GIOPHYSICS ORIGINAL EXAMINATION SERIES

MYP 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**	**270**	**Included**

INSIDE THIS PACK

PAPER 1

MYP Physics · Extended Paper 1

175 minutes | 10 questions | 126 marks

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

PAPER 2

MYP Physics · Extended Paper 2

195 minutes | 10 questions | 144 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.

MYP 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	**175 min**	**10**	**126**

INSTRUCTIONS

- Answer every task using evidence and scientific reasoning.
- Label each calculation, graph interpretation and evaluation clearly.
- Criteria A-D are represented across the two-paper pack.
- Answer in the spaces provided and label any additional pages clearly.

INFORMATION

- The total mark for this paper is 126.
- Marks for each task are shown in brackets.
- The detailed marking guide begins after Paper 2.

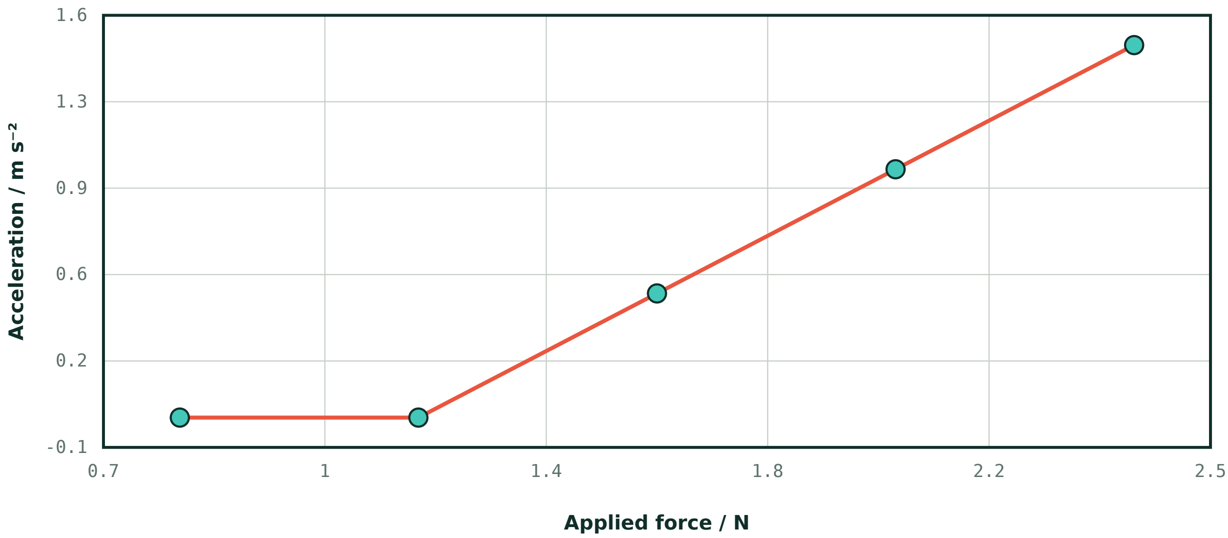
Extract mass and friction from acceleration data

[12]

A trolley is pulled horizontally. The recorded pairs (applied force in N, acceleration in m/s²) are (0.8, 0), (1.2, 0), (1.6, 0.5), (2.0, 1.0), (2.4, 1.5). (a) Describe the pattern and identify the force needed before sustained motion appears. [3] (b) For the moving points, use F = ma + f to determine the trolley mass m and the approximately constant friction f. [5] (c) Assess whether all five readings support one straight-line model. [2] (d) Propose one improvement that would test the model more rigorously. [2]

Applied force and trolley acceleration

Acceleration stays at zero for the first two applied forces, then increases linearly across the three moving readings.



ANSWER SPACE

Can the density identify an unknown alloy?

[12]

A cylindrical sample has mass (44.4 ± 0.2) g, diameter (2.40 ± 0.05) cm and length (5.00 ± 0.05) cm. Use π = 3.142. (a) Distinguish accuracy from precision. [2] (b) Calculate the cylinder volume and density. [4] (c) Estimate the percentage uncertainty in the density by adding percentage uncertainties; remember that diameter is squared. [4] (d) Reference densities are aluminium 2.70 g/cm^3 and magnesium 1.74 g/cm^3. Judge whether density alone securely identifies the sample. [2]

ANSWER SPACE

Choose a safer helmet liner using impulse evidence

[16]

A 4.0 kg instrumented headform moving at 6.0 m/s stops in a crash test. Liner P stops it in 0.012 s and is reusable after small impacts; liner Q stops it in 0.030 s but must be replaced after one severe impact. P costs $18, Q costs $29. (a) Calculate the momentum change and average force magnitude for each liner. [5] (b) Explain why the calculations do not prove either helmet prevents injury. [3] (c) Evaluate the physical, economic, environmental and user-access implications. [6] (d) Make a conditional recommendation and identify further evidence needed. [2]

ANSWER SPACE

Design a fair material-stiffness comparison

[14]

A design team is choosing recycled sheet material for a reusable package. (a) Write a research question about sheet thickness and midpoint deflection under load. [2] (b) Give and justify a hypothesis. [3] (c) Design a method using five thicknesses, a fixed support span and small masses. Identify variables, repeats, measurements, safety and the graph to draw. [6] (d) Explain one limitation that repeats do not remove and a matching improvement. [3] Do not invent results.

ANSWER SPACE

Predict waves entering two harbour gaps

[10]

Regular water waves have wavelength 12 m and frequency 0.40 Hz. They approach two harbour entrances of width 6 m and 30 m. (a) Calculate wave speed and period. [3] (b) Compare the expected diffraction at the two entrances. [3] (c) Explain how a two-dimensional wavefront sketch should differ behind each entrance. [2] (d) State two limits of applying this simple model to a real harbour. [2]

