GIOPHYSICS ORIGINAL EXAMINATION SERIES

# *Cambridge IGCSE Physics*

## Mock examination pack

Two complete original papers with supplied-data graphs, generous working space, and a detailed teacher marking guide.

| PAPERS | QUESTIONS | MARKS | TEACHER KEY |
|---|---|---|---|
| **2** | **20** | **240** | **Included** |

INSIDE THIS PACK

PAPER 1

### Cambridge IGCSE Physics · Extended Paper 1

160 minutes | 10 questions | 116 marks

*A balanced original practice paper with long-form reasoning, calculations, and supplied-data graphs.*

PAPER 2

### Cambridge IGCSE Physics · Extended Paper 2

170 minutes | 10 questions | 124 marks

*A balanced original practice paper with long-form reasoning, calculations, and supplied-data graphs.*

**Original practice - clearly independent**

Every question and solution was independently written by GioPhysics. This pack is not an awarding-body document and does not reproduce a released examination question or mark scheme.

# *Cambridge IGCSE Physics · Extended Paper 1*

A balanced original practice paper with long-form reasoning, calculations, and supplied-data graphs.

| | | | |
|---|---|---|---|
| CANDIDATE NAME | | | |
| CLASS / GROUP | | DATE | |

| PAPER | TIME | QUESTIONS | TOTAL MARKS |
|---|---|---|---|
| **1** | **160 min** | **10** | **116** |

## INSTRUCTIONS

- Answer every question and show all working.
- Use SI units unless a question states otherwise.
- Read graph scales carefully and give answers to a sensible number of significant figures.
- Answer in the spaces provided and label any additional pages clearly.

## INFORMATION

- The total mark for this paper is 116.
- Marks for each task are shown in brackets.
- The detailed marking guide begins after Paper 2.

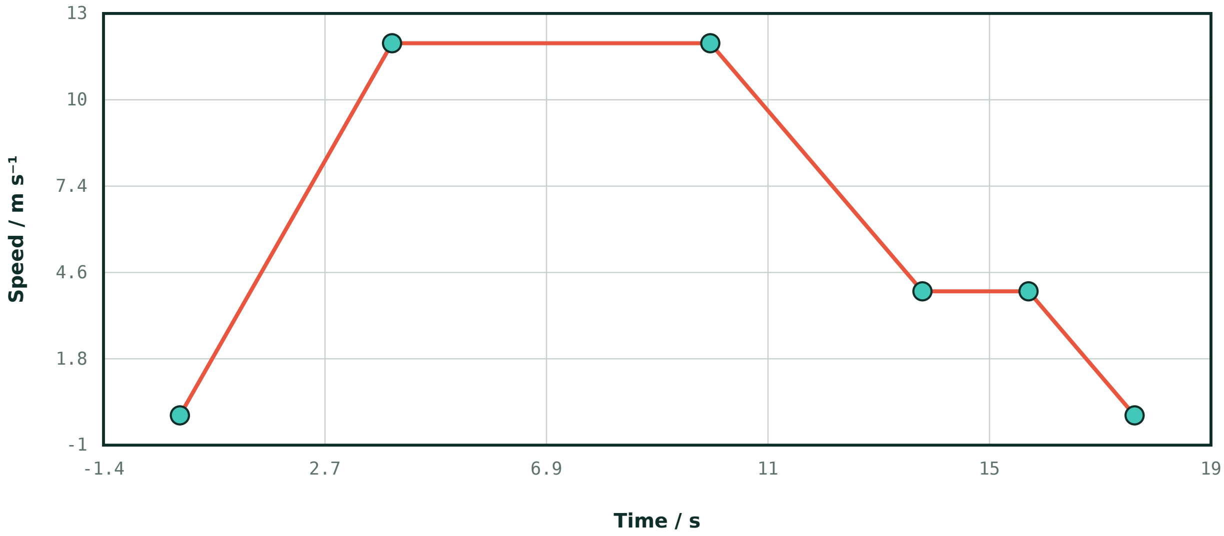
# Electric-bus speed-time evidence

[12]

An electric bus has these (time in s, speed in m/s) readings: (0, 0), (4, 12), (10, 12), (14, 4), (16, 4), (18, 0). Join successive points with straight lines. (a) Describe the motion. (b) Calculate acceleration from 0-4 s and 10-14 s. (c) Calculate total distance. (d) Calculate average speed. (e) Explain why speed data alone may not give displacement.

**Electric-bus speed**

*Speed recorded over an eighteen-second journey.*




ANSWER SPACE

# *Density of an irregular fitting*

**[10]**

A fitting has mass 156.4 g. Water in a measuring cylinder rises from 48.0 $cm^3$ to 67.5 $cm^3$ when it is submerged. (a) Calculate density in $g/cm^3$ and $kg/m^3$. (b) Explain how to make the measurements reliably. (c) A trapped bubble occupies 1.2 $cm^3$. Calculate corrected density and explain the original error direction. (d) Explain why dissolving material needs another method.

ANSWER SPACE

# *Pumped-storage energy chain*

**[12]**

A station raises $2.5 \times 10^6$ kg of water through 120 m in 45 min. Pump efficiency is 78%; generation efficiency is 70%. Take g = 9.8 N/kg. (a) Calculate stored GPE. (b) Calculate pump input energy and power. (c) Calculate generated electrical output. (d) Calculate round-trip efficiency. (e) Explain why the system remains useful below 100% efficiency.

ANSWER SPACE

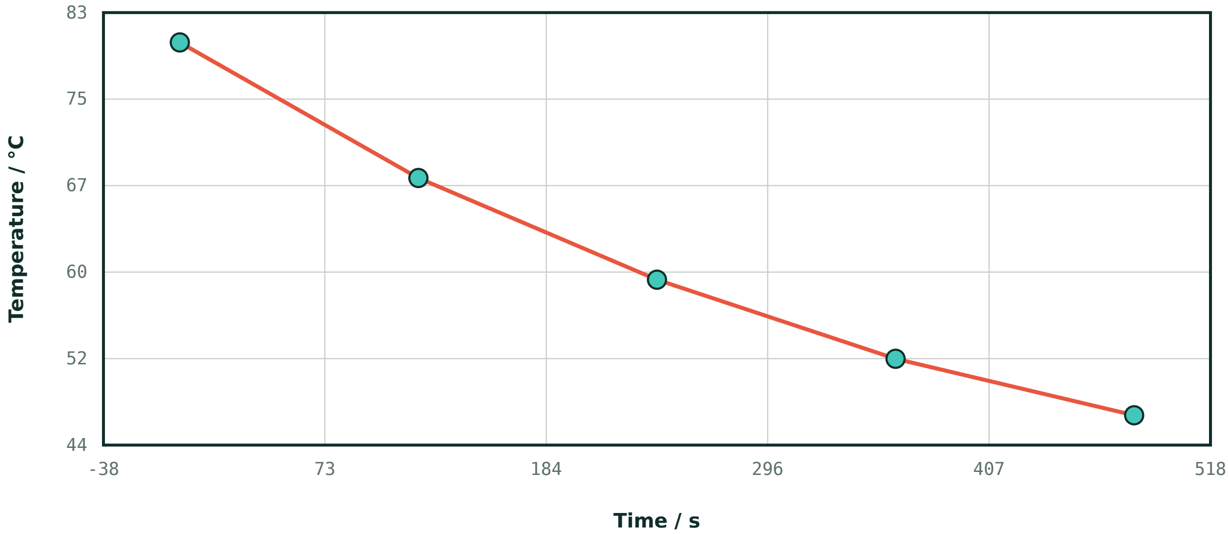
# *Designing a fair insulation comparison*

