GIOPHYSICS ORIGINAL EXAMINATION SERIES

Cambridge AS & A Level 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**	**263**	**Included**

INSIDE THIS PACK

PAPER 1

Cambridge AS & A Level Physics · Extended Paper 1

165 minutes | 10 questions | 122 marks

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

PAPER 2

Cambridge AS & A Level Physics · Extended Paper 2

195 minutes | 10 questions | 141 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 AS & A Level 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	**165 min**	**10**	**122**

INSTRUCTIONS

- Answer every question and show the complete physical argument.
- Use the data and relationships appropriate to your course.
- Give units, directions and justified assumptions where required.
- Answer in the spaces provided and label any additional pages clearly.

INFORMATION

- The total mark for this paper is 122.
- Marks for each task are shown in brackets.
- The detailed marking guide begins after Paper 2.

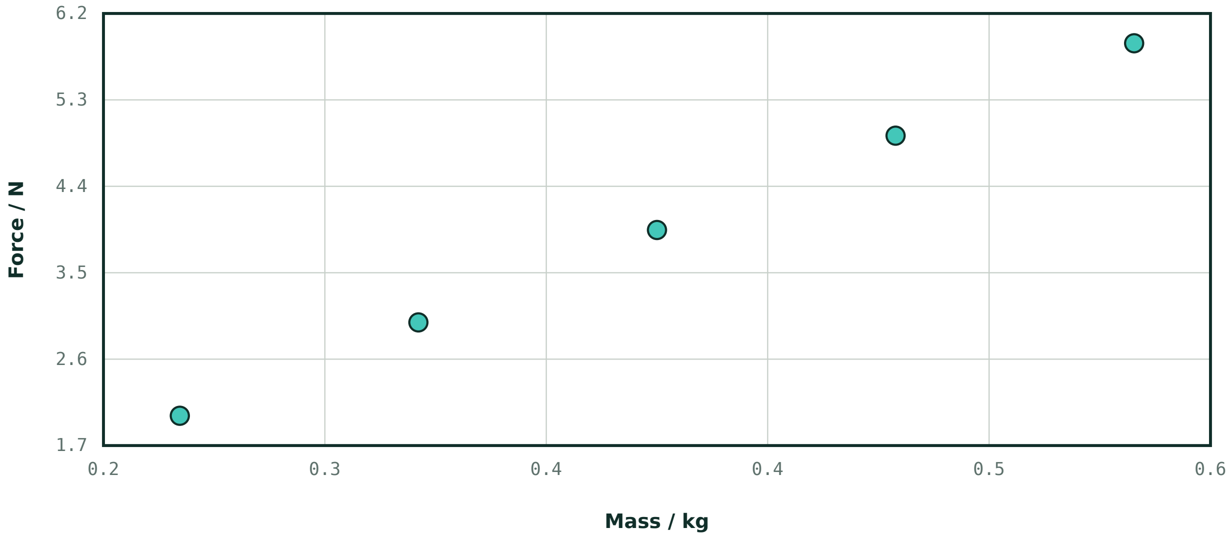
Force-sensor calibration and uncertainty

[12]

Known masses give (mass in kg, force in N) readings (0.2, 1.97), (0.3, 2.95), (0.4, 3.92), (0.5, 4.91), (0.6, 5.88). Mass uncertainty is ±0.001 kg and force uncertainty ±0.02 N. (a) Find endpoint gradient and unit. (b) Estimate g. (c) Find percentage uncertainty in the first mass and force. (d) Test whether the intercept is resolved from zero. (e) Explain steepest/shallowest lines and one systematic error.

Force-sensor calibration

Force reading for independently known masses.



ANSWER SPACE

Rocket-cart ejection and resistance

[14]

A 5.0 kg cart initially at rest ejects a 0.80 kg package backward at 6.0 m/s relative to ground. Remaining cart then experiences 1.4 N resistance for 3.0 s. (a) Find immediate cart speed. (b) Find resistive impulse and later speed. (c) Find total kinetic energy after ejection and explain its source. (d) Explain Newton's third law and when momentum conservation is approximate.

ANSWER SPACE

Winch energy and instantaneous power

[12]

A winch lifts 420 kg through 18 m in 24 s, from rest to 3.0 m/s, losing 1.6×10^4 J. Take $g = 9.81\ m/s^2$. (a) Find GPE and KE gains. (b) Find electrical input and average power. (c) At final speed input power is 18.0 kW and resistance 900 N. Find acceleration. (d) Explain average versus instantaneous power.

ANSWER SPACE

Wave transmission at a string boundary

[10]

A 12 Hz transverse wave of amplitude 3.0 cm travels at 4.8 m/s in a light string, then at 3.2 m/s in a heavier string. (a) Find both wavelengths. (b) Find period, angular frequency and maximum particle speed. (c) Explain unchanged frequency, changed wavelength and partial reflection. (d) State reflected-pulse phase change.

ANSWER SPACE

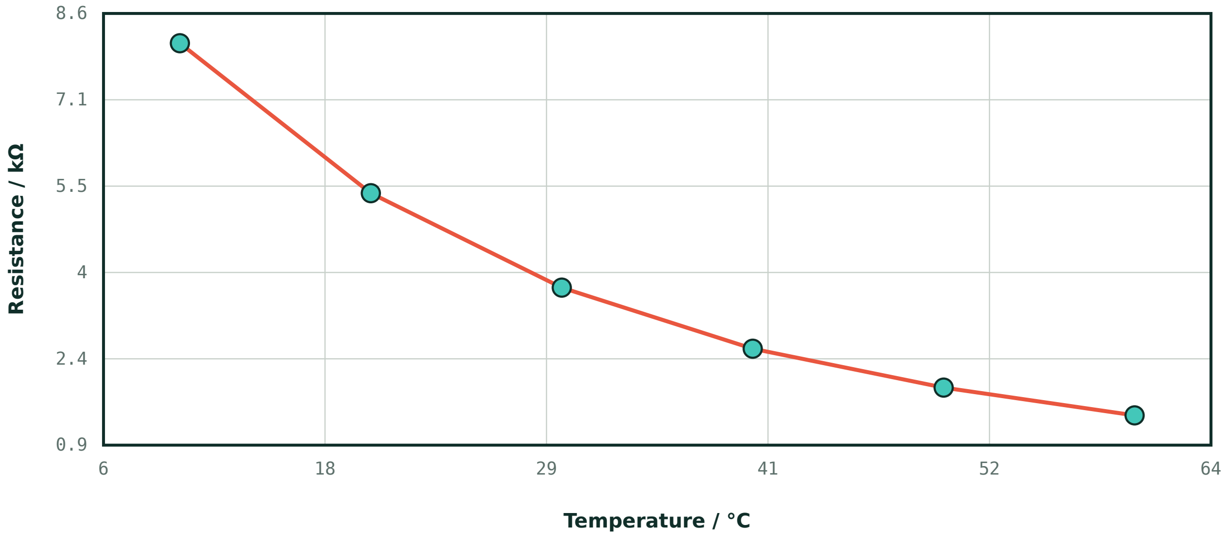
Thermistor divider alarm

[12]

An NTC thermistor has (temperature in °C, resistance in kΩ) values (10, 8.1), (20, 5.4), (30, 3.7), (40, 2.6), (50, 1.9), (60, 1.4). It is series with 3.3 kΩ across 6.0 V; output is across the fixed resistor. (a) Find output at 20 °C and 50 °C. (b) Explain sensitivity direction. (c) Estimate trigger temperature for 3.5 V. (d) Explain voltmeter loading and a comparator improvement.

NTC calibration

Resistance at six temperatures.