ANSWER SPACE

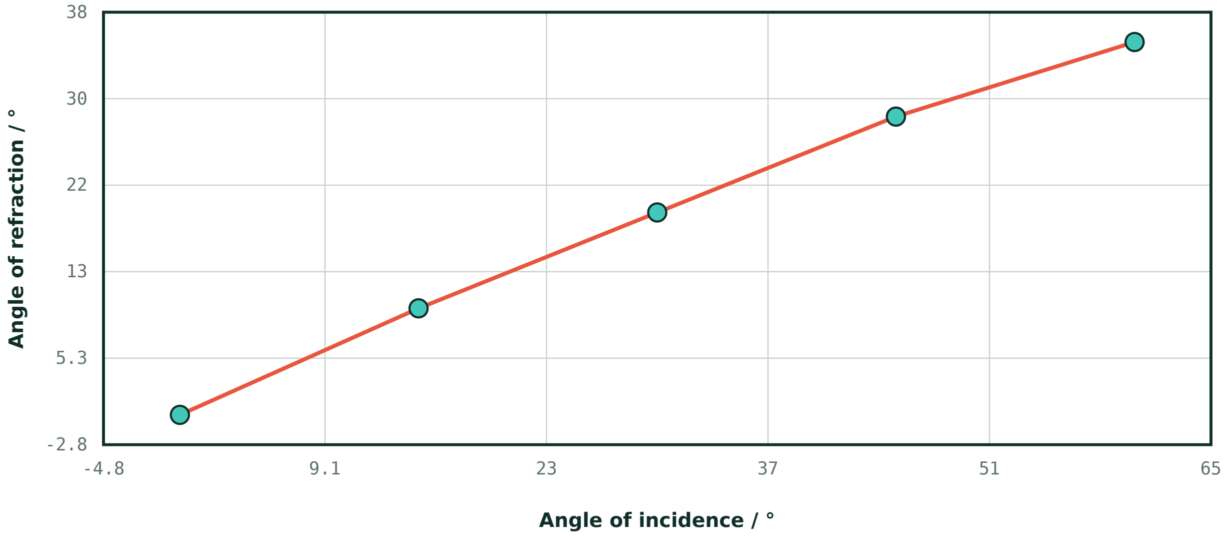
Test whether a transparent block has one refractive index

[14]

Light travels from air into a block. The recorded pairs (angle of incidence i in degrees, angle of refraction r in degrees) are (0, 0), (15, 10), (30, 19), (45, 28), (60, 35). (a) Describe the angle pattern. [2] (b) For each non-zero pair calculate n = sin i / sin r and find a representative value. [5] (c) Use that value to estimate the critical angle for light going from the block to air. [3] (d) Evaluate whether the evidence supports one constant refractive index and propose two improvements. [4]

Incident and refracted angles

The refracted angle rises with incident angle but remains smaller at each non-zero measurement.



ANSWER SPACE

Account for energy inside a real battery

[12]

A 12.0 V battery with internal resistance 0.50 Ω supplies a 5.50 Ω load. (a) Calculate total resistance and current. [3] (b) Calculate terminal potential difference and show that it matches the load voltage. [3] (c) Calculate power in the load, power dissipated inside the battery and efficiency of transfer to the load. [4] (d) Explain why the battery terminal voltage falls when current increases. [2]

ANSWER SPACE

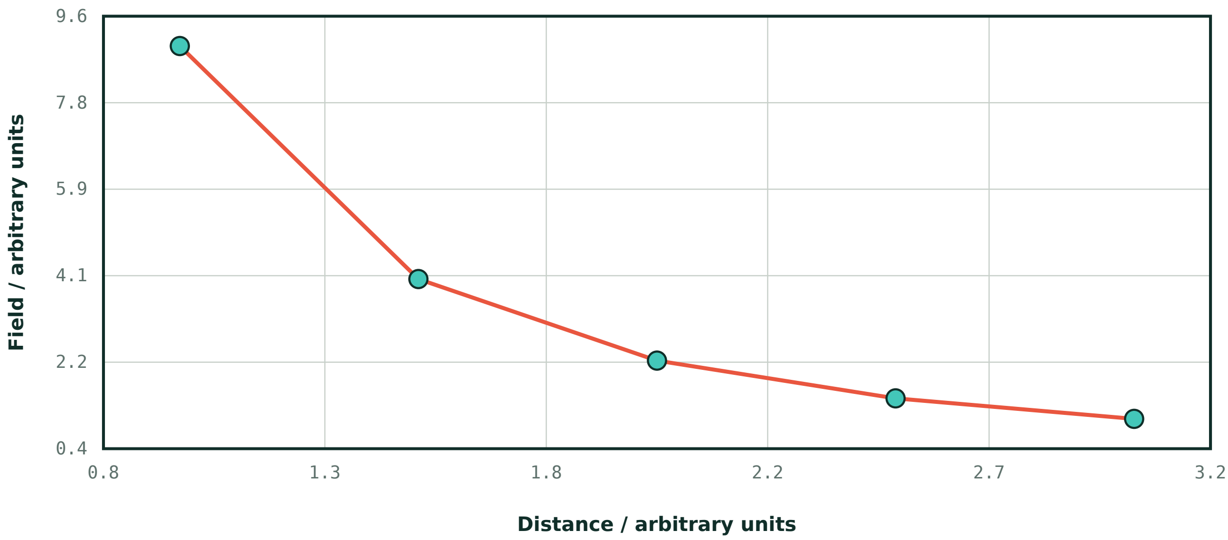
Test an inverse-square gravitational field claim

[12]

A simulation reports the pairs (distance r in arbitrary units, gravitational field g in arbitrary units) (1.0, 9.00), (1.5, 4.00), (2.0, 2.25), (2.5, 1.44), (3.0, 1.00). (a) Describe the pattern without calling it linear. [2] (b) Calculate gr^2 for every pair and use the values to test $g \propto 1/r^2$. [4] (c) Predict g at r = 4.0 and explain the interpolation or extrapolation risk. [3] (d) State what this evidence can and cannot establish about real gravitational fields. [3]

Gravitational field against distance

Field strength falls steeply at first and then more gradually as distance increases.



ANSWER SPACE

Recover half-life from count-rate evidence

[12]

A sealed source gives 920 counts/min initially and 220 counts/min after 18 years. Background is 120 counts/min and is assumed constant. (a) Explain why background must be subtracted. [2] (b) Calculate both net count rates and the number of half-lives elapsed. [4] (c) Determine the half-life. [2] (d) Predict the total detector reading after a further 12 years and state two assumptions. [4]

ANSWER SPACE

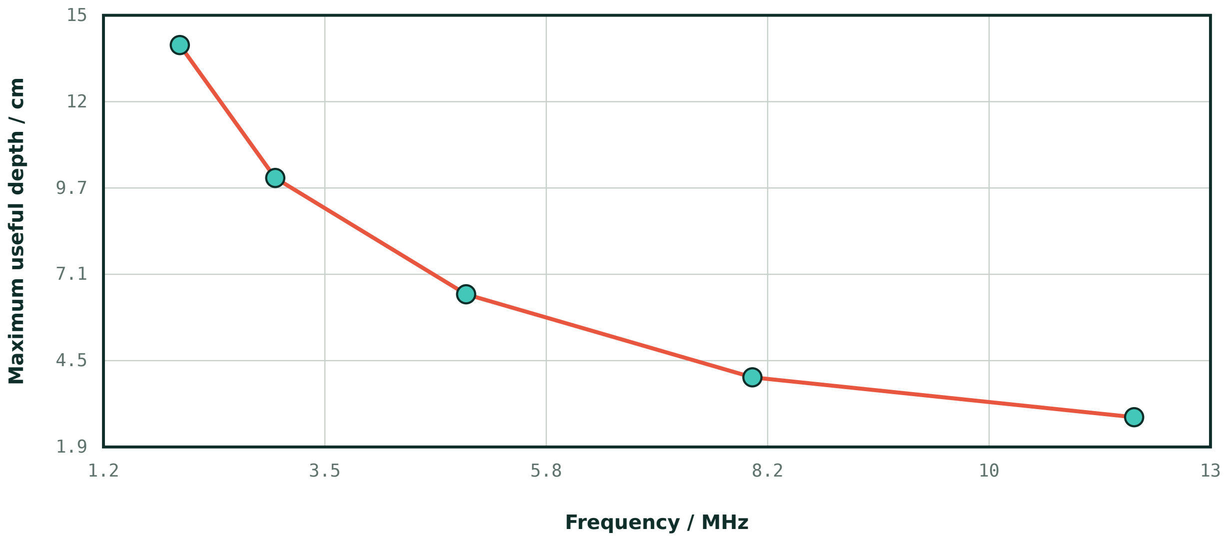
Evaluate an ultrasound frequency-penetration claim