[11]

A covered beaker cools in a 20 °C room with (time in s, temperature in °C) readings (0, 80), (120, 68), (240, 59), (360, 52), (480, 47). (a) Find mean cooling rate over the first and final 240 s. (b) Explain the difference. (c) Design a fair comparison of two insulation materials, including controls, repeats and dependent variable. (d) Explain why equal thickness is not always the fairest engineering comparison.

### Cooling curve

*Covered-beaker temperature in a room at 20 °C.*



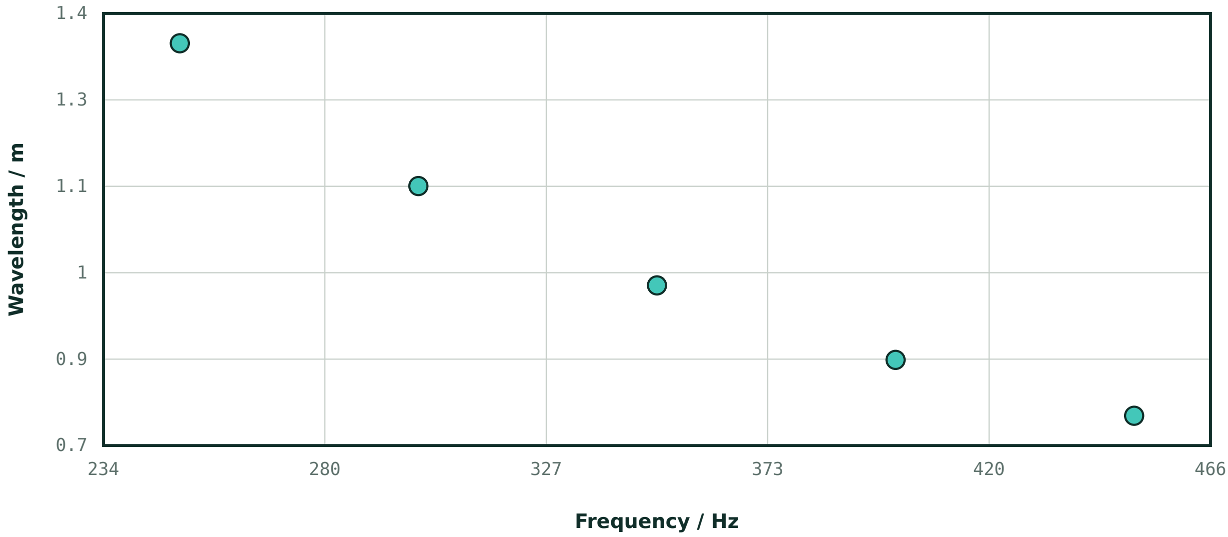

ANSWER SPACE

# *Sound speed from wavelength evidence* [11]

A loudspeaker gives (frequency in Hz, wavelength in m) measurements (250, 1.36), (300, 1.13), (350, 0.97), (400, 0.85), (450, 0.76). (a) Estimate sound speed from two readings. (b) Test another reading for consistency. (c) Explain frequency and wavelength changes on entering warmer air. (d) Describe a stationary-wave wavelength method and uncertainty reduction.

### Sound wavelength data

*Wavelength at five frequency settings.*




ANSWER SPACE

# *Electromagnetic choices in rescue and medicine*

[10]

Choose suitable electromagnetic regions for satellite communication, thermal imaging through smoke and imaging a broken bone, explaining each. (a) Calculate frequency of 3.0 cm satellite radiation using $c = 3.0 \times 10^8$ m/s. (b) Order the chosen regions by photon energy. (c) Explain one hospital safety control. (d) State what all three regions have in common when travelling through a vacuum.

ANSWER SPACE

# *Safe parallel lighting circuit*

[13]

Three 12 V, 24 W lamps are parallel across 12 V. (a) Find current in each and total current. (b) Find equivalent resistance. (c) Explain why parallel is preferable to series. (d) Choose a fuse from 3 A, 5 A and 10 A. (e) One lamp fails open: describe others and total current. (f) Explain live-wire fuse and switch placement in a mains version.

ANSWER SPACE

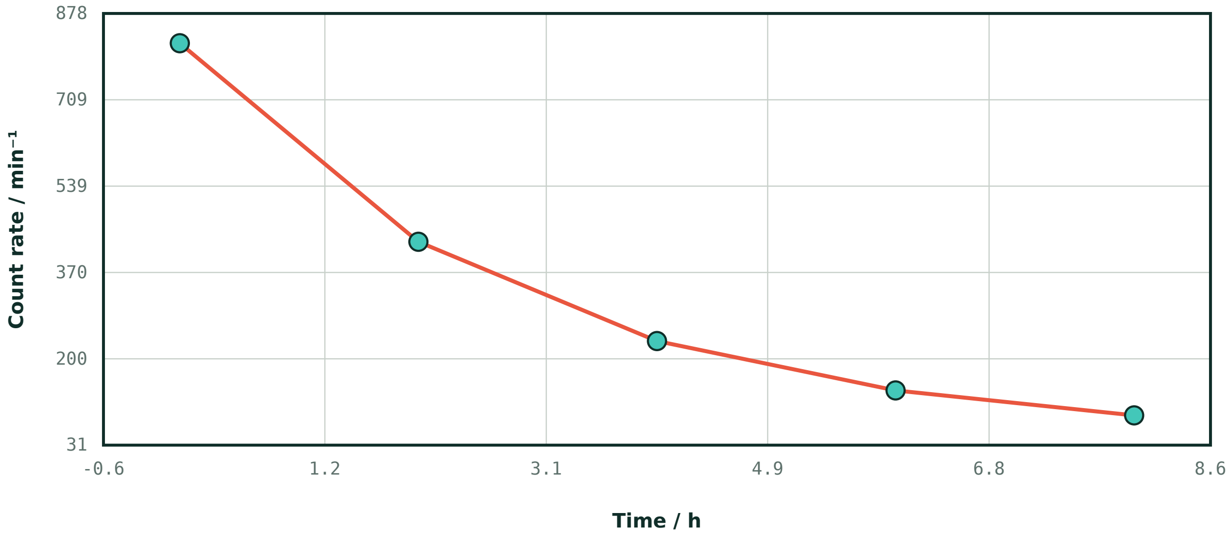
# *Half-life from count-rate data*

[12]

With a source present, a detector gives (time in h, count/min) readings (0, 820), (2, 430), (4, 235), (6, 138), (8, 89). Background is 40 counts/min. (a) Correct the readings and determine half-life. (b) Predict measured rate at 12 h. (c) Explain scatter and a reliable method. (d) Distinguish irradiation from contamination and state precautions.

