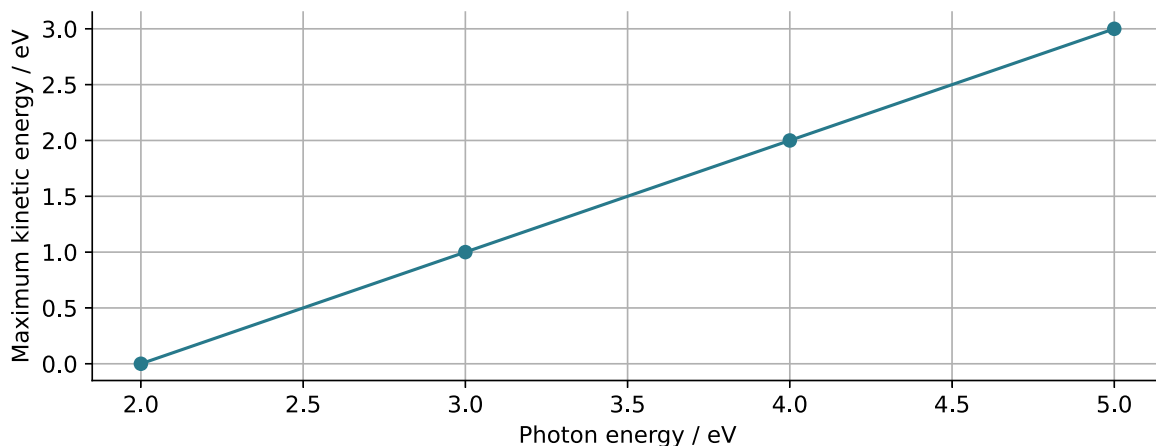
Photons and the photoelectric effect

■ What would explain this observation?

- Bright low-frequency light can fail to eject electrons while dim higher-frequency light succeeds. **Photon** energy depends on frequency, not intensity alone.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- A photon has energy proportional to frequency. The **work function** is the minimum energy needed to release an electron from a surface. Above threshold, excess photon energy can become electron kinetic energy.
- photon: A quantum of electromagnetic radiation; work function: Minimum surface energy needed to release an electron.



■ Choose evidence that can test it

- Use photon energy = Planck constant $\times$ frequency. Maximum kinetic energy = photon energy - work function. Increasing intensity at fixed frequency increases photon arrival rate, not individual photon energy.
 - Read axes carefully on a stopping-potential or kinetic-energy graph. Identify threshold frequency from the zero-energy intercept. State the metal and experimental conditions because work function is material-specific.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: photon energy is 5.0 electronvolts and work function is 2.0 electronvolts. Maximum kinetic energy = photon energy - work function = 5.0 - 2.0 = 3.0 electronvolts. A 1.5 electronvolt photon cannot cause emission from that surface in this model.

Example:

Photon energy is 4.8 eV and work function 2.1 eV. Find maximum kinetic energy. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Electrons do not accumulate many sub-threshold photons in the elementary single-photon model. Do not confuse photon number with photon energy.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Doubling light intensity doubles each photon energy at fixed frequency. This claim is false: Electrons do not accumulate many sub-threshold photons in the elementary single-photon model. Do not confuse photon number with photon energy.

Key:

Photons and the photoelectric effect: Use photon energy = Planck constant $\times$ frequency. Maximum kinetic energy = photon energy - work function. Increasing intensity at fixed frequency increases photon arrival rate, not individual photon energy.