[12]

A training phantom gives the pairs (ultrasound frequency in MHz, maximum useful image depth in cm) (2, 14.0), (3, 10.0), (5, 6.5), (8, 4.0), (12, 2.8). A trainee claims useful depth is inversely proportional to frequency. (a) Describe the trend. [2] (b) Calculate frequency × depth for every pair and assess the claim using a ±10% consistency rule around the first product. [5] (c) Explain the physical trade-off between frequency, attenuation and image detail. [3] (d) Identify one limitation of transferring this phantom result to patients and one improvement. [2]

Ultrasound frequency and useful image depth

Useful depth decreases non-linearly as ultrasound frequency increases.



ANSWER SPACE

MYP 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	**195 min**	**10**	**144**

INSTRUCTIONS

- Answer every task using evidence and scientific reasoning.
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INFORMATION

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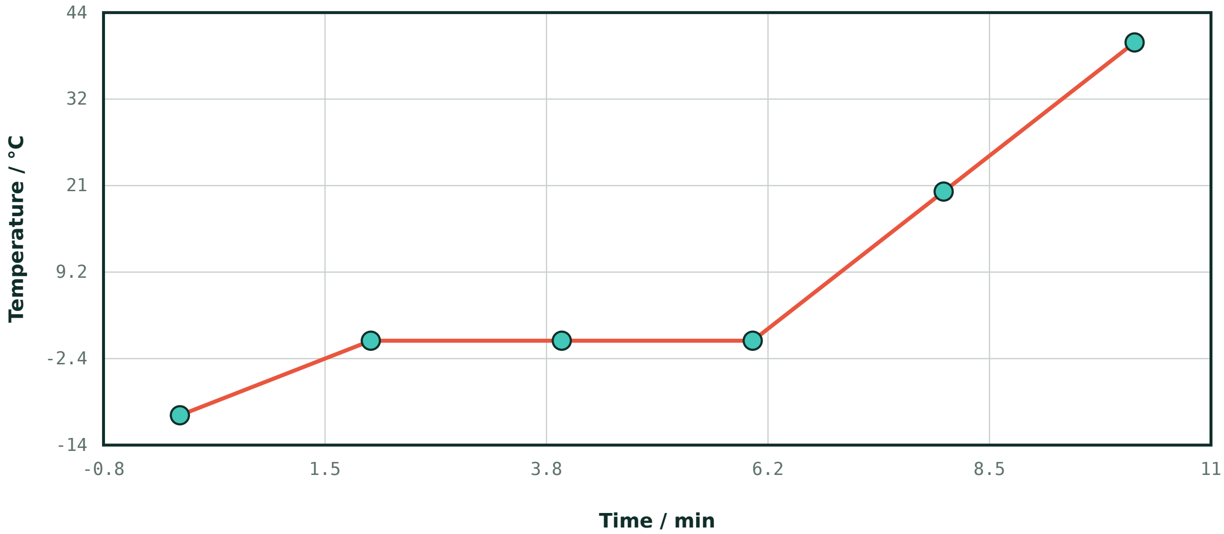
Interpret a phase-change heating record

[12]

A sample is heated at approximately constant power. The recorded pairs (time in min, temperature in °C) are (0, -10), (2, 0), (4, 0), (6, 0), (8, 20), (10, 40). (a) Describe the three distinct regions. [3] (b) Calculate the warming rate before and after the plateau. [3] (c) Explain the plateau using a particle-energy model. [3] (d) Evaluate whether the record proves that heating power was perfectly constant and propose one improvement. [3]

Temperature during constant-power heating

Temperature rises to zero degrees Celsius, remains level for four minutes, then rises more steeply.



ANSWER SPACE

Which launch angle gives the greatest range?

[14]

A spring launcher can fire a foam ball from floor level with one fixed compression. (a) Formulate a focused research question about launch angle and horizontal range. [2] (b) Give a reasoned hypothesis using horizontal and vertical velocity components. [3] (c) Design a safe method using angles from 15° to 75°, identifying the independent, dependent and at least three controlled variables. Include repeats and a results table or graph plan. [6] (d) Explain one important limitation and a specific improvement. [3] Do not invent results.

ANSWER SPACE

Audit the energy ledger of a regenerative lift

[12]

A lift raises a total mass of 600 kg through 12 m in 20 s. Take g = 10 N/kg. The motor draws 90 kW while rising. During descent, 50% of the gravitational energy is returned to the battery. (a) Calculate the gravitational energy gained and useful lifting power. [4] (b) Calculate the electrical energy supplied while rising and the lifting efficiency. [3] (c) Calculate the energy returned during descent and the net battery-energy decrease for the up-down cycle. [3] (d) Explain why energy is conserved although the battery does not recover all its energy. [2]

ANSWER SPACE

Evaluate a community flood-barrier design

[16]

A temporary vertical barrier holds water 1.20 m deep along each 1.0 m width. Use water density 1000 kg/m³ and g = 9.8 N/kg. The pressure rises linearly from zero gauge pressure at the surface to ρgh at the bottom. Design X uses reusable aluminium panels costing $480 per metre; design Y uses single-use filled polymer bags costing $150 per metre. (a) Calculate bottom gauge pressure and the resultant horizontal water force on each metre of barrier. [5] (b) Explain why the force acts below mid-depth. [2] (c) Evaluate safety, cost, deployment, access and environmental consequences. [7] (d) Give a conditional recommendation. [2]

ANSWER SPACE

Map resonance without risking hearing

[14]

A small driven oscillator has an expected resonance between 4 Hz and 8 Hz. (a) Formulate a research question about driving frequency and steady amplitude. [2] (b) Give a reasoned hypothesis that includes resonance and damping. [3] (c) Design a method using a signal generator, low-power driver, motion sensor and computer. Include range, controls, repeats, how to avoid transient readings, graph choice and safety. [7] (d) Explain how the method could compare two damping settings. [2] Do not invent results.