ANSWER SPACE

Quark bookkeeping in two decays

[10]

A free neutron undergoes beta-minus decay and a neutral pion decays into two photons. (a) Write both reactions, including the antineutrino. (b) Give proton and neutron quark compositions. (c) State the quark-level change and weak boson. (d) Check charge, baryon and lepton number. (e) Explain why photons carry no baryon number.

ANSWER SPACE

Molecular interpretation of a heated gas

[12]

A rigid vessel contains 0.80 mol monatomic ideal gas at 300 K and is heated to 450 K. Use $R = 8.31$ J/(mol K), $N_a = 6.02 \times 10^{23}$ mol^{-1}. (a) Find ΔU using $U = 3nRT/2$. (b) Find molecule number. (c) Find rms-speed factor. (d) Find pressure factor and explain molecularly. (e) Explain zero boundary work and contrast constant-pressure heating.

ANSWER SPACE

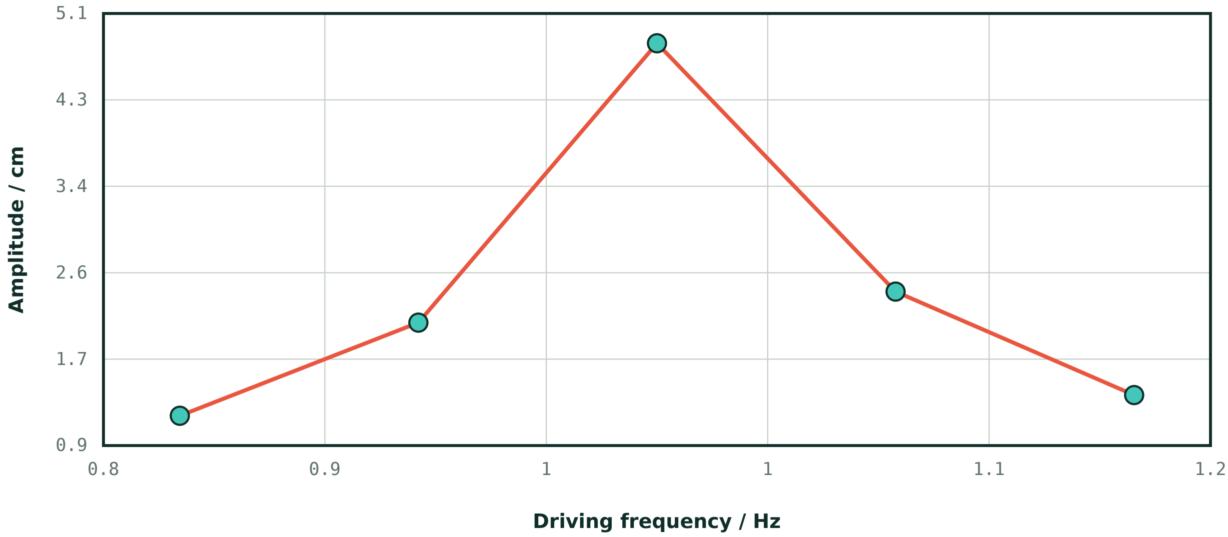
Driven-oscillator resonance

[12]

A driven 0.50 kg oscillator gives (frequency in Hz, steady amplitude in cm) (0.8, 1.2), (0.9, 2.1), (1, 4.8), (1.1, 2.4), (1.2, 1.4). (a) Estimate resonance and angular frequency. (b) Estimate spring constant. (c) Explain phase well below, near and above resonance. (d) Predict increased damping. (e) Explain why finite peak does not prove zero damping and discuss benefit and hazard.

Driven response

Steady amplitude at five frequencies.



ANSWER SPACE

Velocity selector and alternating supply

[13]

Positive singly charged ions pass undeflected through $E = 2.4 \times 10^4$ V/m and $B = 0.080$ T, then curve at radius 0.120 m in $B = 0.150$ T. Charge is 1.60×10^{-19} C. (a) Find speed and mass. (b) Give force direction for east velocity and downward B. (c) Explain magnetic work. (d) A 50 Hz supply is 170 V peak: find rms voltage and explain why unsynchronised a.c. cannot select steadily.

ANSWER SPACE

Nuclear tracer dose and gamma imaging

[15]

A tracer has half-life 6.0 h and initial activity 48 MBq. A 20 min scan begins 12 h later. (a) Find activity at scan start and end. (b) Estimate decays using mean activity. (c) For one 140 keV photon per decay, estimate emitted gamma energy using 1 eV = 1.60×10^{-19} J. (d) Explain suitable gamma and half-life properties. (e) Explain attenuation, collimation and optimisation. (f) Distinguish activity from absorbed dose.

ANSWER SPACE

Cambridge AS & A Level 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**	**141**

INSTRUCTIONS

- Answer every question and show the complete physical argument.
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INFORMATION

- The total mark for this paper is 141.
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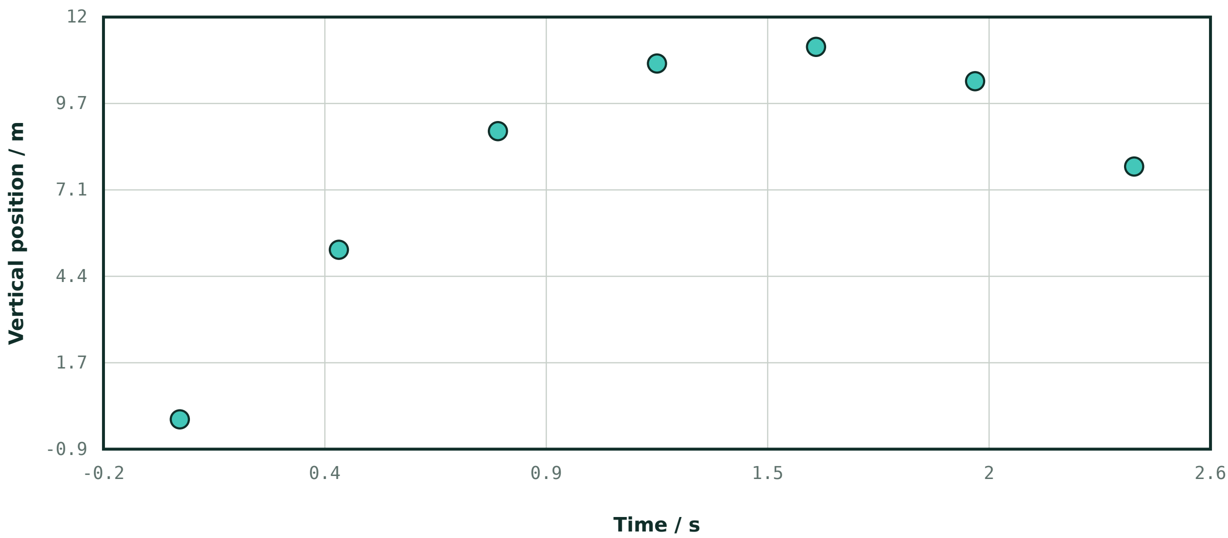
Projectile trajectory reconstructed from data

[14]

A ball has (time in s, vertical position in m) data (0, 0), (0.4, 5.216), (0.8, 8.864), (1.2, 10.944), (1.6, 11.456), (2, 10.4), (2.4, 7.776) and constant horizontal velocity 9.0 m/s. (a) Use $y = u_Y t - \frac{1}{2}gt^2$ to estimate u_Y and g. (b) Find model maximum time and height. (c) Find time and range on return to launch level. (d) State accelerations. (e) Explain two departures from an ideal parabola.

Projectile vertical position

Vertical position sampled during flight.