**Count-rate decay**

*Detector readings including background.*




ANSWER SPACE

# *Circular satellite orbit*

**[11]**

A satellite orbits at radius $4.2 \times 10^7$ m and speed $3.08 \times 10^3$ m/s. Earth's radius is $6.4 \times 10^6$ m. (a) Find altitude. (b) Find period in hours. (c) Identify centripetal force. (d) Explain larger-radius circular speed and period changes. (e) Explain astronaut apparent weightlessness.

ANSWER SPACE

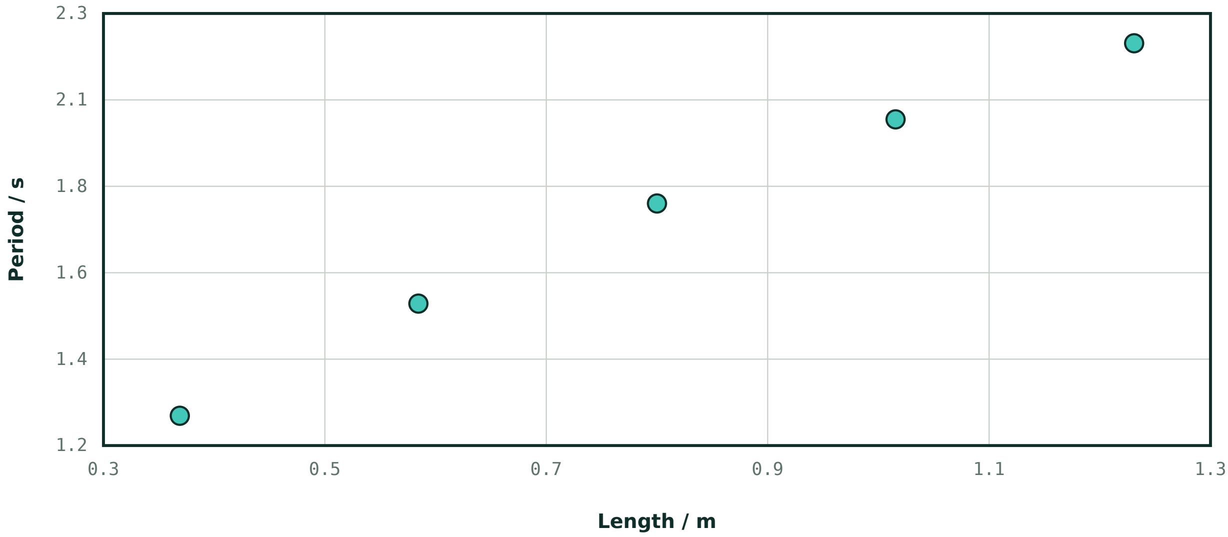
# Pendulum model investigation

[14]

A student measures (length in m, period in s) (0.4, 1.27), (0.6, 1.55), (0.8, 1.8), (1, 2.01), (1.2, 2.2). Model: $T = 2\pi\sqrt{(L/g)}$. (a) Explain a $T^2$-against-$L$ plot. (b) Use $L = 1.00$ m to estimate g. (c) Give a reliable complete method and controls. (d) Explain graph extraction of g and a non-zero intercept. (e) Explain why large amplitude invalidates the model.

**Pendulum period**

*Mean period at five effective lengths.*




ANSWER SPACE

# Cambridge IGCSE Physics · Extended Paper 2

A balanced original practice paper with long-form reasoning, calculations, and supplied-data graphs.

| | | | |
|---|---|---|---|
| CANDIDATE NAME | | | |
| CLASS / GROUP | | DATE | |

| PAPER | TIME | QUESTIONS | TOTAL MARKS |
|---|---|---|---|
| **2** | **170 min** | **10** | **124** |

## INSTRUCTIONS

- Answer every question and show all working.
- Use SI units unless a question states otherwise.
- Read graph scales carefully and give answers to a sensible number of significant figures.
- Answer in the spaces provided and label any additional pages clearly.

## INFORMATION

- The total mark for this paper is 124.
- Marks for each task are shown in brackets.
- The detailed marking guide begins after Paper 2.

*GioPhysics original practice. Not an official MYP, Cambridge, College Board, or IB examination paper.*

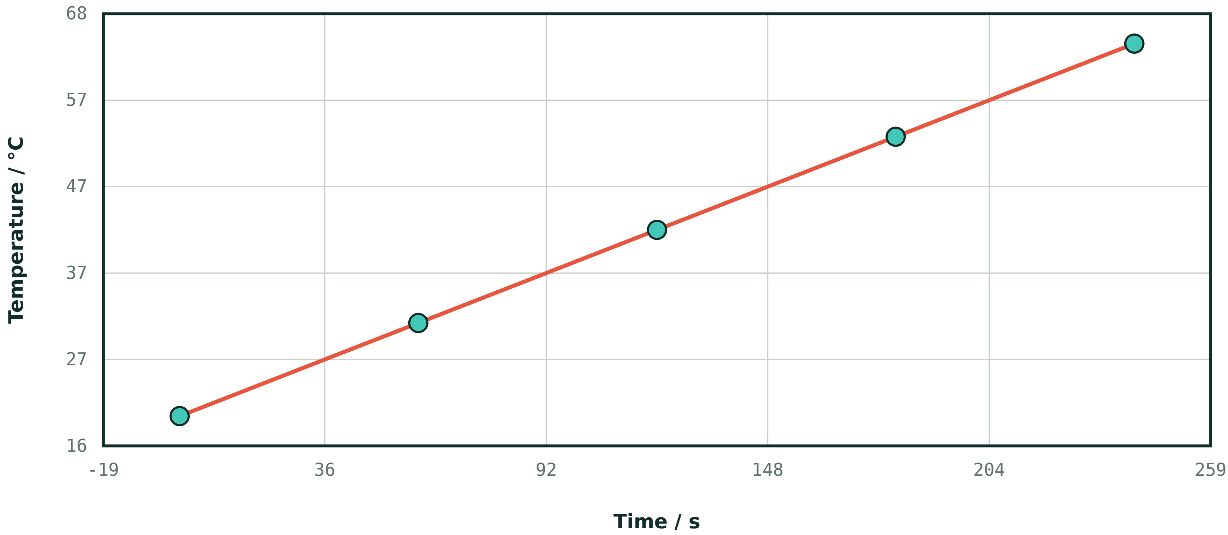
# Specific heat capacity from a heating curve

[12]

A 1.50 kg block is heated by a 300 W heater. Its (time in s, temperature in °C) readings are (0, 20), (60, 31), (120, 42), (180, 53), (240, 64). (a) Find mean temperature-rise rate. (b) Assuming no loss, calculate specific heat capacity. (c) The accepted value is 820 J/(kg °C). Calculate mean energy-loss rate. (d) Explain two improvements and why the straight line cannot continue indefinitely.