ANSWER SPACE

Choose a communication link for a remote community

[16]

A remote community compares a 5.0 GHz microwave relay, fibre cable and satellite internet. The relay needs line of sight and has moderate installation cost; fibre has the highest installation cost but high capacity and low weather sensitivity; satellite starts quickly but has greater delay and recurring cost. Use $c = 3.0 \times 10^8$ m/s. (a) Calculate the microwave wavelength. [2] (b) Explain one physical advantage and limitation of each system. [6] (c) Evaluate access, reliability, maintenance, environmental disturbance and long-term cost for residents, school and clinic. [6] (d) Make a conditional recommendation and name missing evidence. [2]

ANSWER SPACE

Design a solenoid field investigation

[14]

A class has a 400-turn air-core solenoid, adjustable low-voltage supply, ammeter, Hall probe and temperature sensor. (a) Formulate a question about current and central magnetic flux density. [2] (b) Give and justify a hypothesis. [3] (c) Design a method from 0.10 A to 1.00 A, including variables, repeats, zero correction, graph choice and safety. [7] (d) Explain how to modify the method to test the effect of turns per metre. [2] Do not invent results.

ANSWER SPACE

Select an Earth-observation orbit responsibly

[16]

A small Earth-observation satellite is proposed for wildfire monitoring in a circular orbit of radius 7.0×10^6 m from Earth's centre. Use $GM = 3.99 \times 10^{14}$ m^3/s^2 and $T = 2\pi\sqrt{(r^3/GM)}$. A lower orbit gives finer ground detail but more atmospheric drag and a smaller field of view; a higher orbit gives wider coverage but coarser detail. (a) Calculate the orbital period in minutes. [4] (b) Explain the physical trade-off between altitude, resolution, coverage and revisit planning. [4] (c) Evaluate public benefit, privacy, launch emissions, debris and unequal access to data. [6] (d) Make a conditional recommendation. [2]

ANSWER SPACE

Design a solar-panel angle field study

[14]

A school wants evidence for the fixed tilt of a small roof-mounted solar panel. (a) Formulate a research question linking tilt angle to electrical power under stated conditions. [2] (b) Give a reasoned hypothesis based on radiation incident on a surface. [3] (c) Design a method using a panel, adjustable stand, resistive load, voltmeter, ammeter and irradiance meter. Include range, controls, repeats, normalisation, graph and safety. [7] (d) Explain why one clear-day investigation cannot determine annual energy yield. [2] Do not invent results.

ANSWER SPACE

Build a defensible classroom-cooling recommendation

[16]

A classroom is used 6 h/day for 180 warm days. Option F is a 50 W fan. Option H is a 900 W heat pump. External reflective shading would reduce heat-pump electrical energy by an estimated 25% but costs $1200 to install. Grid emissions are 0.40 kg CO_2e/kWh. The fan moves air but does not lower room temperature. (a) Calculate annual electrical energy and operational emissions for F and H. [5] (b) Calculate H energy and emissions with shading. [3] (c) Explain why these totals alone cannot identify the best option. [3] (d) Evaluate comfort, health, cost, emissions, noise, access and building constraints, then give a conditional recommendation and further evidence required. [5]

ANSWER SPACE

TEACHER COPY

Detailed marking guide

MYP 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**	**270**

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.

Extract mass and friction from acceleration data

[12]

EXPECTED CONCLUSION

The stationary readings show a threshold up to about 1.2 N. For the moving data Δa/ΔF = 1.25 kg^{-1}, so m = 0.80 kg and f = 1.20 N. Static and moving behaviour should not be forced onto one line.

REASONING AND MARKING CHECKPOINTS

01

(a) Acceleration remains zero at 0.8 N and 1.2 N, then rises by 0.5 m/s^2 for each further 0.4 N. Sustained motion begins only above an applied force of about 1.2 N.

02

(b) For moving points, a = (F - f)/m, so the gradient of acceleration against force is 1/m. Gradient = (1.5 - 0.5)/(2.4 - 1.6) = 1.25 kg^{-1}.

03

(b) Therefore m = 1/1.25 = 0.80 kg. Substituting F = 1.6 N and a = 0.5 m/s^2 gives f = F - ma = 1.6 - 0.80 × 0.5 = 1.20 N.

04

(c) The three moving readings fit F = 0.80a + 1.20 exactly, but the two zero-acceleration readings represent adjustable static friction. They are not evidence that the same kinetic straight line extends to rest.

05

(d) Add closely spaced force values around 1.2-1.6 N and repeat each measurement. A force sensor and motion sensor would show both the breakaway peak and the steadier force while moving.

COMMON MISTAKE

Drawing one best-fit line through the origin and all five points; that erases the physically meaningful transition between static friction and kinetic motion.

Can the density identify an unknown alloy? [12]

EXPECTED CONCLUSION

The volume is 22.62 cm^3 and the density is 1.96 g/cm^3. The estimated percentage uncertainty is 5.62%, or about ±0.11 g/cm^3, so the interval does not match either reference closely enough to identify the alloy securely.

REASONING AND MARKING CHECKPOINTS

01

(a) Precision describes how closely repeated readings agree; accuracy describes closeness to an accepted value. A set can be precise yet inaccurate if every reading has the same calibration offset.

02

(b) Radius = 2.40/2 = 1.20 cm. Volume $V = \pi r^2 L = 3.142 \times 1.20^2 \times 5.00 = 22.62$ cm^3, with units carried through the calculation.

03

(b) Density $\rho = m/V = 44.4/22.62 = 1.96$ g/cm^3 to three significant figures, matching the precision of the supplied measurements.

04

(c) Mass uncertainty = $0.2/44.4 \times 100 = 0.45\%$. Volume uncertainty $\approx 2(0.05/2.40 \times 100) + 0.05/5.00 \times 100 = 5.17\%$.

05

(c) Density is a quotient, so the estimated percentage uncertainty is 0.45% + 5.17% = 5.62%. Its absolute uncertainty is $0.0562 \times 1.96 \approx 0.11$ g/cm^3.

06

(d) The plausible range is approximately 1.85-2.07 g/cm^3. It excludes the two pure reference values, suggesting an alloy or a systematic measurement problem; density alone cannot determine composition.

COMMON MISTAKE

Using diameter as the radius, or adding the diameter percentage only once even though the volume contains diameter squared; either error changes the conclusion materially.

Choose a safer helmet liner using impulse evidence

[16]

EXPECTED CONCLUSION

The momentum change magnitude is 24 kg m/s. Average force is 2000 N for P and 800 N for Q. Q reduces average force in this test, but a recommendation also needs peak-force, fit, certification, replacement and user-context evidence.

REASONING AND MARKING CHECKPOINTS

01

(a) Initial momentum is $mv = 4.0 \times 6.0 = 24$ kg m/s and final momentum is zero, so the change has magnitude 24 kg m/s opposite the original motion.