ANSWER SPACE

Submerged gate in equilibrium

[13]

A uniform horizontal gate of length 2.4 m and mass 90 kg is hinged at one end. Its centre is 1.8 m below liquid of density 850 kg/m³. Liquid gives 3.6 kN downward at 1.5 m from hinge; a vertical cable acts at far end. Take g = 9.81 m/s². (a) Find gauge pressure at centre. (b) Find cable tension. (c) Find hinge vertical force. (d) Explain centre of pressure and complete equilibrium.

ANSWER SPACE

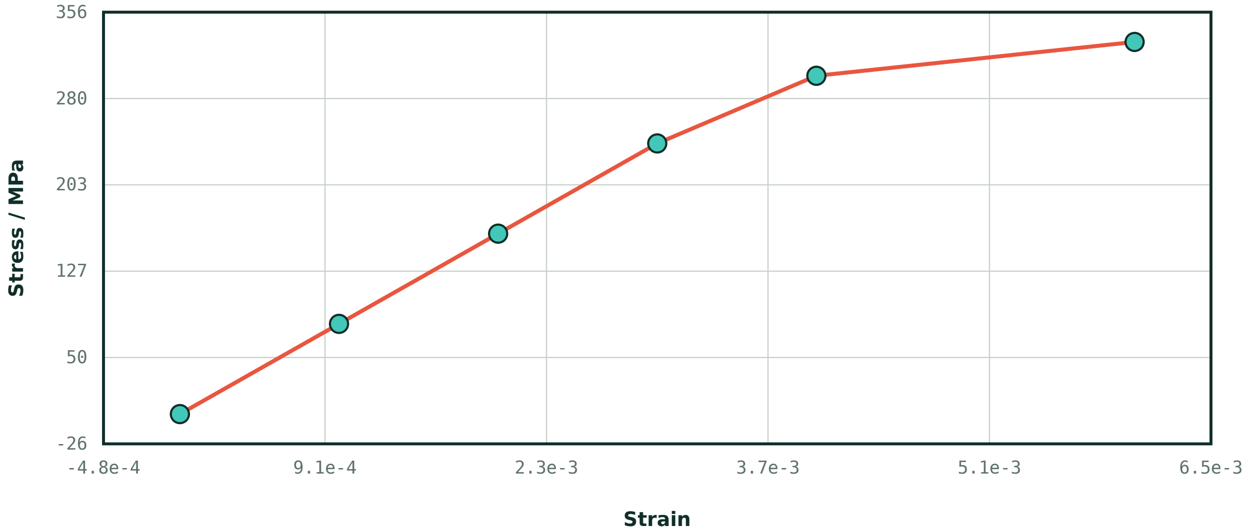
Stress-strain energy and elastic behaviour

[15]

A wire gives (strain, stress in MPa) readings (0, 0), (0.001, 80), (0.002, 160), (0.003, 240), (0.004, 300), (0.006, 330). Original length is 2.0 m, area 1.5×10^{-6} m² and volume 3.0×10^{-6} m³. (a) Find Young modulus. (b) Find force and extension at strain 0.003. (c) Find energy density and energy. (d) Identify departure from proportionality. (e) Describe a safe experiment and distinguish proportional from elastic limit.

Metal stress-strain data

Stress measured during tensile loading.



ANSWER SPACE

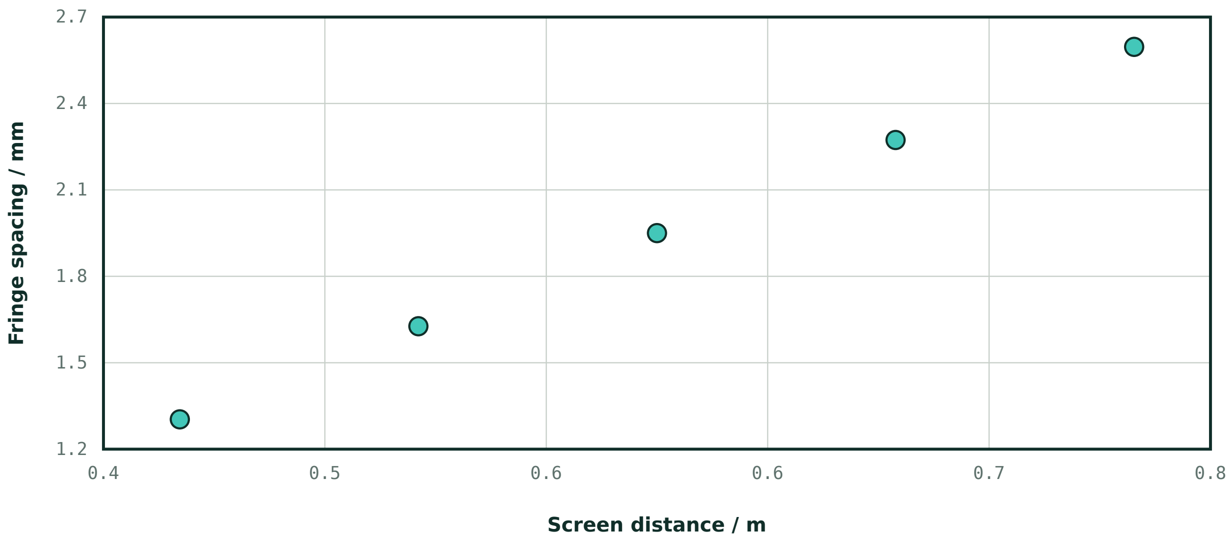
Double-slit gradient and measurement design

[13]

For 640 nm light and slit separation 0.200 mm, measured (screen distance in m, fringe spacing in mm) data are (0.4, 1.28), (0.5, 1.6), (0.6, 1.92), (0.7, 2.24), (0.8, 2.56). (a) Find graph gradient and slit separation. (b) Compare with stated value. (c) Predict spacing at 1.20 m. (d) Explain covering one slit and reducing wavelength. (e) Explain multi-fringe measurement and a control.

Fringe spacing against screen distance

Bright-fringe spacing at several screen distances.



ANSWER SPACE

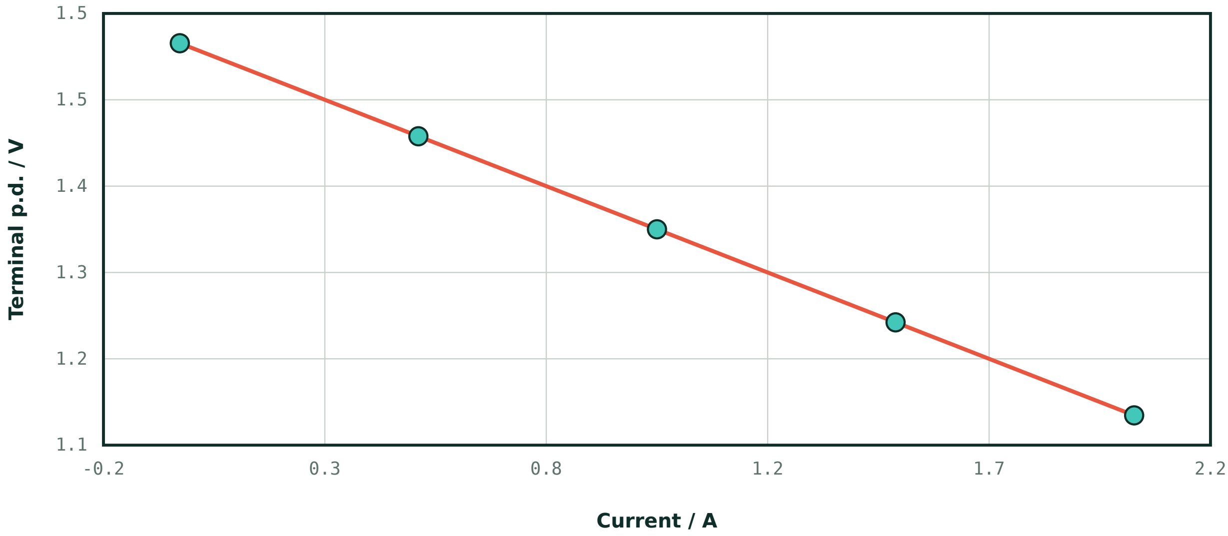
Cell e.m.f., internal resistance and power

[13]

A cell gives (current in A, terminal p.d. in V) readings (0, 1.52), (0.5, 1.43), (1, 1.34), (1.5, 1.25), (2, 1.16). (a) Find e.m.f. and internal resistance. (b) At 1.50 A find external resistance, load power, internal heating and chemical power. (c) Verify conservation. (d) Find load for maximum power and its efficiency. (e) Explain why that operation is inefficient.