Radioactive decay · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

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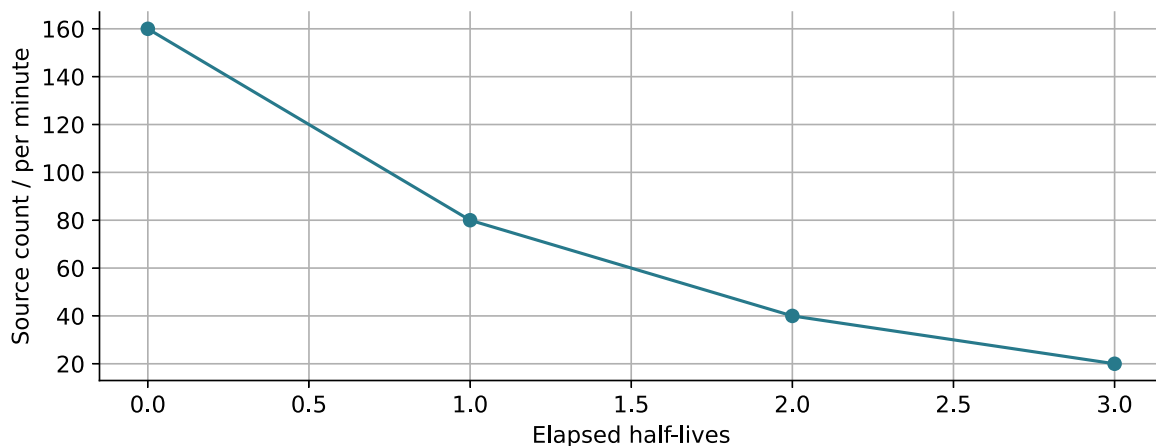
Nuclear changes and radiation evidence

■ What would explain this observation?

- A detector records counts even when the classroom source is removed. Background must be considered before attributing every count to the source.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- Radioactive decay is spontaneous and random for an individual nucleus. **Half-life** describes the time for half the undecayed nuclei in a large population to decay, or for background-corrected activity to halve.
- half-life: Time for activity or undecayed population to halve; **background radiation** : Radiation measured apart from the investigated source.



■ Choose evidence that can test it

- Subtract background counts measured over the same time interval. Distinguish irradiation from contamination. Shielding, distance and reduced exposure time can reduce risk under a school-controlled procedure.
 - Use teacher-managed sources and the school radiation rules. Record count duration and repeat background measurements. Do not extrapolate a half-life from one nucleus or from uncorrected readings.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: measured count rate falls from 100 to 55 counts per minute; background is 10. Source rates are 90 and 45, so one half-life has elapsed. Without subtraction, 55/100 would obscure the exact half in this example.

Example:

An initial source count is 160 per minute. Find it after three half-lives. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- An irradiated object is not automatically radioactive. A half-life does not predict the exact decay time of one nucleus.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Half-life predicts the exact decay time of an individual nucleus. This claim is false: An irradiated object is not automatically radioactive. A half-life does not predict the exact decay time of one nucleus.

Key:

Nuclear changes and radiation evidence: Subtract background counts measured over the same time interval. Distinguish irradiation from contamination. Shielding, distance and reduced exposure time can reduce risk under a school-controlled procedure.

Fission · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; full Physics guide acquired (84 PDF pages). Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: read the stated quantities and units, use arithmetic and the model conditions below. Each lesson develops its own method before independent transfer.

These are original or explicitly fictional teaching examples, not actual measurements or completed assessed learner investigations.

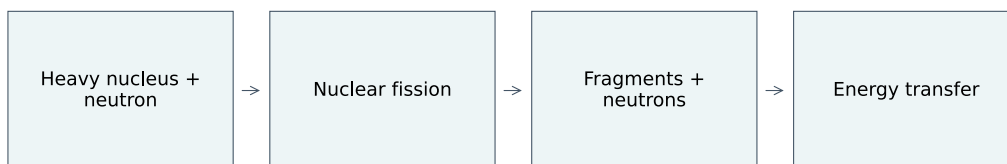
Fission : conserve charge and nucleons, account for energy

■ What would explain this observation?

- A neutron can trigger a heavy nucleus to split, releasing energy and further neutrons. Whether the process becomes a **chain reaction** depends on what happens to those neutrons.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- In nuclear **fission** a heavy nucleus splits into lighter nuclei. Proton number and nucleon number balance in a nuclear equation. The total rest mass can decrease; the difference corresponds to released energy through $E = \Delta mc^2$.
- fission: Splitting of a heavy nucleus into lighter nuclei; chain reaction: A sequence in which products initiate further events.