02

(a) Average force magnitude for P is $\Delta p/\Delta t = 24/0.012 = 2000$ N. For Q it is $24/0.030 = 800$ N, so the longer stopping time lowers the average force in this test.

03

(b) Injury can depend on peak rather than average force, rotational acceleration, impact direction, fit and biological variation. One headform speed is not a complete safety test or a guarantee for a rider.

04

(c) Q offers the lower calculated average force in the stated severe impact, while P's reuse after minor impacts may reduce replacement cost and material waste. A damaged liner that looks unchanged also creates a behaviour and inspection risk.

05

(c) Higher purchase and replacement costs can reduce access, especially for families or shared-cycle schemes. Manufacturers, users, emergency clinicians, waste services and regulators value different outcomes, so price alone is not the decision rule.

06

(d) Prefer a certified design that keeps both peak linear and rotational acceleration within accepted limits and fits the user. If Q meets those tests materially better, recommend Q for severe-impact protection while making replacement guidance and support affordable.

07

(d) Seek repeated impacts at several speeds and angles, peak-force and rotational data, fit testing, certification results, material life-cycle evidence and real replacement compliance before a final procurement decision.

COMMON MISTAKE

Claiming that a lower average force guarantees no injury, or recommending the cheaper reusable liner without considering peak force, hidden damage, fit and certification evidence.

Design a fair material-stiffness comparison [14]

EXPECTED CONCLUSION

Vary sheet thickness and measure midpoint deflection under the same force, span and specimen geometry. Predict that thicker sheets deflect less, then use repeated loading measurements and a deflection-thickness graph to test the relationship.

REASONING AND MARKING CHECKPOINTS

01

(a) A focused question is: How does the measured thickness of an equal-width recycled sheet affect its midpoint deflection under a fixed load across a fixed support span?

02

(b) Predict that deflection decreases as thickness increases because distributing material farther from the neutral layer increases bending stiffness. This predicts a direction without pretending the exact exponent is already known.

03

(c) Measure each specimen's thickness at several positions with a micrometer. Cut equal widths and lengths, place each across the same two supports, add the same small central load and measure vertical deflection against a fixed scale or from calibrated photographs.

04

(c) Thickness is independent and deflection is dependent. Control material batch, width, span, grain direction, load, load position, loading time, temperature and whether a specimen has previously been bent.

05

(c) Test at least five thicknesses and three fresh specimens per thickness. Record raw thickness and deflection with units, calculate mean and range, and plot mean deflection against measured thickness with uncertainty visible.

06

(c) Keep fingers clear of loads, use a tray for falling masses and stay well below sudden-failure loads. Stop and replace any creased specimen rather than quietly reusing it.

07

(d) Lamination adhesive or fibre orientation may change with nominal thickness, producing a material-structure difference rather than thickness alone. Build specimens from the same layer stock, standardise adhesive mass and alternate test order.

COMMON MISTAKE

Using a heavier mass on thicker sheets to make the deflection easier to see; this changes force together with thickness and destroys the intended causal comparison.

Predict waves entering two harbour gaps

[10]

EXPECTED CONCLUSION

Wave speed is 4.8 m/s and period is 2.5 s. The 6 m gap is narrower than one wavelength and produces strong spreading; the 30 m gap is 2.5 wavelengths wide and produces less spreading.

REASONING AND MARKING CHECKPOINTS

01

(a) Wave speed $v = f\lambda = 0.40 \times 12 = 4.8$ m/s. The period is $T = 1/f = 1/0.40 = 2.5$ s.

02

(b) For the 6 m entrance, width/wavelength = 6/12 = 0.50, so diffraction is strong and energy spreads through a broad range of directions.

03

(b) For the 30 m entrance, width/wavelength = 30/12 = 2.5, so most wavefronts continue roughly forward with only edge spreading. Diffraction is not literally zero.

04

(c) Behind 6 m, draw widely curved, nearly semicircular fronts with 12 m separation. Behind 30 m, draw a broad central region of straighter fronts and curvature mainly near both edges.

05

(d) Real seas contain many frequencies and directions, while water depth changes wave speed. Reflection from walls, irregular entrances, wind and breaking also violate the simple uniform-wave model.

COMMON MISTAKE

Saying the narrower gap blocks all waves or the wider gap gives no diffraction; diffraction changes continuously with the ratio of gap width to wavelength.

Test whether a transparent block has one refractive index

[14]

EXPECTED CONCLUSION

The refracted angle increases more slowly than the incident angle. The non-zero n values are about 1.50, 1.54, 1.51 and 1.51, giving n ≈ 1.51 and a critical angle $\sin^{-1}(1/1.51) \approx 41.5°$.

REASONING AND MARKING CHECKPOINTS

01

(a) Refraction is towards the normal because $r < i$ for every non-zero reading. Both angles increase, but equal angle increments do not produce equal refracted-angle increments.

02

(b) The ratios sin i/sin r are approximately 1.49, 1.54, 1.51 and 1.51 for 15°, 30°, 45° and 60°. The 0° pair cannot be used because it gives 0/0.

03

(b) A representative mean is about 1.51. The small scatter is plausible for degree-scale angle readings and supports, but does not prove, a constant index for this wavelength and material.

04

(c) At the block-air critical angle, $\sin c = n_{air}/n_{block} \approx 1/1.51$. Therefore $c \approx \sin^{-1}(0.662) = 41.5°$.

05

(d) Repeat independently, use a narrow laser line, draw a thin normal and measure from the normal rather than the surface. Plot sin i against sin r; a straight line through the origin tests the model more directly.

06

(d) Wavelength and block homogeneity are uncontrolled in the claim of one universal value, so repeat with stated colours and several entry positions before generalising.

COMMON MISTAKE

Averaging i/r instead of sin i/sin r, including the undefined 0/0 pair, or measuring angles from the surface rather than from the normal.

Account for energy inside a real battery

[12]

EXPECTED CONCLUSION

Total resistance is 6.00 Ω and current is 2.00 A. Terminal/load voltage is 11.0 V. Load power is 22.0 W, internal dissipation is 2.00 W and transfer efficiency is 91.7%.

REASONING AND MARKING CHECKPOINTS

01

(a) The internal and external resistances are in series for the complete circuit, so R_{total} = 0.50 + 5.50 = 6.00 Ω.

02

(a) Current is $I = emf/R_{total}$ = 12.0/6.00 = 2.00 A.

03

(b) Lost voltage inside the battery is Ir = 2.00 × 0.50 = 1.00 V, so terminal potential difference is 12.0 - 1.00 = 11.0 V.

04

(b) Across the load, $V = IR$ = 2.00 × 5.50 = 11.0 V, which independently checks the terminal-voltage calculation.