Cell terminal characteristic

Terminal potential difference as current changes.



ANSWER SPACE

Circular orbit, energy and transfer

[14]

A 750 kg spacecraft circles a 6.0×10^{24} kg planet at radius 8.0×10^{6} m. Use $G = 6.67 \times 10^{-11}$ N m²/kg². (a) Find field strength, orbital speed and period. (b) Find angular speed and verify centripetal acceleration. (c) Find energy needed to move to a circular orbit of radius 1.20×10^{7} m using $E = -GMm/(2r)$. (d) Explain why one forward burn first makes an ellipse.

ANSWER SPACE

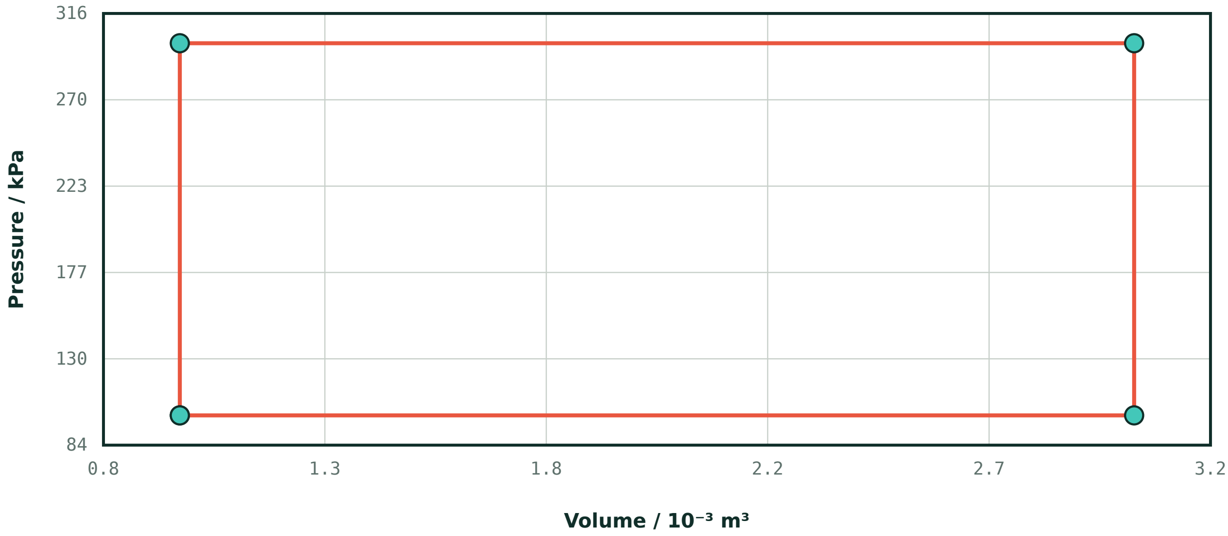
Ideal-gas cycle and first law

[15]

One mole of monatomic ideal gas follows clockwise vertices (volume in 10^{-3} m³, pressure in kPa) (1, 100), (1, 300), (3, 300), (3, 100), (1, 100). (a) Find work on every leg and net work. (b) Find temperatures A, B and C using R = 8.31 J/(mol K). (c) Find ΔU and Q on A→B and B→C. (d) Verify net heat equals net work. (e) Explain orientation and heat rejection.

Rectangular gas cycle

Constant-volume and constant-pressure processes.



ANSWER SPACE

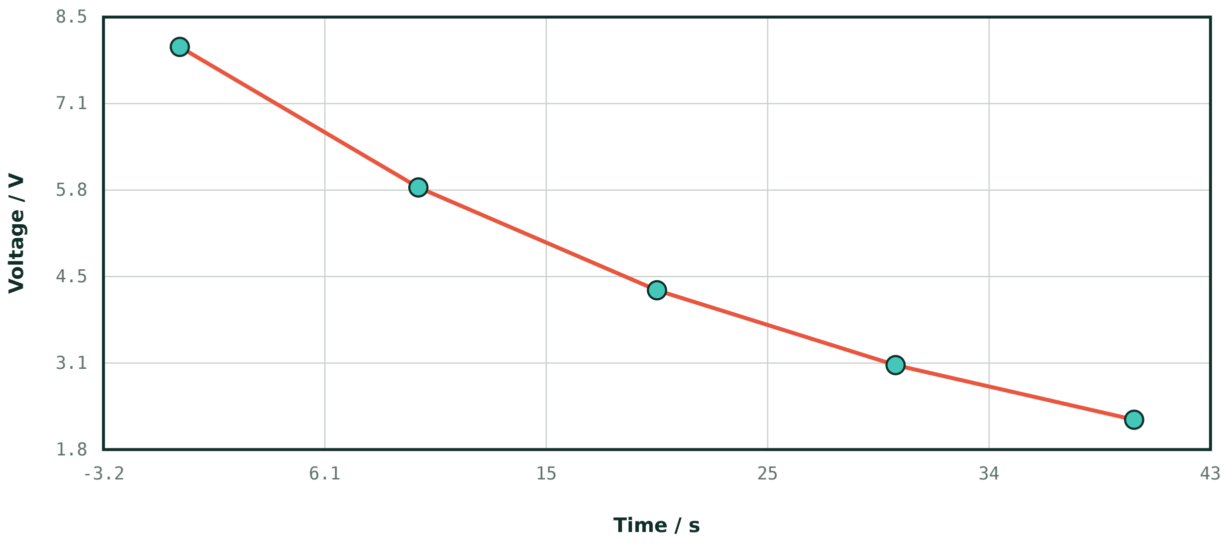
Capacitor discharge and stored field energy

[14]

A capacitor discharges through 220 kΩ with (time in s, voltage in V) readings (0, 8), (10, 5.84), (20, 4.26), (30, 3.11), (40, 2.27). (a) Estimate time constant and capacitance. (b) Find initial charge and energy. (c) Find initial current and resistor power. (d) Find energy fraction at 40 s. (e) Explain voltmeter loading and a semilog test.

Capacitor discharge

Voltage during resistor discharge.