■ Choose evidence that can test it

- Separate conservation of nucleon number from conservation of total energy. Released neutrons may initiate further fissions, escape or be absorbed. A controlled reactor and an uncontrolled chain reaction have different neutron-management conditions.
 - Balance a supplied nuclear equation, use the specified mass data and identify the system. Analyse models or published reactor data; this is not a school attempt to produce fission or handle reactor materials.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: U-235 absorbs one neutron, forming Ba-141, Kr-92 and three neutrons. Nucleon balance: $235+1 = 141+92+3 = 236$. Proton balance: $92 = 56+36$. A mass decrease of 2.0×10^{-28} kg corresponds to 1.8×10^{-11} J using $c=3.0 \times 10^8$ m/s.

Example:

A U-235 nucleus plus one neutron produces fragments with mass numbers 141 and 92. How many neutrons balance the equation? Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- Mass number is not a precise mass in kilograms. Balanced integer labels alone do not calculate the released energy. Radioactive decay and neutron-induced fission are not interchangeable descriptions.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A balanced nucleon-number equation alone gives the energy release in joules. This claim is false: Mass number is not a precise mass in kilograms. Balanced integer labels alone do not calculate the released energy. Radioactive decay and neutron-induced fission are not interchangeable descriptions.

Key:

Fission: conserve charge and nucleons, account for energy: Separate conservation of nucleon number from conservation of total energy. Released neutrons may initiate further fissions, escape or be absorbed. A controlled reactor and an uncontrolled chain reaction have different neutron-management conditions.

Fusion and stars · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; full Physics guide acquired (84 PDF pages). Remaining guide, assessment and practical requirements retain their recorded holds.

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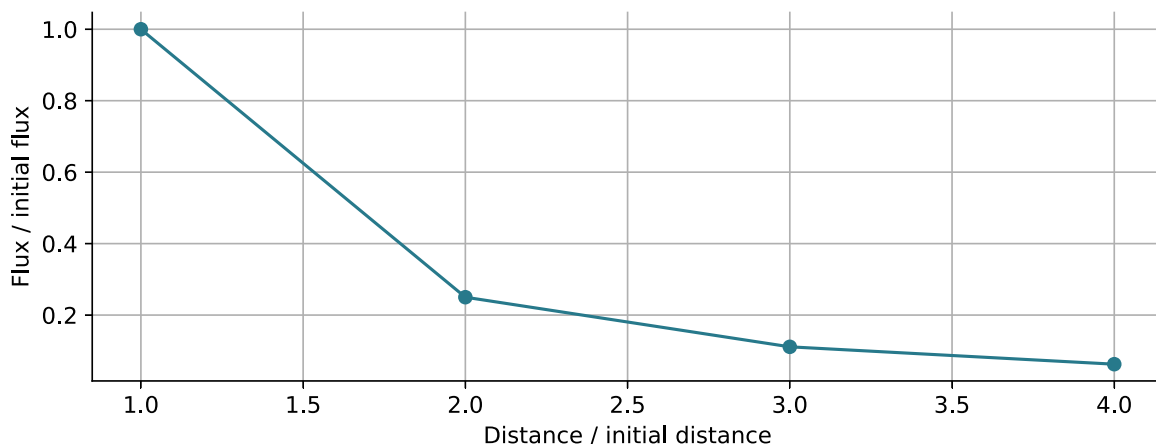
Stars, radiation and scale

■ What would explain this observation?

- Two stars can have the same apparent brightness while having different luminosities. Distance changes the **flux** reaching an observer.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **Luminosity** is total power emitted; flux is power received per area. A stellar spectrum carries information about surface temperature and composition. Fusion transfers energy as light nuclei combine.
- luminosity: Total emitted power; flux: Power received per unit area.



■ Choose evidence that can test it

- For isotropic emission without absorption, flux follows an inverse-square relationship with distance. Observed brightness alone therefore cannot establish luminosity.
 - Keep distance units consistent, identify which quantities are intrinsic to the star, and distinguish observational evidence from a model of stellar evolution. Do not confuse a red giant stage with every possible final remnant.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: distance doubles while luminosity remains fixed. Use F proportional to $1/d^2$. Flux ratio = $1/2^2 = 1/4$. A flux of 12 units becomes 3 units. This assumes no change in absorption or source output.