05

(c) Load power is $I^2R = 2.00^2 \times 5.50$ = 22.0 W; internal power is $I^2r = 2.00^2 \times 0.50$ = 2.00 W. Total 24.0 W also equals emf × current.

06

(c) Efficiency to the load is 22.0/24.0 × 100 = 91.7%. The remainder heats the battery internally.

07

(d) A larger current produces a larger internal drop Ir, so terminal voltage emf - Ir falls even if the emf is approximately unchanged.

COMMON MISTAKE

Using 12.0 V directly across the 5.50 Ω load and ignoring the internal resistor, which overestimates current and loses the energy-conservation check.

Test an inverse-square gravitational field claim

[12]

EXPECTED CONCLUSION

The field decreases non-linearly. Every gr^2 value is 9.00, so the dataset exactly follows $g = 9/r^2$; at r = 4.0 the model predicts g = 0.5625. Simulation agreement does not independently verify nature.

REASONING AND MARKING CHECKPOINTS

01

(a) As distance increases, field strength decreases by progressively smaller absolute amounts. A straight line through the raw g-r points would not describe the curved pattern.

02

(b) The products gr^2 are $9.00\times1.0^2 = 9.00$, $4.00\times1.5^2 = 9.00$, $2.25\times2.0^2 = 9.00$, $1.44\times2.5^2 = 9.00$ and $1.00\times3.0^2 = 9.00$.

03

(b) A constant gr^2 means $g = \text{constant}/r^2$ for these values, so the supplied record is exactly consistent with an inverse-square model.

04

(c) At r = 4.0, $g = 9.00/4.0^2 = 0.5625$ arbitrary units. This is extrapolation beyond the measured 1.0-3.0 range and depends on the same model continuing to apply.

05

(d) The evidence checks that the simulation implements an inverse-square rule over its sampled range. It does not measure a real source mass, establish the units, reveal uncertainty or independently test Newtonian gravity in nature.

COMMON MISTAKE

Looking for equal decreases in g for equal increases in r, or checking gr rather than gr squared; neither is the invariant predicted by an inverse-square relationship.

Recover half-life from count-rate evidence [12]

EXPECTED CONCLUSION

Net activity falls from 800 to 100 counts/min, a factor of eight or three half-lives in 18 years, so the half-life is 6 years. After 12 more years the predicted total is 25 + 120 = 145 counts/min.

REASONING AND MARKING CHECKPOINTS

01 (a) The detector records environmental and instrumental background as well as the source. Radioactive decay applies to the source contribution, not to the unchanged background count.

02 (b) Initial net count = 920 - 120 = 800 counts/min; later net count = 220 - 120 = 100 counts/min.

03 (b) The net count falls 800 → 400 → 200 → 100, which is three halvings, so three half-lives have elapsed in 18 years.

04 (c) Half-life = 18/3 = 6 years.

05 (d) A further 12 years is two half-lives, so net count becomes 100/4 = 25 counts/min. Add background back for the detector prediction: 25 + 120 = 145 counts/min.

06 (d) Assumptions include constant detector geometry and efficiency, constant mean background, no contamination or source loss, and a single radionuclide with unchanged decay probability.

COMMON MISTAKE

Halving the total detector reading, including its constant background; doing so gives the wrong decay ratio and therefore the wrong half-life and future count.

Evaluate an ultrasound frequency-penetration claim

[12]

EXPECTED CONCLUSION

Useful depth falls as frequency rises. Products are 28.0, 30.0, 32.5, 32.0 and 33.6 MHz·cm; the last exceeds ±10% of 28.0, so the complete dataset fails the stated consistency rule even though the inverse trend is approximate.

REASONING AND MARKING CHECKPOINTS

01

(a) Maximum useful image depth decreases as frequency increases, with large losses at first and smaller absolute losses at the highest frequencies. The raw relationship is curved rather than linear.

02

(b) The products frequency × depth are 2×14.0 = 28.0, 3×10.0 = 30.0, 5×6.5 = 32.5, 8×4.0 = 32.0 and 12×2.8 = 33.6 MHz·cm.

03

(b) Ten percent of the first product is 2.8, so the allowed interval is 25.2-30.8. The 5, 8 and 12 MHz products lie above that interval; the full record does not meet the stated inverse-proportion rule.

04

(c) Higher-frequency waves generally have shorter wavelength and can resolve smaller structures, but tissue attenuates them more strongly, reducing useful depth. The operator chooses a compromise for the target anatomy.

05

(d) A uniform phantom cannot reproduce varied tissue, body size, bone, gas or operator technique. Repeat with tissue-equivalent phantoms of several compositions and blinded image-quality criteria before informing clinical practice.

COMMON MISTAKE

Calling the claim proven because depth decreases, without testing the specific invariant frequency times depth or applying the tolerance to every point.

Interpret a phase-change heating record

[12]

EXPECTED CONCLUSION

The sample warms at 5 °C/min, remains at 0 °C from 2-6 min, then warms at 10 °C/min. During the plateau, supplied energy changes state rather than temperature. Six readings do not prove perfectly constant input power.

REASONING AND MARKING CHECKPOINTS

01

(a) From 0-2 min temperature rises from -10 °C to 0 °C; from 2-6 min it remains at 0 °C; from 6-10 min it rises from 0 °C to 40 °C.

02

(b) Initial warming rate = [0 - (-10)]/(2 - 0) = 5 °C/min. Final warming rate = (40 - 0)/(10 - 6) = 10 °C/min.

03

(c) At 0 °C, energy is used to separate particles and change the phase mixture rather than increase mean kinetic energy, so temperature stays approximately constant while heating continues.

04

(c) After the phase change, a different specific heat capacity and thermal-loss pattern can give a different rate even if heater power is similar.

05

(d) The record supports an approximately steady process but does not directly measure electrical power; heat loss also changes with temperature. Log voltage and current continuously and collect more frequent temperature readings with repeats.

COMMON MISTAKE

Saying the heater stops during the plateau or that energy disappears; the prompt says heating continues, and the energy is associated with changing state and transfers to the surroundings.

Which launch angle gives the greatest range?

[14]

EXPECTED CONCLUSION

Vary only launch angle, measure horizontal range to first impact, and keep launch speed, release height, ball and landing level constant. A model without drag predicts a maximum near 45°, but the experiment must test that prediction.

REASONING AND MARKING CHECKPOINTS

01

(a) A focused question is: How does launch angle from 15° to 75° affect the horizontal range of a foam ball launched at constant speed from and to the same height?

02

(b) At low angle the horizontal component is large but flight time is short; at high angle flight time is longer but the horizontal component is small. The ideal no-drag model therefore predicts a maximum near 45°.

03

(c) Set 15°, 25°, 35°, 45°, 55°, 65° and 75° with a securely clamped launcher and protractor. Fire into a clear, supervised landing lane and mark the first impact, not the bounce.