ANSWER SPACE

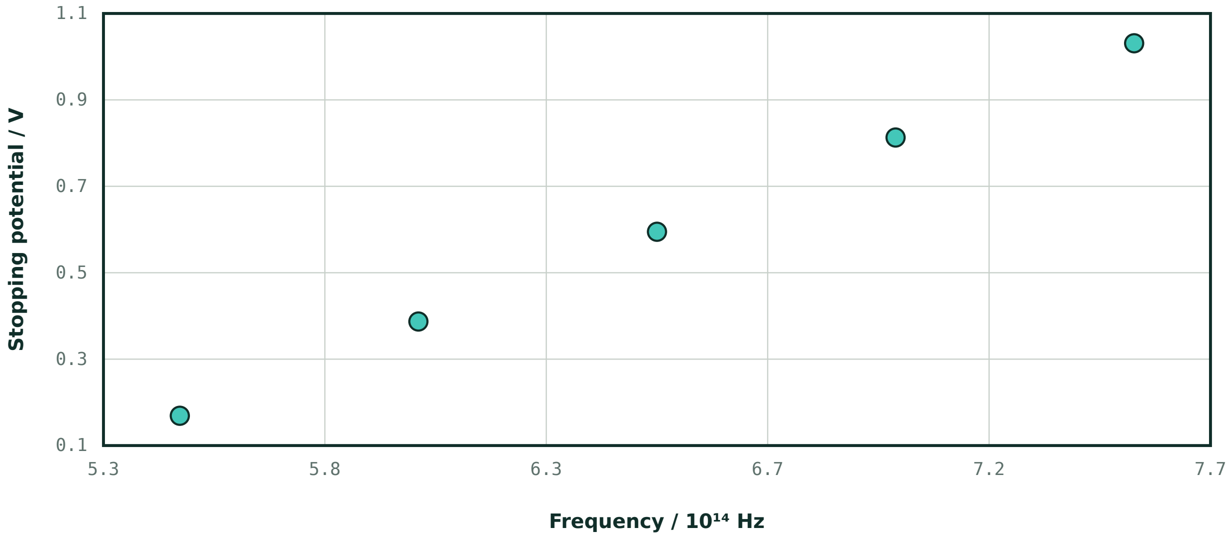
Photoelectric stopping-potential evidence

[14]

A metal gives (frequency in 10^{14} Hz, stopping potential in V) readings (5.5, 0.18), (6, 0.39), (6.5, 0.59), (7, 0.8), (7.5, 1.01). Use $e = 1.60 \times 10^{-19}$ C and $m_e = 9.11 \times 10^{-31}$ kg. (a) Find gradient and h. (b) Estimate threshold frequency and work function in eV. (c) At 7.0×10^{14} Hz find maximum speed. (d) Explain intensity below/above threshold. (e) Explain photon evidence.

Photoelectric stopping potential

Stopping potential at five frequencies.



ANSWER SPACE

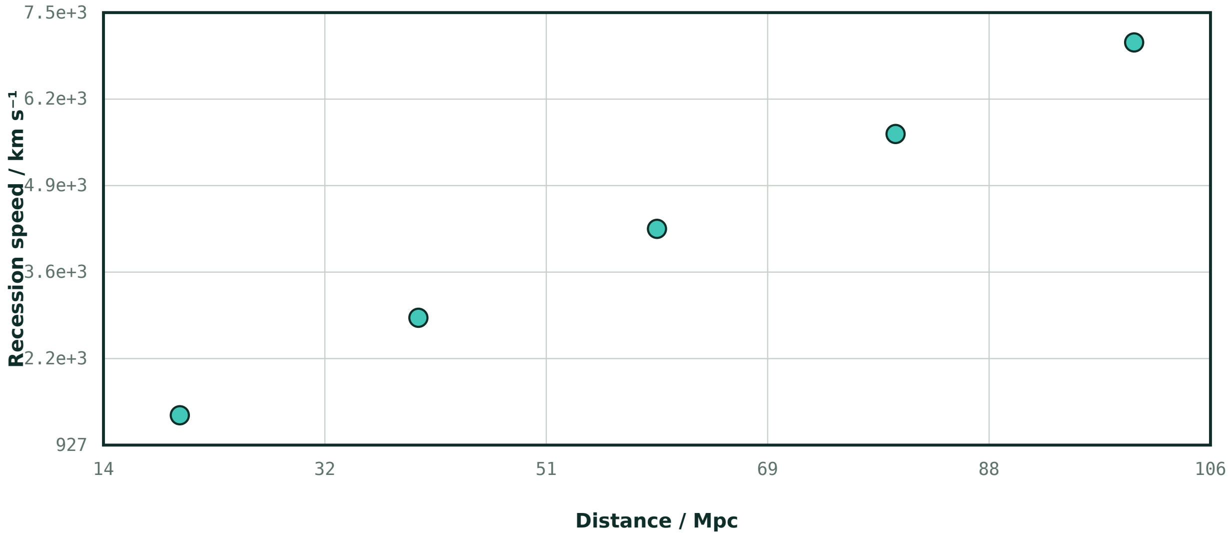
Hubble plot and cosmological evidence

[16]

Galaxies give (distance in Mpc, recession speed in km/s) (20, 1380), (40, 2860), (60, 4210), (80, 5650), (100, 7040). Use 1 Mpc = 3.086×10^{19} km and 1 year = 3.156×10^{7} s. (a) Find H_0. (b) Convert to s^{-1} and calculate $1/H_0$ in years. (c) Predict speed at 150 Mpc. (d) Explain population fitting. (e) Explain standard candles and redshift. (f) Explain two age limitations and two other hot-Big-Bang observations.

Galaxy recession relation

Recession speeds with independently estimated distances.



ANSWER SPACE

TEACHER COPY

Detailed marking guide

Cambridge AS & A Level 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**	**263**

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.

Force-sensor calibration and uncertainty

[12]

EXPECTED CONCLUSION

Gradient and g ≈9.78 N/kg; first-reading percentage uncertainties 0.50% and 1.02%; endpoint intercept about 0.015 N, smaller than stated force uncertainty.

REASONING AND MARKING CHECKPOINTS

01

Endpoint gradient = (5.88 - 1.97)/(0.60 - 0.20) = 3.91/0.40 = 9.775 N kg^{-1}. The unit follows force divided by mass.

02

For F = mg, the best-fit gradient estimates gravitational field strength, so g ≈9.78 N/kg. Agreement with expectation is evidence for calibration, not a reason to replace the measured value.

03

First mass percentage uncertainty is 0.001/0.200 × 100 = 0.50%. Force percentage uncertainty is 0.02/1.97 × 100 = 1.02%, so force resolution contributes the larger fraction.

04

Endpoint-line intercept is 1.97 - 9.775(0.20) = 0.015 N. Since this is smaller than ±0.02 N force uncertainty, the data do not resolve it from zero.

05

Draw steepest and shallowest lines compatible with error bars; half their gradient range estimates uncertainty. A zero offset shifts intercept, whereas mass calibration or force scale error changes gradient.

COMMON MISTAKE

Quoting instrument resolution as a percentage without dividing by the reading, or forcing the line through an assumed value of g.

Rocket-cart ejection and resistance

[14]

EXPECTED CONCLUSION

Immediate cart speed 1.14 m/s forward; impulse -4.2 N s; later speed 0.143 m/s; post-ejection kinetic energy about 17.1 J.

REASONING AND MARKING CHECKPOINTS

01

Remaining mass is 5.0 - 0.80 = 4.20 kg. With negligible external impulse during ejection, 0 = 4.20v + 0.80(-6.0), giving v = 1.14 m/s forward.

02

Resistance impulse is $F\Delta t = -1.4 \times 3.0 = -4.2$ N s. Initial post-ejection cart momentum is 4.80 kg m/s, so later momentum is 0.60 kg m/s and speed 0.60/4.20 = 0.143 m/s.

03

Kinetic energy is $\frac{1}{2}(4.20)(1.1429^2) + \frac{1}{2}(0.80)(6.0^2) = 2.74 + 14.4 = 17.1$ J. Internal chemical or elastic energy supplies it; kinetic energy was not conserved.

04

Cart and package exert equal opposite forces for equal times, giving opposite impulses. Those third-law forces act on different bodies and are internal to the combined system.