**Block heating curve**

*Temperature under constant heater power.*




ANSWER SPACE

# *Vehicle rebound and collision safety*

**[14]**

A 1200 kg vehicle moving at 18 m/s strikes a barrier and rebounds at 2.0 m/s. Contact lasts 0.25 s. (a) Calculate momentum before and after, with initial direction positive. (b) Calculate impulse and average force. (c) Relate the force on the barrier to that on the vehicle. (d) A new barrier gives the same momentum change in 0.60 s. Calculate its average force, explain the safety advantage and state one model limitation.

ANSWER SPACE

# Hydraulic lift and rotational balance

[11]

A hydraulic lift has piston areas 4.0 $cm^2$ and 240 $cm^2$. The input force is 180 N and the output platform weighs 1200 N. (a) Calculate transmitted pressure. (b) Calculate output force and maximum added load in equilibrium. (c) Explain the output displacement. (d) An off-centre load rests on two supports. State the complete equilibrium conditions and explain how support forces are found.

ANSWER SPACE

# *Heating gas in a rigid canister*

**[10]**

A rigid sealed canister contains gas at 100 kPa and 290 K. It is heated to 348 K. (a) Calculate final pressure. (b) Explain the change using particles. (c) Explain the difference with a freely moving piston. (d) State two reasons the ideal particle model may fail at very high pressure.

ANSWER SPACE

# *Refraction through a glass block*

**[12]**

A ray enters glass from air at 50.0° to the normal and refracts at 30.0°. (a) Calculate refractive index. (b) Calculate critical angle. (c) Explain the parallel but displaced emerging ray. (d) Describe a ray-pin experiment, precautions and a graph method for refractive index.

ANSWER SPACE

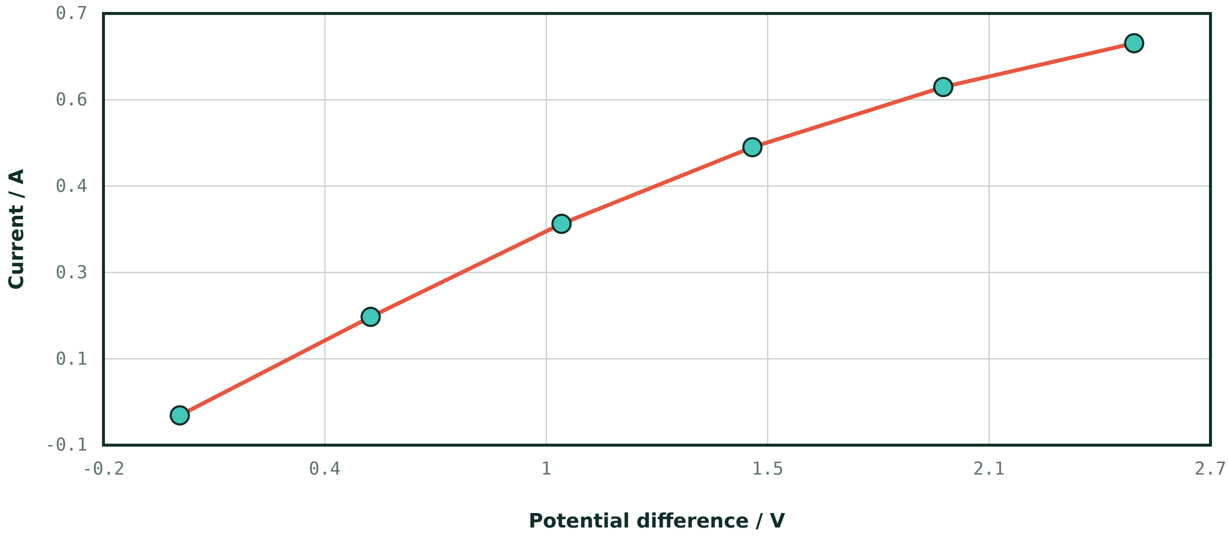
# *Filament-lamp characteristic*

[12]

A lamp gives (potential difference in V, current in A) readings (0, 0), (0.5, 0.18), (1, 0.35), (1.5, 0.49), (2, 0.6), (2.5, 0.68). (a) Calculate resistance at 0.50 V and 2.50 V. (b) Explain the change. (c) Find power at 2.0 V and energy in 5.0 min. (d) Describe a circuit and safe method for both signs of the characteristic.

### Lamp current-voltage data

*Current measured at increasing lamp potential differences.*




ANSWER SPACE

# *Generator and high-voltage transmission*

[14]

A 200-turn coil changes flux per turn from $+3.0 \times 10^{-4}$ Wb to $-3.0 \times 10^{-4}$ Wb in 0.020 s. (a) Find mean induced e.m.f. (b) Explain polarity and two output improvements. (c) An ideal transformer raises 120 V to 6000 V while transmitting 24 kW. Find both currents. (d) For cable resistance 8.0 Ω, compare high-voltage loss with direct 120 V transmission. (e) Explain the grid advantage.

ANSWER SPACE

# *Nuclear equations and radiation evidence*

**[10]**

$^{226}_{88}Ra$ emits alpha and its daughter then emits beta-minus. (a) Write equations using X and Y for daughters. (b) Explain the beta-minus nuclear change. (c) Compare alpha, beta and gamma ionisation and penetration. (d) Explain why gamma changes neither proton nor nucleon number and why heating does not trigger decay.