04

(c) The independent variable is angle and the dependent variable is horizontal range. Control spring compression, ball, launcher position, release height, landing height and the rule used to locate impact.

05

(c) Take at least five independently reset launches per angle. Record every range with units, calculate a mean and range, and plot mean range against launch angle with the spread shown.

06

(d) The launcher may not give identical speed after each reset. Measuring launch speed with video or two light gates would reveal this variation; randomising the angle order also separates drift from an angle effect.

07

(d) Wear eye protection, never aim at people, use a light foam projectile and establish a no-entry landing zone before firing.

COMMON MISTAKE

Changing spring compression to make high-angle shots travel farther, which changes launch speed at the same time and prevents launch angle from being isolated as the cause.

Audit the energy ledger of a regenerative lift

[12]

EXPECTED CONCLUSION

The lift gains 72 kJ at 3.6 kW. It receives 1.8 MJ electrically, so lifting efficiency is 4.0%. Descent returns 36 kJ and the net battery decrease is 1.764 MJ.

REASONING AND MARKING CHECKPOINTS

01
(a) Gravitational energy gained is ΔE = mgh = 600 × 10 × 12 = 72,000 J = 72 kJ.

02
(a) Useful lifting power is 72,000/20 = 3600 W = 3.6 kW. Power must use the same 20 s interval as the energy transfer.

03
(b) Electrical energy supplied is Pt = 90,000 × 20 = 1,800,000 J = 1.8 MJ. Efficiency = 72,000/1,800,000 × 100 = 4.0%.

04
(c) Returned energy is 0.50 × 72,000 = 36,000 J. Net battery decrease = 1,800,000 - 36,000 = 1,764,000 J = 1.764 MJ.

05
(d) The unrecovered energy has not disappeared: it is transferred to thermal energy in the motor, electronics, cables, brakes, air and mechanism, plus sound. The selected battery-lift store is not an isolated system.

COMMON MISTAKE

Subtracting the returned energy from the 72 kJ useful gain instead of from the 1.8 MJ battery input, which omits the large dissipative transfers during lifting.

Evaluate a community flood-barrier design [16]

EXPECTED CONCLUSION

Bottom gauge pressure is 11,760 Pa. The triangular pressure distribution gives force 7056 N per metre. Procurement should depend on anchoring, failure tests, deployment time, reuse and the community's flood frequency-not purchase price alone.

REASONING AND MARKING CHECKPOINTS

01

(a) Bottom gauge pressure is $p = \rho gh = 1000 \times 9.8 \times 1.20 = 11{,}760$ Pa.

02

(a) Average gauge pressure over a vertical wall is half the bottom value because the distribution is triangular: 5880 Pa. Area per metre width is 1.20 m^2.

03

(a) Resultant horizontal force is $5880 \times 1.20 = 7056$ N per metre of barrier, before adding waves, seepage, impacts or a safety factor.

04

(b) Pressure is larger at greater depth, so the lower part contributes more force. The centre of pressure for an ideal vertical rectangular wall is one-third of the depth above the bottom, not at mid-depth.

05

(c) Aluminium costs more initially but can reduce material use across repeated floods if inspection, storage and transport are feasible. Single-use bags may be faster and cheaper for a rare emergency yet produce waste and need filling material and labour.

06

(c) Residents, emergency teams, taxpayers, waste workers and people with limited mobility have different needs. Failure can endanger lives, so certified anchoring, leakage, overtopping and debris-impact evidence must outweigh a simple cost-per-metre comparison.

07

(d) For a flood-prone community with trained staff and storage, choose a tested reusable system if whole-life cost and safety performance are better. For a rare event, a bag system may be justified only with a credible deployment, collection and disposal plan.

COMMON MISTAKE

Multiplying bottom pressure by the whole wall area as though pressure were uniform, which doubles the ideal hydrostatic resultant and distorts the design comparison.

Map resonance without risking hearing

[14]

EXPECTED CONCLUSION

Vary frequency through and beyond 4-8 Hz, measure steady amplitude at fixed driving strength, and plot amplitude against frequency. The amplitude should peak near the natural frequency; increased damping should lower and broaden the peak.

REASONING AND MARKING CHECKPOINTS

01

(a) Ask: How does driving frequency from 2 Hz to 10 Hz affect the steady displacement amplitude of this oscillator at fixed driving force and damping?

02

(b) Predict a maximum near the natural frequency because energy transfer is most effective when drive and response remain appropriately phased. Damping removes mechanical energy and therefore limits the peak.

03

(c) Sweep 2-10 Hz using 1 Hz steps first, then 0.2 Hz steps around the observed maximum. Keep drive amplitude, moving mass, spring, geometry, sensor position and damping setting constant.

04

(c) At each frequency, wait a fixed number of cycles for transients to decay, record at least ten later cycles, and calculate mean half peak-to-peak displacement. Repeat after stopping and restarting the system.

05

(c) Plot steady amplitude against frequency and show repeat spread. Stay below the apparatus displacement limit, secure masses and springs, use a low-power driver and keep sound output at a safe, non-startling level.

06

(d) Repeat the complete randomised frequency sequence with one measured damping change while all other controls remain fixed. Compare peak frequency, maximum amplitude and width at a stated fraction of the maximum.

07

(d) Temperature or spring fatigue can drift over time; alternating the two damping settings at selected frequencies helps distinguish damping from time-order effects.

COMMON MISTAKE

Recording immediately after changing frequency, when the motion still contains a transient response, or changing driving amplitude together with frequency and calling the peak resonance.

Choose a communication link for a remote community

[16]

EXPECTED CONCLUSION

The microwave wavelength is 0.060 m. No technology is universally best: a recommendation depends on terrain, required latency and capacity, outage tolerance, affordability, maintenance skills and verified whole-life data.

REASONING AND MARKING CHECKPOINTS

01

(a) Wavelength $\lambda = c/f = 3.0 \times 10^8/(5.0 \times 10^9) = 0.060$ m, or 6.0 cm.

02

(b) Microwave relays can span difficult ground without continuous trenching, but obstacles, alignment and some weather conditions can weaken the link. Towers also need power and maintenance access.

03

(b) Fibre offers high capacity, low latency and immunity to radio interference, but trenching or submarine work can disturb land and cost heavily. A single cable break may take specialist repair.

04

(b) Satellite can connect dispersed users quickly without a continuous local route, but signal travel and network architecture increase delay; recurring charges, weather attenuation and provider dependence matter.

05

(c) The clinic may prioritise reliable low-latency consultations, the school capacity and affordability, and residents broad household access. Ownership, repair training, backup power, cultural or land permissions and ecosystem disturbance belong in the decision.

06

(d) Choose fibre where demand and route feasibility justify its whole-life cost; use a microwave backbone where line of sight is dependable; use satellite as an interim or resilient backup. Obtain measured latency, capacity, outage, energy, maintenance and ten-year cost data before committing.

