Delegate Booklet

A Level Physics: Exam Insights May/June 2024

9PH0-24O1

Aims and Objectives of the event

- Receive feedback on the performance of candidates in the June 2024 exam series
- Consider the variation of candidates' performance on different questions and explore why performance varies
- Discuss the Examiner's Report
- Address common issues and FAQs.

Session Agenda

Item	Time
Introduction	3 min
Detailed analysis of questions:	
Strand 1: unstructured calculations	6 min
Strand 2: deduction questions	15 min
Strand 3: explanation questions	8 min
Strand 4: linkage questions	16 min
Strand 5: experimental skills	5 min
Common mistakes (and how to avoid them)	5 min
Support/Future events	2 min

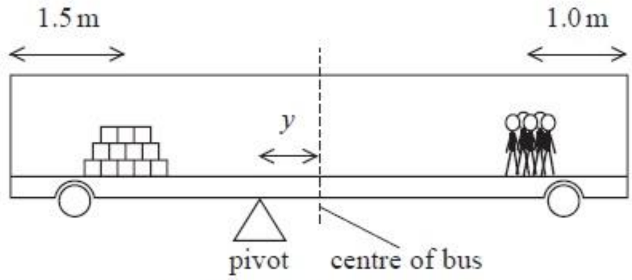
Feedback strand 1: unstructured calculations
Paper 1, Q11b

11 A film involves a gang of bank robbers making a getaway on a bus loaded with gold bars. The bus spins out of control and ends up balancing on the edge of a cliff, as shown.

(Source: © maforche/Shutterstock)

(b) The bus is balanced on a pivot that is a distance y from the centre of the bus.

The centre of mass of the gold is 1.5 m from one end of the bus. The centre of mass of the bank robbers is 1.0 m from the other end of the bus, as shown.



The unloaded bus can be treated as a uniform body with a weight of 32 000 N.

Calculate the distance y when the bus is balanced.

length of bus = 11.0 m
weight of gold bars = 31 000 N
weight of bank robbers = 8700 N

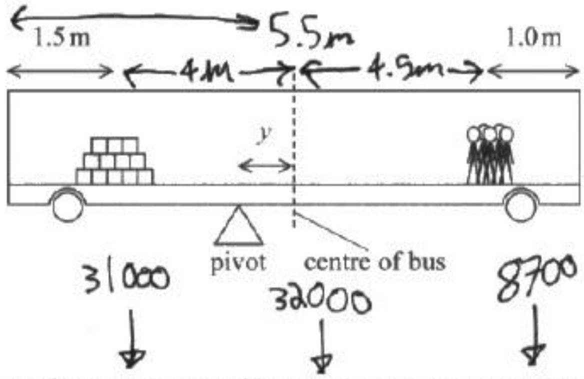
(4)

• Takes one moment around pivot (1) • Equates a clockwise and anticlockwise moment (1) • Correct distance to gold or people (1) • $y = 1.2$ m (1)	Example of calculation $32000\ \text{N} \times y + 8700\ \text{N} \times (y + 4.5) = 31000\ \text{N} \times (4.0 - y)$ $71700\,y = 124000 - 39150 = 84850$ $y = 1.18$ m
Alternative • Resolves vertical forces • Takes one moment around CoG • Equates a clockwise and anticlockwise moment • $y = 1.2$ m	Alternative: $R = 31000 + 32000 + 8700 = 71700$ N Moments about CoG $71700\ \text{N} \times y + 8700\ \text{N} \times 4.5 = 31000\ \text{N} \times 4.0$ $y = 1.18$ m

Example 1

(b) The bus is balanced on a pivot that is a distance y from the centre of the bus.

The centre of mass of the gold is 1.5 m from one end of the bus. The centre of mass of the bank robbers is 1.0 m from the other end of the bus, as shown.



The unloaded bus can be treated as a uniform body with a weight of 32 000 N.