ANSWER SPACE

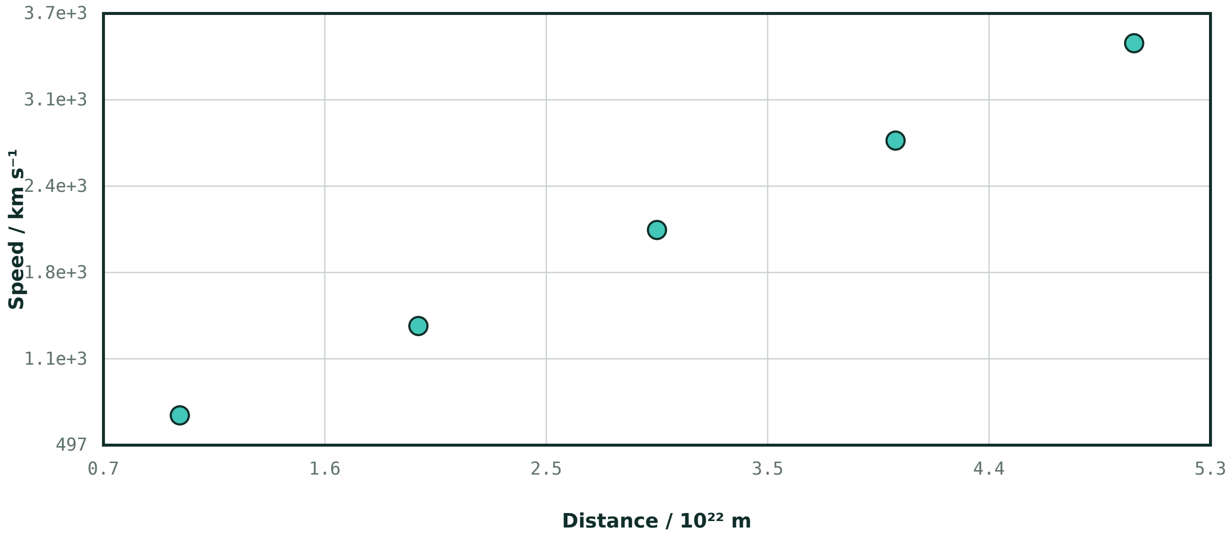
# Galaxy recession and expansion age

[13]

Original teaching data give (distance in $10^{22}$ m, speed in km/s) (1, 720), (2, 1390), (3, 2110), (4, 2780), (5, 3510). (a) Find endpoint gradient. (b) Convert it to $s^{-1}$ and estimate 1/H in years using $3.16 \times 10^7$ s/year. (c) Explain redshift evidence. (d) Explain sample scatter. (e) State limitations of treating 1/H as exact cosmic age.

### Illustrative galaxy data

*Original simplified recession-speed measurements.*




ANSWER SPACE

# *Household solar-storage audit*

**[16]**

A home uses a 1.8 kW heater for 2.5 h, six 9 W lamps for 5.0 h, and a 120 W refrigerator for an effective 8.0 h daily. Solar supplies 6.2 kWh through a battery of 82% round-trip efficiency. (a) Find each and total demand. (b) Find useful battery energy and grid shortfall. (c) Convert demand to joules. (d) At 230 V find heater current and choose 3, 5, 10 or 13 A fuse. (e) Explain two reasons this balance does not prove off-grid operation.

ANSWER SPACE

TEACHER COPY

# *Detailed marking guide*

Cambridge IGCSE Physics

### How to use this guide

Award credit for equivalent correct physics expressed clearly. The numbered solution stages show a complete route, not the only valid route. Use the stated common mistake as feedback rather than as a penalty beyond the lost physics marks.

| PAPERS | QUESTIONS | TOTAL MARKS |
| --- | --- | --- |
| **2** | **20** | **240** |

*This guide is original GioPhysics material. It is not an official awarding-body mark scheme and must not be used to predict a grade boundary.*

# *Electric-bus speed-time evidence*

[12]

EXPECTED CONCLUSION

**Accelerations +3.0 m/s² and -2.0 m/s²; distance 140 m; average speed 7.78 m/s; displacement also needs direction.**

REASONING AND MARKING CHECKPOINTS

01

The rising line from 0-4 s is uniform acceleration from rest, 4-10 s is constant speed, 10-14 s is uniform slowing, 14-16 s is constant slower motion and 16-18 s is uniform slowing to rest.

02

Acceleration is graph gradient: $(12 - 0)/4 = +3.0$ m/s² initially and $(4 - 12)/(14 - 10) = -2.0$ m/s² during the first slowing interval. The sign describes the chosen direction.

03

Distance is area below the graph: $\frac{1}{2}(4)(12) + (6)(12) + \frac{1}{2}(12 + 4)(4) + (2)(4) + \frac{1}{2}(2)(4) = 24 + 72 + 32 + 8 + 4 = 140$ m.

04

Average speed is total distance divided by total time: $140/18 = 7.78$ m/s. Averaging the highest and lowest speeds would ignore the unequal durations spent at each speed.

05

Speed has no sign. If the bus reverses, distance still accumulates positively but displacement must subtract travel in the opposite direction; a velocity-time graph or explicit directions are required.

COMMON MISTAKE

*Reading distance from the graph's final height instead of summing the triangular, rectangular and trapezium areas.*

# *Density of an irregular fitting*

[10]

EXPECTED CONCLUSION

**8.02 g/cm³ = 8.02 × 10³ kg/m³; corrected density 8.55 g/cm³. A bubble makes apparent volume too large and density too small.**

REASONING AND MARKING CHECKPOINTS

01

The fitting volume is the water displacement, 67.5 - 48.0 = 19.5 cm³. It must be fully submerged without overflow because this difference is being equated to object volume.

02

Density is $\rho = m/V = 156.4/19.5 = 8.02$ g/cm³. Since 1 g/cm³ equals 1000 kg/m³, the SI density is $8.02 \times 10^3$ kg/m³.

03

Zero the balance, dry the fitting before weighing, read the cylinder at eye level at the bottom of the meniscus and repeat. A narrower graduated cylinder can reduce the percentage volume uncertainty.

04

The bubble is not metal, so corrected volume = 19.5 - 1.2 = 18.3 cm³. Corrected density = 156.4/18.3 = 8.55 g/cm³; the original oversized denominator biased density downward.

05

If material dissolves, both specimen mass and liquid composition change, and final volume is not simply water plus original solid volume. Use an inert displacement liquid or geometric method instead.

COMMON MISTAKE

*Using 67.5 cm³ as the object's volume, or adding the bubble volume when the needed correction is to remove it.*

# *Pumped-storage energy chain*

[12]

EXPECTED CONCLUSION

**Stored $2.94 \times 10^9$ J; pump input $3.77 \times 10^9$ J; power 1.40 MW; output $2.06 \times 10^9$ J; round-trip efficiency 54.6%.**

REASONING AND MARKING CHECKPOINTS

01

Stored gravitational energy is mgh = $2.5 \times 10^6 \times 9.8 \times 120 = 2.94 \times 10^9$ J.

02

Efficiency is useful output divided by input, so pump input = $2.94 \times 10^9/0.78 = 3.77 \times 10^9$ J. Dividing is required because input exceeds stored energy.

03

Forty-five minutes is 2700 s. Average input power = $3.77 \times 10^9/2700 = 1.40 \times 10^6$ W = 1.40 MW.

04

Generated output = $0.70 \times 2.94 \times 10^9 = 2.06 \times 10^9$ J. Round-trip efficiency = output/original input = $0.78 \times 0.70 = 0.546$ or 54.6%.

05

Losses become thermal energy and sound through turbulence, friction and resistance. Storage remains valuable because surplus electricity can be shifted to high-demand periods and released quickly to stabilise supply.