COMMON MISTAKE

Choosing the option with the highest advertised speed without distinguishing wavelength, latency, capacity, reliability, installation impact and who can actually afford access.

Design a solenoid field investigation

[14]

EXPECTED CONCLUSION

Vary current and measure axial field at the fixed centre while controlling coil geometry, probe orientation, temperature and nearby magnetic materials. Predict a proportional field-current relationship within the supply and heating limits.

REASONING AND MARKING CHECKPOINTS

01

(a) Ask: How does current from 0.10 A to 1.00 A affect magnetic flux density at the geometric centre of this fixed air-core solenoid?

02

(b) Predict B proportional to I because each turn's field contribution increases with current and superposition adds the contributions. This model assumes unchanged geometry and negligible magnetic material effects.

03

(c) Clamp the solenoid, align and mark the Hall probe at its centre, measure ambient field with zero current, then take readings at ten planned current settings in random order after the value stabilises.

04

(c) Control turns, coil length, probe position and orientation, distance from magnetic objects and coil temperature. Subtract the signed zero-current reading; repeat complete current sequences rather than only repeated display readings.

05

(c) Plot corrected B against measured I with repeat spread. Use a current limit and series protection, switch off between readings, monitor temperature, avoid short circuits and do not touch a hot coil.

06

(d) To test turns per metre, prepare equal-length coils with different known turns, use the same current and centre-probe geometry, and keep wire heating comparable. Plot B against N/L.

COMMON MISTAKE

Moving the Hall probe to wherever the reading is largest at every current; that changes position with the independent variable and manufactures an apparent relationship.

Select an Earth-observation orbit responsibly

[16]

EXPECTED CONCLUSION

The ideal circular-orbit period is about 5828 s, or 97.1 min. The mission can be justified only if its resolution and revisit evidence meet the wildfire need and governance addresses privacy, debris, emissions and fair data access.

REASONING AND MARKING CHECKPOINTS

01 (a) Cube the radius: $r^3 = (7.0 \times 10^6)^3 = 3.43 \times 10^{20}$ m³. Divide by GM to obtain about 8.596×10^5 s².

02 (a) The square root is about 927.2 s, and multiplying by 2π gives T ≈ 5828 s = 97.1 min. This is the period, not the time over one community.

03 (b) Lower altitude can improve spatial resolution for a fixed instrument and shorten the orbital period, but drag shortens orbital life and the instantaneous field of view is smaller. Revisit time also depends on inclination, swath and Earth's rotation.

04 (b) Higher altitude increases area visible per pass and can reduce drag, but a fixed detector resolves larger ground pixels. The best orbit follows the actual warning requirement rather than maximising one metric.

05 (c) Earlier fire detection can protect lives and ecosystems, yet high-resolution imagery can expose private activity. Launch and replacement create emissions, and failed spacecraft add collision and debris risks.

06 (c) Governments, residents, firefighters, Indigenous communities, researchers and commercial operators may not have equal control or access. A public-benefit claim needs transparent data rules, consent-sensitive use and an end-of-life plan.

07 (d) Proceed if validated coverage and latency meet emergency needs, data access is equitable, privacy is governed and disposal reliability is demonstrated. Otherwise improve or share an existing constellation rather than launch by default.

COMMON MISTAKE

Treating the 97-minute period as a 97-minute revisit time for the same place; Earth rotation, orbital plane, sensor swath and constellation design determine revisit.

Design a solar-panel angle field study

[14]

EXPECTED CONCLUSION

Vary tilt, calculate P = VI at a controlled load, and normalise power by measured irradiance and panel area. Predict the largest normalised power when the panel is closest to perpendicular to the incoming sunlight.

REASONING AND MARKING CHECKPOINTS

01

(a) Ask: At a stated date and time range, how does panel tilt from 0° to 80° affect electrical power per unit incident irradiance for the same panel and load?

02

(b) Predict a maximum when the panel normal points closest to the Sun because the same beam power is spread over the smallest panel-plane area. Electrical conversion and temperature may prevent a perfect cosine response.

03

(c) Test 0°-80° in 10° steps in randomised order. At each angle record irradiance in the panel plane, panel temperature, load voltage and current after a fixed settling time; calculate P = VI and P divided by irradiance and area.

04

(c) Control panel, load, cable, orientation around the vertical axis, location, shading and measurement timing. Repeat complete angle sequences and include a reference-panel reading to identify cloud drift.

05

(c) Plot normalised power against tilt with repeat spread. Secure the panel and stand against wind, keep electrical connections dry and insulated, avoid roof work by performing the study at ground level, and manage glare.

06

(d) Sun elevation and direction vary with time, season, weather and latitude; temperature, dirt and shading also change yield. Combine longer monitoring with a validated solar-path model before choosing an annual optimum.

COMMON MISTAKE

Comparing raw power readings taken sequentially as clouds and solar elevation change, then attributing every difference to tilt instead of measuring and normalising the irradiance.

Build a defensible classroom-cooling recommendation

[16]

EXPECTED CONCLUSION

F uses 54 kWh and produces 21.6 kg CO_2e; H uses 972 kWh and 388.8 kg CO_2e; shaded H uses 729 kWh and 291.6 kg CO_2e. These options deliver different thermal outcomes, so a fair decision needs measured comfort and building evidence.

REASONING AND MARKING CHECKPOINTS

01

(a) Annual operating time is 6 × 180 = 1080 h. Fan energy = 0.050 kW × 1080 h = 54 kWh; emissions = 54 × 0.40 = 21.6 kg CO_2e.

02

(a) Heat-pump energy = 0.900 kW × 1080 h = 972 kWh; emissions = 972 × 0.40 = 388.8 kg CO_2e.

03

(b) A 25% reduction leaves 75%: shaded heat-pump energy = 0.75 × 972 = 729 kWh and emissions = 729 × 0.40 = 291.6 kg CO_2e.

04

(c) The fan increases convective and evaporative cooling of occupants but does not lower air temperature, while the heat pump removes energy from the room. Energy totals compare inputs, not equal comfort or health outcomes.

05

(d) Measure indoor temperature, humidity, radiant heat, occupancy, noise, air quality, heat-pump efficiency under local conditions and student comfort. Include installation, maintenance, electricity affordability, glare, façade permission and the needs of heat-sensitive users.

06

(d) Use passive shading first where it is structurally suitable, combine fans with ventilation during moderate conditions, and reserve efficient heat-pump cooling for unsafe heat. The final operating rule should be triggered by measured conditions, not a single calendar schedule.

07

(d) Consult students, staff, families, facilities workers and building owners; compare whole-life cost and embodied impacts. Reassess the recommendation as the grid mix, climate and occupancy change.

COMMON MISTAKE

Calling the fan four times better because it uses less electricity, without recognising that the fan and heat pump provide different services and may protect health under different conditions.