05

If resistance gives appreciable impulse during the ejection interval, system momentum changes externally. Conservation is then approximate and must be justified by comparing external impulse with ejection momenta.

COMMON MISTAKE

Using 5.0 kg as remaining mass or assuming momentum conservation requires kinetic-energy conservation.

Winch energy and instantaneous power

[12]

EXPECTED CONCLUSION

GPE 7.42×10^4 J; KE 1.89×10^3 J; input 9.21×10^4 J; average 3.84 kW; final acceleration about 2.33 m/s² upward.

REASONING AND MARKING CHECKPOINTS

01

GPE gain = mgh = 420 × 9.81 × 18 = 7.42×10^4 J. KE gain = ½mv² = ½ × 420 × 3.0² = 1.89×10^3 J.

02

Input energy supplies both gains plus losses: 74164 + 1890 + 16000 = 9.21×10^4 J. Average power = 92054/24 = 3.84 kW.

03

At final speed, motor force follows P = Fv: F = 18000/3.0 = 6000 N upward.

04

Net force = 6000 - mg - 900 = 6000 - 4120 - 900 = 980 N upward, so acceleration = 980/420 = 2.33 m/s².

05

Instantaneous power depends on force and speed at one instant; average power divides total energy by whole time, including low-speed starting and varying losses.

COMMON MISTAKE

Equating input directly with mgh/t or finding motor force from P/v without subtracting weight and resistance.

Wave transmission at a string boundary

[10]

EXPECTED CONCLUSION

Wavelengths 0.400 m and 0.267 m; period 0.0833 s; angular frequency 75.4 rad/s; maximum particle speed 2.26 m/s; reflected pulse is inverted.

REASONING AND MARKING CHECKPOINTS

01

From $v = f\lambda$, wavelengths are 4.8/12 = 0.400 m and 3.2/12 = 0.267 m.

02

Period $T = 1/12 = 0.0833$ s and angular frequency $\omega = 2\pi f = 75.4$ rad/s.

03

A string point has maximum transverse speed $\omega A = 75.4 \times 0.030 = 2.26$ m/s, distinct from propagation speed.

04

The source fixes frequency and boundary displacement remains continuous. Lower transmitted speed therefore gives shorter wavelength; impedance mismatch requires reflected and transmitted components.

05

Reflection from the higher-impedance, more fixed-like boundary is inverted, a phase change of π. Energy is shared, not duplicated, between reflected and transmitted waves.

COMMON MISTAKE

Changing frequency at the boundary or confusing particle transverse speed with wave propagation speed.

Thermistor divider alarm

[12]

EXPECTED CONCLUSION

Outputs 2.28 V and 3.81 V; output rises with temperature; 3.5 V corresponds to about 43.4 °C.

REASONING AND MARKING CHECKPOINTS

01

Vout = VsRfixed/(Rfixed + Rthermistor). At 20 °C, Vout = 6.0 × 3.3/(3.3 + 5.4) = 2.28 V.

02

At 50 °C, Vout = 6.0 × 3.3/(3.3 + 1.9) = 3.81 V. NTC resistance falls as temperature rises, increasing fixed-resistor voltage share.

03

At 3.5 V, solve 3.5/6.0 = 3.3/(3.3 + R), giving R = 2.36 kΩ.

04

Interpolate between 2.6 kΩ at 40 °C and 1.9 kΩ at 50 °C: T ≈40 + (2.6 - 2.36)/(2.6 - 1.9) × 10 = 43.4 °C.

05

A finite voltmeter lies parallel with 3.3 kΩ and changes the divider. A high-input-resistance comparator with adjustable reference and hysteresis produces a sharper, stable switch.

COMMON MISTAKE

Using the divider formula for output across the thermistor despite measurement across the fixed resistor.

Quark bookkeeping in two decays

[10]

EXPECTED CONCLUSION

$n \rightarrow p + e^- +$ electron antineutrino; $\pi^0 \rightarrow \gamma + \gamma$; neutron udd, proton uud; $d \rightarrow u + W^-$, then $W^- \rightarrow e^- +$ antineutrino.

REASONING AND MARKING CHECKPOINTS

01

The reactions are $n \rightarrow p + e^- + \text{anti-}\nu_e$ and $\pi^0 \rightarrow \gamma + \gamma$. Two photons can conserve momentum in the pion rest frame by leaving oppositely.

02

Neutron valence composition is udd and proton is uud. Converting one d to u raises the hadron charge by one elementary unit.

03

At the weak vertex $d \rightarrow u + W^-$; the virtual W^- produces $e^- + \text{anti-}\nu_e$. The electron is created rather than stored inside the neutron.

04

Charge is $0 = +1 - 1$; baryon number remains 1; electron and antineutrino lepton numbers +1 and -1 cancel. Energy and momentum also remain conserved.

05

Photons are gauge bosons, not three-quark baryons, so baryon number is zero. The neutral pion is a quark-antiquark meson and also has baryon number zero.

COMMON MISTAKE

Writing a neutrino rather than an antineutrino in beta-minus decay, violating electron-family lepton-number conservation.

Molecular interpretation of a heated gas

[12]

EXPECTED CONCLUSION

ΔU = 1.50 kJ; N = 4.82 × 10^{23}; rms-speed factor 1.225; pressure factor 1.50; rigid-volume boundary work is zero.

REASONING AND MARKING CHECKPOINTS

01

$\Delta U = 3nR\Delta T/2 = 1.5 \times 0.80 \times 8.31 \times 150 = 1496$ J = 1.50 kJ.

02

Molecule number is $nN_a = 0.80 \times 6.02 \times 10^{23} = 4.82 \times 10^{23}$.

03

Mean translational kinetic energy is proportional to T, so rms speed changes by $\sqrt{(450/300)} = \sqrt{1.5} = 1.225$.

04

At fixed amount and volume, $p \propto T$, giving factor 1.50. Faster molecules collide more often and transfer more momentum to vessel walls.

05

Rigid volume has $\Delta V = 0$, so boundary work is zero and heating equals ΔU. A constant-pressure piston expands, does work and needs additional heat for the same temperature rise.

COMMON MISTAKE

Making rms speed directly proportional to temperature or claiming zero work means no energy was transferred.

Driven-oscillator resonance

[12]

EXPECTED CONCLUSION

Resonance about 1.0 Hz; ω = 6.28 rad/s; k ≈19.7 N/m; greater damping lowers and broadens the peak.

REASONING AND MARKING CHECKPOINTS

01

Largest sampled amplitude is 4.8 cm at 1.0 Hz, so resonance is near 1.0 Hz; finer frequency steps are needed for precision.

02

Angular frequency $\omega = 2\pi f = 6.28$ rad/s. For light damping, $k \approx m\omega^2 = 0.50 \times 6.28^2 = 19.7$ N/m.

03

Displacement is approximately in phase with drive well below resonance, lags about π/2 near resonance and approaches antiphase well above it.

04

Greater damping lowers and broadens the peak and can shift it slightly lower, reducing frequency selectivity.

05

A finite steady peak actually requires dissipation balanced by input. Resonance supports tuning and sensing but can produce destructive structural motion, managed through damping or frequency separation.

COMMON MISTAKE

Treating the largest sampled point as an exact undamped natural frequency or saying resonance is in phase with the drive.

Velocity selector and alternating supply

[13]

EXPECTED CONCLUSION

Speed 3.0×10^5 m/s; mass 9.60×10^{-27} kg; force north; $V_{rms} \approx 120$ V; alternating field changes selection with entry phase.

REASONING AND MARKING CHECKPOINTS

01

Undeflected condition $qE = qvB$ gives $v = E/B = 2.4 \times 10^4/0.080 = 3.0 \times 10^5$ m/s.