Example:

A source gives flux 18 units. Find flux at three times the distance. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- The Sun is not expected to become a supernova. Redshift can support cosmological expansion; it does not mean every nearby object must move away from every observer.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Apparent brightness alone always determines a star luminosity. This claim is false: The Sun is not expected to become a supernova. Redshift can support cosmological expansion; it does not mean every nearby object must move away from every observer.

Key:

Stars, radiation and scale: For isotropic emission without absorption, flux follows an inverse-square relationship with distance. Observed brightness alone therefore cannot establish luminosity.

Experimental programme · supported focus

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; full Physics guide acquired (84 PDF pages). Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: read the stated quantities and units, use arithmetic and the model conditions below. Each lesson develops its own method before independent transfer.

These are original or explicitly fictional teaching examples, not actual measurements or completed assessed learner investigations.

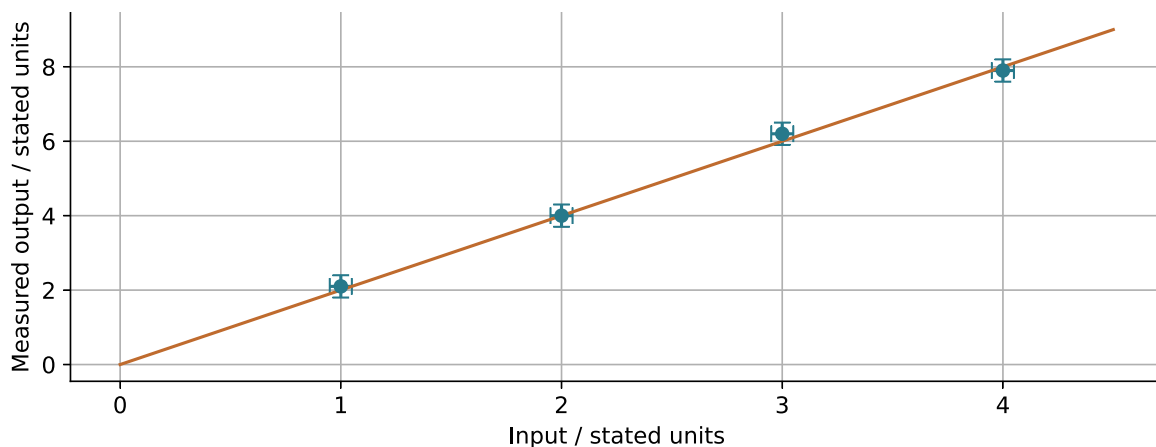
Uncertainty, gradients and model testing

■ What would explain this observation?

- A line passing near every data point is useful, but its gradient can still be uncertain. A graph is evidence for a model within the measurement range.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- Random variation makes repeated readings differ. **Systematic error** shifts results consistently. Absolute **uncertainty** has the measured unit; relative or percentage uncertainty compares uncertainty with the measured value.
- uncertainty: A quantified limitation on a measured result; systematic error: A consistent measurement bias.



■ Choose evidence that can test it

- For a product or quotient, adding fractional uncertainties is a common maximum-uncertainty approximation. For a difference, add absolute uncertainties. A nonzero intercept can reveal an offset or an incomplete model.
 - Show units on axes and choose a sensible scale. Plot uncertainty bars where justified, draw a best-fit line rather than joining every point, and estimate steepest and shallowest plausible gradients when the course method calls for them.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: length = 50.0 mm with uncertainty 1.0 mm. Percentage uncertainty = $\text{absolute uncertainty}/\text{value} \times 100 = 1.0/50.0 \times 100 = 2.0\%$. For a quotient of two independently measured quantities with maximum percentage uncertainties 2% and 3%, the summed maximum estimate is 5%.

Example:

A 40 cm reading has an absolute uncertainty of 1 cm. Find percentage uncertainty. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- Repeating readings reduces random uncertainty in a mean but does not automatically remove a zero error. Do not quote more decimal places than your measurement can support.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Repeating a measurement always removes a calibration offset. This claim is false: Repeating readings reduces random uncertainty in a mean but does not automatically remove a zero error. Do not quote more decimal places than your measurement can support.

Key:

Uncertainty, gradients and model testing: For a product or quotient, adding fractional uncertainties is a common maximum-uncertainty approximation. For a difference, add absolute uncertainties. A nonzero intercept can reveal an offset or an incomplete model.