COMMON MISTAKE

*Multiplying stored energy by pump efficiency to find input, which incorrectly makes supplied energy smaller than useful output.*

# Designing a fair insulation comparison

[11]

EXPECTED CONCLUSION

**Rates 0.0875 °C/s and 0.0500 °C/s; cooling slows as temperature difference falls. Use matched containers and repeated, defined cooling measures.**

REASONING AND MARKING CHECKPOINTS

01

First 240 s: temperature drop is 80 - 59 = 21 °C, so mean rate = 21/240 = 0.0875 °C/s. Final 240 s: drop is 59 - 47 = 12 °C, giving 0.0500 °C/s.

02

Thermal-transfer rate depends on temperature difference. The water-room difference falls from 60 °C toward 27 °C, reducing conduction, convection and net radiation rates.

03

Use identical lidded containers with equal water mass and initial temperature, equal exposed area and simultaneous placement away from draughts. Change only insulation material.

04

Use matched probes, record fixed intervals, compare time to a chosen temperature or drop over a chosen time, repeat and compare means and spread. Swap probes to check sensor bias.

05

Equal thickness can mean unequal mass, cost or environmental burden because materials have different density. The controlled basis should match the design constraint: thickness, mass per area, price or available space.

COMMON MISTAKE

*Comparing final temperatures after different starting conditions or calling one material better without a defined measured outcome.*

# *Sound speed from wavelength evidence* [11]

EXPECTED CONCLUSION

**Sound speed about 340 m/s; 350 Hz gives 339.5 m/s and is consistent. Source frequency stays fixed while speed and wavelength depend on medium.**

REASONING AND MARKING CHECKPOINTS

01

Use $v = f\lambda$. The 250 Hz reading gives 250 × 1.36 = 340 m/s; the 400 Hz reading gives 400 × 0.85 = 340 m/s.

02

At 350 Hz, $v$ = 350 × 0.97 = 339.5 m/s, only 0.5 m/s different. This is consistent with measurement precision rather than evidence of a speed change.

03

Source oscillation fixes frequency, which remains continuous across a boundary. If wave speed changes in warmer air, wavelength changes because $\lambda = v/f$.

04

Create resonance in a tube or reflection from a wall and locate successive nodes with a microphone. Adjacent nodes are $\lambda/2$ apart, so double the spacing.

05

Measure across several node gaps and divide by their number; repeat in both directions, keep frequency and temperature controlled and reduce unwanted room reflections.

COMMON MISTAKE

*Treating the gradient of wavelength against frequency as speed even though the plotted relationship is inverse.*

# *Electromagnetic choices in rescue and medicine*

[10]

EXPECTED CONCLUSION

**Microwave, infrared and X-ray respectively; 3.0 cm gives $1.0 \times 10^{10}$ Hz; energy order X-ray > infrared > microwave.**

REASONING AND MARKING CHECKPOINTS

01

Microwaves in suitable bands pass through the atmosphere and can be directed with dishes for satellite communication. Convert 3.0 cm to 0.030 m before calculation.

02

Frequency $f = c/\lambda = 3.0 \times 10^8/0.030 = 1.0 \times 10^{10}$ Hz.

03

Warm surfaces emit infrared related to temperature, so infrared cameras map heat. X-rays are absorbed more strongly by bone than soft tissue, producing detector contrast.

04

Photon energy $E = hf$ increases with frequency, so X-ray has greatest energy, then infrared, then microwave. All travel at c in vacuum.

05

Ionising X-ray exposure is minimised using the lowest diagnostic exposure, beam collimation, shielding, distance and avoiding unnecessary repeats; benefit must justify risk.

COMMON MISTAKE

*Claiming high-energy electromagnetic waves travel faster in vacuum rather than recognising that their photon energy differs.*

# *Safe parallel lighting circuit*

[13]

EXPECTED CONCLUSION

**Each 2.0 A; total 6.0 A; equivalent 2.0 Ω; choose 10 A. One failed branch leaves two normal lamps and 4.0 A total.**

REASONING AND MARKING CHECKPOINTS

01
Each branch has 12 V, so I = P/V = 24/12 = 2.0 A. Junction conservation gives total current 6.0 A.

02
Equivalent resistance is V/Itotal = 12/6.0 = 2.0 Ω. It is below each operating lamp resistance, as expected for parallel paths.

03
Parallel branches each receive rated voltage and operate independently. Series lamps would share voltage, be dimmer and all extinguish if one filament opened.

04
The lowest listed fuse above normal 6.0 A is 10 A. A 5 A fuse would interrupt normal operation.

05
An open branch removes only one path. Two lamps remain at 12 V and normal brightness; total current becomes 4.0 A.

06
Put switch and fuse in live so operation disconnects dangerous live potential. A neutral-only fuse could open while internal components remain live relative to Earth.

COMMON MISTAKE

*Adding parallel resistances or selecting a fuse below normal current merely because it is numerically closest.*

# *Half-life from count-rate data*

[12]

EXPECTED CONCLUSION

**Corrected rates 780, 390, 195, 98, 49; half-life ≈2.0 h; predicted 12 h measured rate ≈52 counts/min.**

REASONING AND MARKING CHECKPOINTS

01

Subtract background to obtain 780, 390, 195, 98 and 49 counts/min. The small rounding later is compatible with random decay statistics.

02

Corrected rate halves from 780 to 390 in 2 h and to about 195 after another 2 h, so half-life is approximately 2.0 h.

03

From 8 h to 12 h is two half-lives: corrected rate ≈49/4 = 12.25. Add background to predict about 52 counts/min.

04

Decay is random, so finite counts scatter. Count longer, repeat equal intervals and average while keeping geometry fixed to reduce fractional uncertainty.

05

Irradiation is external exposure and stops when source is removed; contamination is radioactive material present and can spread. Minimise time, maximise distance, shield appropriately and use tongs/storage protocols.

COMMON MISTAKE

*Finding half-life from uncorrected total count rate, which makes the late decay appear too slow.*

# *Circular satellite orbit*

[11]

EXPECTED CONCLUSION

**Altitude $3.56 \times 10^7$ m; period $8.57 \times 10^4$ s = 23.8 h; gravity is inward force; larger orbit is slower with longer period.**

REASONING AND MARKING CHECKPOINTS

01

Altitude is orbital radius minus Earth radius: $4.2 \times 10^7 - 6.4 \times 10^6 = 3.56 \times 10^7$ m.

02

Period T = circumference/speed = $2\pi(4.2 \times 10^7)/(3.08 \times 10^3) = 8.57 \times 10^4$ s = 23.8 h.

03

Earth's gravitational attraction supplies the inward centripetal resultant. Centripetal force is a role of gravity here, not an extra force added to it.

04

At larger radius gravity is weaker, so circular speed is lower. The path is longer and speed lower, producing a longer period, consistent with $T^2$ proportional to $r^3$.