02

In analyser, $qvB = mv^2/r$, so $m = qBr/v = 9.60 \times 10^{-27}$ kg.

03

For positive charge, $v \times B$ with east velocity and downward field points north; negative charge reverses direction.

04

Magnetic force stays perpendicular to velocity, so $F \cdot v = 0$. It changes direction without speed or kinetic-energy change.

05

$V_{rms} = 170/\sqrt{2} = 120$ V. An unsynchronised a.c. electric field changes magnitude and direction during ion entry, so balance and deflection depend on phase rather than selecting one steady speed.

COMMON MISTAKE

Using rms electric field as a constant instantaneous selector field or claiming magnetic force increases kinetic energy.

Nuclear tracer dose and gamma imaging

[15]

EXPECTED CONCLUSION

Start 12.0 MBq; end 11.55 MBq; about 1.41 × 10^{10} decays; emitted gamma energy about 3.16 × 10^{-4} J.

REASONING AND MARKING CHECKPOINTS

01

Twelve hours is two half-lives, so start activity = 48/4 = 12.0 MBq. Over 1/3 h, decay factor 2^(-1/18) = 0.9622, giving 11.55 MBq.

02

Mean activity ≈11.775 MBq = 1.1775 × 10^{7} s^{-1}. Over 1200 s, decays ≈1.41 × 10^{10}.

03

Photon energy = 140000 × 1.60 × 10^{-19} = 2.24 × 10^{-14} J; total emitted energy ≈3.16 × 10^{-4} J.

04

Gamma penetrates tissue to an external detector; an hours-long half-life supports preparation and imaging but then falls, reducing prolonged exposure.

05

Attenuation lowers counts; collimation maps direction but rejects photons. Optimise administered activity and scan time while staff minimise time, maximise distance and shield.

06

Activity is decays per second. Absorbed dose is deposited energy per unit mass and also depends on energy, geometry and absorption; not every emitted photon is absorbed.

COMMON MISTAKE

Using initial activity throughout the delayed scan or equating emitted activity directly with patient absorbed dose.

Projectile trajectory reconstructed from data

[14]

EXPECTED CONCLUSION

u_Y = 15.0 m/s; g = 9.80 m/s²; peak 1.53 s and 11.5 m; flight 3.06 s; range 27.6 m; accelerations 0 horizontally and -9.8 m/s² vertically.

REASONING AND MARKING CHECKPOINTS

01

For example at 0.8 s: $8.864 = 0.8u_Y - 0.32g$, and at 2.0 s: $10.4 = 2u_Y - 2g$. Solving gives u_Y = 15.0 m/s and g = 9.80 m/s².

02

At the peak $v_Y = u_Y - gt = 0$, so t = 15.0/9.80 = 1.53 s. Height $u_Y^2/(2g)$ = 225/19.6 = 11.5 m, consistent with nearby samples.

03

The non-zero solution of y = 0 is $t = 2u_Y/g$ = 3.06 s. Horizontal range = 9.0 × 3.06 = 27.6 m.

04

Neglecting resistance, horizontal acceleration is zero and vertical acceleration remains -9.8 m/s², including at maximum height where only vertical velocity is momentarily zero.

05

Air resistance reduces horizontal speed and changes symmetry. Camera scale, parallax, timing offset or tracking the ball edge instead of its centre can also move points away from the model.

COMMON MISTAKE

Setting acceleration to zero at maximum height or taking the highest sampled point as the exact continuous maximum.

Submerged gate in equilibrium

[13]

EXPECTED CONCLUSION

Gauge pressure 15.0 kPa; cable tension 2.69 kN; hinge force 1.79 kN upward; both resultant force and moment must vanish.

REASONING AND MARKING CHECKPOINTS

01 Gauge pressure $p = \rho gh = 850 \times 9.81 \times 1.8 = 1.50 \times 10^4$ Pa = 15.0 kPa. Atmospheric pressure cancels if it acts on both sides.

02 Gate weight is $90 \times 9.81 = 883$ N at 1.2 m. Taking moments about hinge: $T(2.4) = 883(1.2) + 3600(1.5)$, so $T = 2692$ N = 2.69 kN.

03 Vertical balance gives hinge force + 2692 - 883 - 3600 = 0, hence hinge force = 1791 N = 1.79 kN upward.

04 Pressure increases with depth, so deeper areas contribute more strongly and the liquid resultant need not act at the geometric centre; its line is the centre of pressure.

05 Complete static equilibrium requires vector sum of forces zero and sum of moments about any point zero. Moment balance alone does not prevent translation.

COMMON MISTAKE

Placing a non-uniform pressure resultant automatically at the geometric centre or failing to check vertical force balance.

Stress-strain energy and elastic behaviour

[15]

EXPECTED CONCLUSION

$E = 8.0 \times 10^{10}$ Pa; force 360 N; extension 6.0 mm; energy density 3.6×10^{5} J/m³; energy 1.08 J.

REASONING AND MARKING CHECKPOINTS

01

Initial Young modulus E = stress/strain = $240 \times 10^{6}/0.003 = 8.0 \times 10^{10}$ Pa; earlier points give the same ratio.

02

Force $F = \sigma A = 240 \times 10^{6} \times 1.5 \times 10^{-6} = 360$ N. Extension = strain × length = $0.003 \times 2.0 = 0.0060$ m.

03

Linear-region energy density is triangular graph area $\frac{1}{2}\sigma\varepsilon = \frac{1}{2} \times 240 \times 10^{6} \times 0.003 = 3.6 \times 10^{5}$ J/m³. Total energy is 1.08 J.

04

At strain 0.006, linear extrapolation predicts 480 MPa but observed stress is 330 MPa, so direct proportionality has ended.

05

Clamp behind a shield, add small loads and measure extension with a long gauge length. The proportional limit is loss of linearity; the elastic limit requires unloading to test return to original length.

COMMON MISTAKE

Using MPa as Pa or claiming nonlinearity alone proves permanent deformation without an unloading test.

Double-slit gradient and measurement design

[13]

EXPECTED CONCLUSION

Gradient 3.20 mm/m gives slit separation 0.200 mm; predicted spacing at 1.20 m is 3.84 mm.

REASONING AND MARKING CHECKPOINTS

01

From $w = \lambda D/a$, gradient of w against D is λ/a. Endpoint gradient = (2.56 - 1.28)/(0.80 - 0.40) = 3.20 mm/m = 3.20×10^{-3}.

02

Thus $a = \lambda/\text{gradient} = 640 \times 10^{-9}/(3.20 \times 10^{-3}) = 2.00 \times 10^{-4}$ m = 0.200 mm, agreeing with the stated spacing.

03

At D = 1.20 m, w = gradient × D = 3.20 × 1.20 = 3.84 mm.

04

Covering one slit removes two-source interference, leaving a single-slit diffraction pattern. Reducing wavelength reduces fringe spacing directly if geometry is fixed.

05

Measure across n fringe gaps then divide by n, reducing fractional ruler uncertainty. Keep wavelength, slit separation and screen alignment fixed while changing D.

COMMON MISTAKE

Failing to convert the graph gradient from millimetres per metre before calculating slit separation.

Cell e.m.f., internal resistance and power [13]

EXPECTED CONCLUSION

E.m.f. 1.52 V; r = 0.18 Ω; at 1.50 A: R = 0.833 Ω, load 1.875 W, loss 0.405 W, chemical 2.28 W; maximum power at R = r with 50% efficiency.

REASONING AND MARKING CHECKPOINTS

01

From $V = \varepsilon - Ir$, intercept gives $\varepsilon = 1.52$ V and gradient $(1.16 - 1.52)/2.0 = -0.18$ V/A gives $r = 0.18$ Ω.