05

Spacecraft and astronauts fall together under gravity, leaving little normal contact force from the floor. Apparent weight vanishes although gravitational force does not.

COMMON MISTAKE

*Using altitude instead of centre-to-centre radius or drawing gravity and centripetal force as separate forces.*

# *Pendulum model investigation*

[14]

EXPECTED CONCLUSION

**At 1.00 m, g ≈9.77 m/s²; $T^2$-L gradient is $4\pi^2/g$, so $g = 4\pi^2/\text{gradient}$.**

REASONING AND MARKING CHECKPOINTS

01

Squaring gives $T^2 = (4\pi^2/g)L$, a straight line through the origin. This linearisation makes model testing and extracting g clearer than a curved T-L plot.

02

At L = 1.00 m and T = 2.01 s, $g = 4\pi^2L/T^2 = 9.77$ m/s².

03

Measure pivot to bob centre, use a small fixed release angle without push, time 10-20 complete oscillations from the same directional crossing, divide by count and repeat each length.

04

Use several well-spaced lengths, a rigid stand, fiducial marker and no draught. Plot $T^2$ against L; gradient m gives $g = 4\pi^2/m$, with steep/shallow acceptable lines estimating uncertainty.

05

A non-zero intercept suggests timing offset, effective-length zero error or miscounting. At large angles, period depends on amplitude because the small-angle approximation fails.

COMMON MISTAKE

*Measuring only string length or timing a single oscillation so reaction time dominates.*

# *Specific heat capacity from a heating curve* [12]

EXPECTED CONCLUSION

**Rate 0.183 °C/s; uncorrected c = 1090 J/(kg °C); mean non-stored power about 74.5 W.**

REASONING AND MARKING CHECKPOINTS

01

Temperature rises 64 - 20 = 44 °C in 240 s, so mean rate is 44/240 = 0.183 °C/s. The equal eleven-degree rises each minute support approximate linearity over this interval.

02

Heater supplies E = Pt = 300 × 240 = 72000 J. With no losses, c = E/(mΔT) = 72000/(1.50 × 44) = 1090 J/(kg °C).

03

Using the accepted c, energy stored in block = 1.50 × 820 × 44 = 54120 J. Energy not stored = 72000 - 54120 = 17880 J, giving 17880/240 = 74.5 W.

04

Insulate the block and improve heater/thermometer contact; record more points, fit a gradient and repeat. Include energy used to heat apparatus when refining the model.

05

As temperature difference from the room grows, loss rate generally rises. Eventually heater power can balance losses, so temperature approaches a steady value instead of rising linearly forever.

COMMON MISTAKE

*Reporting the no-loss value as exact even though energy also heats apparatus and escapes to the surroundings.*

# Vehicle rebound and collision safety

[14]

EXPECTED CONCLUSION

**Momenta +21600 and -2400 kg m/s; impulse -24000 N s; average forces -96000 N and -40000 N.**

REASONING AND MARKING CHECKPOINTS

01

Initial momentum is 1200 × 18 = +21600 kg m/s. Rebound is opposite the chosen positive direction, so final momentum is 1200 × (-2.0) = -2400 kg m/s.

02

Impulse equals final minus initial momentum: -2400 - 21600 = -24000 N s. The negative sign is physically important because the impulse points opposite the original motion.

03

Average resultant force is $\Delta p/\Delta t$ = -24000/0.25 = -96000 N. This average does not reveal the usually larger instantaneous peak force.

04

Newton's third law gives equal-magnitude opposite-direction interaction forces on vehicle and barrier. They act on different objects, so they must not be cancelled on one free-body diagram.

05

For 0.60 s, average force = -24000/0.60 = -40000 N. Greater stopping time reduces average force, but occupant safety also depends on peak acceleration, restraint, deformation distance and force history.

COMMON MISTAKE

*Treating rebound speed as positive, which omits the additional momentum change required to reverse direction.*

# *Hydraulic lift and rotational balance*

[11]

EXPECTED CONCLUSION

**Pressure $4.5 \times 10^5$ Pa; output force $1.08 \times 10^5$ N; added load $1.068 \times 10^5$ N; volume displacement is conserved and both force and moment sums vanish.**

REASONING AND MARKING CHECKPOINTS

01

Convert input area: $4.0\ cm^2 = 4.0 \times 10^{-4}\ m^2$. Pressure $p = F/A = 180/(4.0 \times 10^{-4}) = 4.5 \times 10^5$ Pa.

02

Output area is $0.0240\ m^2$, so force $= pA = 4.5 \times 10^5 \times 0.0240 = 1.08 \times 10^5$ N. Added load = 108000 - 1200 = 106800 N.

03

For an incompressible liquid, displaced volumes approximately match: $A_i d_i = A_o d_o$. The sixty-times-larger output area therefore moves one-sixtieth of the input distance, preserving the work trade-off.

04

Static equilibrium requires zero vector resultant force and zero resultant moment about any point. Either condition alone is insufficient.

05

The two upward support forces sum to total weight. Taking moments about one support removes its unknown force and determines the other; an off-centre load generally gives unequal support forces.

COMMON MISTAKE

*Using $cm^2$ as $m^2$ or claiming a hydraulic lift multiplies both force and distance without an energy cost.*

# *Heating gas in a rigid canister*

[10]

EXPECTED CONCLUSION

**Final pressure 120 kPa; faster particles collide more often and transfer more momentum. A moving piston permits expansion.**

REASONING AND MARKING CHECKPOINTS

01

At fixed amount and rigid volume, p/T is constant using kelvin temperatures. Therefore $p_2 = 100 \times 348/290 = 120$ kPa.

02

Heating increases mean molecular kinetic energy and speed. Particles reach the walls more frequently and each collision generally transfers more momentum, increasing force per area.

03

Kelvin temperature must be used because it is proportional to mean kinetic energy. A Celsius ratio would imply 0 °C means no molecular motion.

04

A freely moving piston allows volume to increase and can keep pressure near external pressure during slow motion; some heating then supplies boundary work.

05

At high pressure, molecular volume is not negligible and intermolecular forces affect motion, violating ideal assumptions of point particles and no forces except elastic collisions.

COMMON MISTAKE

*Using Celsius temperatures in the ratio or describing increased pressure only through collision frequency without momentum transfer.*

# *Refraction through a glass block*

[12]

EXPECTED CONCLUSION

**Refractive index 1.53; critical angle 40.8°. Opposite refractions at parallel faces restore direction while finite thickness creates lateral shift.**

REASONING AND MARKING CHECKPOINTS

01 For air to glass, $n = \sin i/\sin r = \sin 50.0°/\sin 30.0° = 1.532$, so $n = 1.53$.

02 At a glass-air critical angle, refracted angle is 90° and $\sin c = 1/n$. Thus $c = \sin^{-1}(1/1.532) = 40.8°$.

03 Parallel faces have parallel normals. Refraction toward the normal at entry is reversed by refraction away at exit, restoring direction; travel through finite thickness leaves lateral displacement.