02

At 1.50 A and 1.25 V, external $R = 1.25/1.50 = 0.833$ Ω and load power $VI = 1.875$ W.

03

Internal power $I^2r = 1.50^2 \times 0.18 = 0.405$ W. Chemical power $\varepsilon I = 1.52 \times 1.50 = 2.28$ W; $1.875 + 0.405 = 2.280$ W.

04

Maximum load power occurs at $R = r = 0.18$ Ω. Then terminal p.d. is $\varepsilon/2$ and equal powers go to load and internal heating, so efficiency is 50%.

05

Maximum power is not maximum efficiency: half the chemical power heats the cell, wasting energy and potentially reducing life. Efficient supply normally uses R much larger than r.

COMMON MISTAKE

Calling the negative graph gradient a negative resistance or claiming maximum power transfer means maximum efficiency.

Circular orbit, energy and transfer

[14]

EXPECTED CONCLUSION

$g = 6.25$ m/s²; $v = 7.07$ km/s; $T = 7.11 \times 10^3$ s; $\omega = 8.84 \times 10^{-4}$ rad/s; energy increase 6.25×10^9 J.

REASONING AND MARKING CHECKPOINTS

01 Field strength $GM/r^2 = 6.67 \times 10^{-11} \times 6.0 \times 10^{24}/(8.0 \times 10^6)^2 = 6.25$ m/s².

02 Circular balance gives $v = \sqrt{(GM/r)} = 7.07 \times 10^3$ m/s. Period $2\pi r/v = 7.11 \times 10^3$ s.

03 Angular speed is $2\pi/T = 8.84 \times 10^{-4}$ rad/s. Check $\omega^2 r = 6.25$ m/s², equal to gravitational acceleration in the circular orbit.

04 Energy increase is $GMm/2(1/r_1 - 1/r_2) = 6.25 \times 10^9$ J. The less negative final energy represents added mechanical energy.

05 A short forward burn changes velocity at one location, not position everywhere, so it creates an ellipse with the burn point at lower apsis. A second burn at the raised side circularises; the final larger circular speed is lower despite added energy.

COMMON MISTAKE

Using $-GMm/r$ as total circular-orbit energy or assuming one impulse instantly creates a larger circular path.

Ideal-gas cycle and first law

[15]

EXPECTED CONCLUSION

Work 0, +600, 0, -200 J; net +400 J. T_a = 12.0 K, T_β = 36.1 K, $T_{\square}$ = 108 K. A→B: ΔU = Q = 300 J; B→C: ΔU = 900 J, Q = 1500 J.

REASONING AND MARKING CHECKPOINTS

01

Constant-volume work is zero. B→C work = 300000(0.003 - 0.001) = +600 J; D→A work = 100000(0.001 - 0.003) = -200 J. Net is +400 J.

02

Using pV = RT: T_a = 100000(0.001)/8.31 = 12.0 K; T_β = 36.1 K; $T_{\square}$ = 300000(0.003)/8.31 = 108 K.

03

For monatomic gas ΔU = 3RΔT/2. A→B gives about 300 J and W = 0, so Q = 300 J.

04

B→C gives ΔU about 900 J. With W = +600 J by gas, Q = ΔU + W = 1500 J. Cooling legs reject a total about 1400 J.

05

Over a cycle ΔU = 0, so net Q = net W = +400 J. Clockwise orientation means positive enclosed work; heat rejection occurs on the falling-temperature C→D and D→A legs.

COMMON MISTAKE

Using kPa and plotted volume units without conversion or treating compression work as positive work by the gas.

Capacitor discharge and stored field energy

[14]

EXPECTED CONCLUSION

$\tau \approx 31.8$ s; $C \approx 145$ μF; $Q_0 \approx 1.16$ mC; $U_0 \approx 4.64$ mJ; $I_0 = 36.4$ μA; $P_0 = 0.291$ mW; energy fraction ≈ 0.0805.

REASONING AND MARKING CHECKPOINTS

01

From $V = V_0e^{(-t/\tau)}$, use 5.84/8.0 at 10 s: $\tau = -10/\ln(5.84/8.0) = 31.8$ s.

02

$C = \tau/R = 31.8/220000 = 1.45 \times 10^{-4}$ F = 145 μF. Initial charge $CV = 1.16 \times 10^{-3}$ C and energy $\frac{1}{2}CV^2 = 4.64 \times 10^{-3}$ J.

03

Initial current $V/R = 8.0/220000 = 36.4$ μA. Initial power $V^2/R = 2.91 \times 10^{-4}$ W.

04

At 40 s, voltage fraction = 2.27/8.0 = 0.28375. Since $U \propto V^2$, energy fraction = $0.28375^2 = 0.0805$.

05

A finite-resistance voltmeter adds a parallel path and reduces τ. A straight ln V against t plot with gradient $-1/\tau$ tests single-exponential decay.

COMMON MISTAKE

Using voltage fraction as energy fraction or ignoring the voltmeter's parallel resistance.

Photoelectric stopping-potential evidence [14]

EXPECTED CONCLUSION

Gradient 4.15×10^{-15} V s; h = 6.64×10^{-34} J s; threshold 5.07×10^{14} Hz; work function 2.10 eV; maximum speed 5.30×10^{5} m/s.

REASONING AND MARKING CHECKPOINTS

01

Endpoint gradient = $(1.01 - 0.18)/[(7.5 - 5.5) \times 10^{14}] = 4.15 \times 10^{-15}$ V s.

02

From $eV_s = hf - \varphi$, gradient = h/e. Thus h = $1.60 \times 10^{-19} \times 4.15 \times 10^{-15} = 6.64 \times 10^{-34}$ J s.

03

Threshold $f_0 = 5.5 \times 10^{14} - 0.18/(4.15 \times 10^{-15}) = 5.07 \times 10^{14}$ Hz. Work function is gradient × f_0 = 2.10 eV.

04

At 7.0×10^{14} Hz, Vs = 0.80 V and Kmax = eVs. Then $v = \sqrt{(2eV_s/m)} = 5.30 \times 10^{5}$ m/s.

05

Below threshold, more intensity gives no ideal emission; above it, intensity raises electron rate but not maximum energy. Immediate emission, threshold and linear energy-frequency relation support photons hf.

COMMON MISTAKE

Ignoring the $\times 10^{14}$ frequency scale or claiming intensity determines maximum photoelectron energy.

Hubble plot and cosmological evidence

[16]

EXPECTED CONCLUSION

$H_0 \approx 70.8$ km s^{-1} Mpc^{-1} = 2.29×10^{-18} s^{-1}; Hubble time 1.38×10^{10} years; predicted 150 Mpc speed 1.06×10^4 km/s.

REASONING AND MARKING CHECKPOINTS

01

Endpoint gradient H_0 = (7040 - 1380)/(100 - 20) = 70.75 km s^{-1} Mpc^{-1}; full regression would use all points.

02

Convert H_0 = 70.75/(3.086×10^{19}) = 2.29×10^{-18} s^{-1}. Reciprocal is 4.36×10^{17} s = 1.38×10^{10} years.

03

At 150 Mpc, $v = H_0 d$ = 70.75 × 150 = 1.06×10^4 km/s under the fitted linear relation.

04

Peculiar velocities and distance uncertainty make one galaxy unreliable. Standard candles infer distance from known luminosity and measured flux; shifted spectral lines provide recession evidence.

05

Expansion rate changes through history and distance calibration affects H_0, so $1/H_0$ is not exact age. Cosmic microwave background and primordial light-element abundances independently support a hot early Universe.

COMMON MISTAKE

Taking a reciprocal before converting megaparsecs to kilometres or treating one galaxy's v/d as exact.