04 Trace the block, place two widely separated incident pins, align two image pins without parallax, remove the block and draw rays and normals accurately. Use thin vertical pins.

05 Repeat several incidence angles and plot sin i vertically against sin r horizontally. A best-fit gradient through the origin estimates n; repeats and large pin separation reduce uncertainty.

COMMON MISTAKE

*Measuring angles from the glass face rather than the normal, or applying critical-angle theory to air-to-glass travel.*

# *Filament-lamp characteristic*

[12]

EXPECTED CONCLUSION

**Resistances 2.78 Ω and 3.68 Ω; power 1.20 W; five-minute energy 360 J; heating raises filament resistance.**

REASONING AND MARKING CHECKPOINTS

01
At 0.50 V, R = V/I = 0.50/0.18 = 2.78 Ω. At 2.50 V, R = 2.50/0.68 = 3.68 Ω, so resistance is not constant.

02
Greater current heats the filament. Stronger lattice vibrations increase charge-carrier collisions, causing the curved non-ohmic characteristic.

03
At 2.0 V and 0.60 A, P = VI = 1.20 W. Five minutes is 300 s, so E = Pt = 1.20 × 300 = 360 J.

04
Place ammeter and variable resistor in series with the lamp and voltmeter in parallel. Adjust a low-voltage supply gradually and stay within the lamp rating.

05
Reverse supply connections for negative values, take readings quickly and repeat. A filament characteristic should be approximately symmetric, but should not be forced into a straight line.

COMMON MISTAKE

*Using one overall gradient as constant resistance despite the visibly changing V/I ratio.*

# Generator and high-voltage transmission

[14]

EXPECTED CONCLUSION

**Mean e.m.f. 6.0 V; currents 200 A and 4.0 A; cable losses 128 W and $3.20 \times 10^5$ W respectively.**

REASONING AND MARKING CHECKPOINTS

01

Flux change magnitude per turn is $6.0 \times 10^{-4}$ Wb. Faraday's law gives mean e.m.f. $N\Delta\Phi/\Delta t = 200 \times 6.0 \times 10^{-4}/0.020 = 6.0$ V.

02

Lenz's law makes induced effects oppose the flux change, conserving energy. More turns, larger area, stronger field or faster rotation increases rate of flux-linkage change.

03

Ideal power conservation gives primary current 24000/120 = 200 A and secondary current 24000/6000 = 4.0 A.

04

High-voltage cable loss $I^2R = 4.0^2 \times 8.0 = 128$ W. At 120 V, current 200 A gives $200^2 \times 8.0 = 3.20 \times 10^5$ W.

05

High voltage reduces current for specified power, so heating falls with current squared. The voltage is stepped down near consumers for insulation practicality and safety.

COMMON MISTAKE

*Using only final flux rather than the positive-to-negative change, or assuming a transformer creates power.*

# *Nuclear equations and radiation evidence*

[10]

EXPECTED CONCLUSION

**$^{226}_{88}Ra \rightarrow\, ^{222}_{86}X +\, ^{4}_{2}He$; $^{222}_{86}X \rightarrow\, ^{222}_{87}Y +\, ^{0}_{-1}e$ + antineutrino.**

REASONING AND MARKING CHECKPOINTS

01

Conserve nucleon and proton numbers: alpha emission gives $^{226}_{88}Ra \rightarrow\, ^{222}_{86}X +\, ^{4}_{2}He$.

02

In beta-minus decay, a neutron becomes a proton while an electron and electron antineutrino are emitted: $^{222}_{86}X \rightarrow\, ^{222}_{87}Y +\, ^{0}_{-1}e$ + anti-$\nu_e$.

03

Alpha is most ionising and least penetrating; beta is intermediate; gamma is least ionising per path length and most penetrating, requiring substantial shielding for reduction.

04

Gamma is an energy photon with no proton or neutron, so nuclear numbers do not change. It can follow a decay that leaves an excited daughter.

05

Radioactive decay is a spontaneous nuclear process. Ordinary heating changes atomic motion on energy scales far below nuclear transitions and does not schedule individual decays.

COMMON MISTAKE

*Changing nucleon number in beta decay or treating the emitted electron as an orbital electron already outside the nucleus.*

# Galaxy recession and expansion age

[13]

EXPECTED CONCLUSION

**Gradient 697.5 km $s^{-1}$ per $10^{22}$ m = $6.98 \times 10^{-17}$ $s^{-1}$; illustrative expansion timescale $4.54 \times 10^{8}$ years.**

REASONING AND MARKING CHECKPOINTS

01

Using endpoints, gradient = (3510 - 720)/(5 - 1) = 697.5 km $s^{-1}$ per $10^{22}$ m. Wide separation limits relative reading uncertainty.

02

Convert: $H = 697.5 \times 1000/10^{22} = 6.975 \times 10^{-17}$ $s^{-1}$. Its reciprocal is $1.434 \times 10^{16}$ s = $4.54 \times 10^{8}$ years.

03

The dataset is intentionally simplified original teaching data, not a current cosmological measurement. Spectral lines shifted to longer wavelengths provide recession evidence by comparison with laboratory wavelengths.

04

Galaxies have local peculiar velocities and distance uncertainty, so one v/d value is unreliable. A large sample and best-fit trend reveal the expansion relation.

05

The expansion rate changes with cosmic contents and history, and distance calibration affects the gradient. Therefore 1/H is a model timescale, not automatically exact age.

COMMON MISTAKE

*Taking the reciprocal before converting the plotted gradient to $s^{-1}$.*

# *Household solar-storage audit*

[16]

EXPECTED CONCLUSION

**Demand 5.73 kWh; battery output 5.084 kWh; shortfall 0.646 kWh; $2.06 \times 10^7$ J; heater current 7.83 A, choose 10 A.**

REASONING AND MARKING CHECKPOINTS

01

Heater uses 1.8 × 2.5 = 4.50 kWh. Lamps total 54 W = 0.054 kW and use 0.270 kWh. Refrigerator uses 0.120 × 8.0 = 0.960 kWh.

02

Total = 4.50 + 0.270 + 0.960 = 5.73 kWh. Battery delivers 0.82 × 6.2 = 5.084 kWh, leaving 0.646 kWh from grid.

03

Using 1 kWh = $3.6 \times 10^6$ J, demand = $5.73 \times 3.6 \times 10^6 = 2.06 \times 10^7$ J.

04

Heater current = 1800/230 = 7.83 A. The smallest listed fuse above normal current is 10 A; a 5 A fuse would interrupt normal use.

05

Daily totals omit timing, battery capacity and peak power. Weather, state of charge, inverter loss and appliance starting currents can prevent off-grid operation despite an average energy balance.

COMMON MISTAKE

*Adding watts to kilowatt-hours or applying battery efficiency to demand rather than energy passing through the battery.*