Calculate the distance y when the bus is balanced.

length of bus = 11.0 m
weight of gold bars = 31 000 N
weight of bank robbers = 8700 N

(4)

$\curvearrowright = \curvearrowleft$

$(4 - y) \times 31000 = y \times 32000 + (y + 4.5) \times 8700$

$124000 - 31000y = 32000y + 8700y + 39150$ $\quad -39150,\ +31000y$

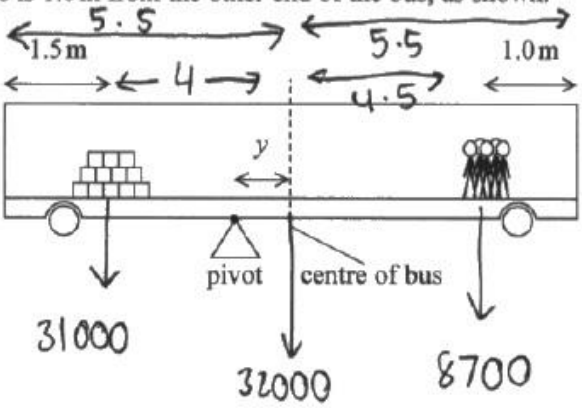
$84850 = 71700y \quad \div 71700$

$y = 1.18$ m

Example 2

(b) The bus is balanced on a pivot that is a distance y from the centre of the bus.

The centre of mass of the gold is 1.5 m from one end of the bus. The centre of mass of the bank robbers is 1.0 m from the other end of the bus, as shown.



The unloaded bus can be treated as a uniform body with a weight of 32 000 N.

Calculate the distance y when the bus is balanced.

length of bus = 11.0 m
weight of gold bars = 31 000 N
weight of bank robbers = 8700 N

(4)

Sum of clockwise = sum of anticlockwise.

$32000y + 8700(4.5) = 4(31000)$

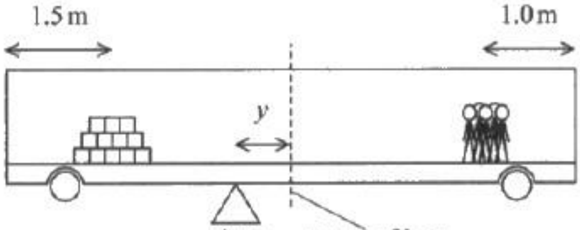
$32000y = 84850$

$y = 2.65\text{ m}$ (3 s.f.)

Example 3

(b) The bus is balanced on a pivot that is a distance y from the centre of the bus.

The centre of mass of the gold is 1.5 m from one end of the bus. The centre of mass of the bank robbers is 1.0 m from the other end of the bus, as shown.



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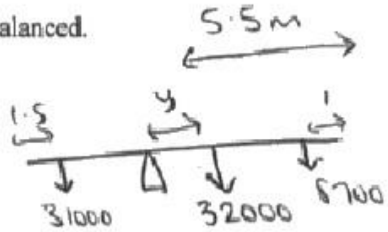


(4)

P = pivot

↻P = 32000y + (4.5 × 8700) = 32000y + 39150

↺P = (5.5 − 1.5 − y) × 31000 = (4 − y)31000

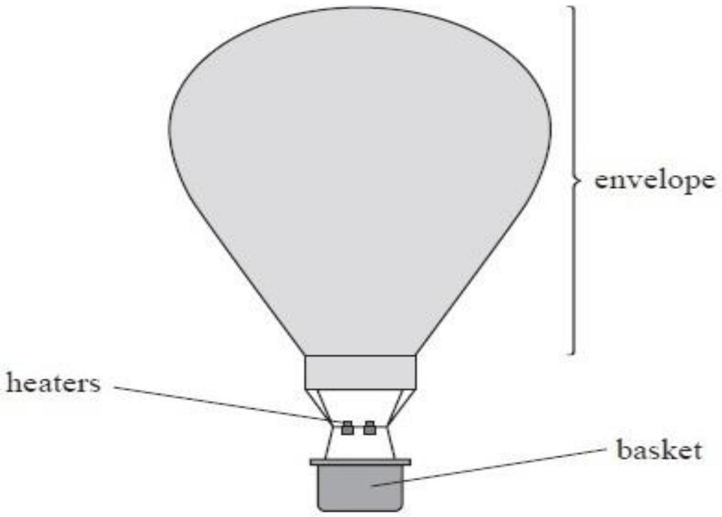
32000y + 39150 = 124000 − 31000y

63000y = 84850

y = 1.35 m (3sf)

Feedback strand 2: deduction questions
Paper 2, Q17a

17 (a)
A hot air balloon consists of a fabric envelope, heaters and a basket, as shown.



When the balloon is set up, the envelope is partly filled with air at 20°C. The air is then heated to 120°C and expands to fill the envelope and becomes less dense.

The air pressure inside the envelope is always equal to the air pressure outside the envelope because the envelope is open at the bottom.

The balloon takes off when the upthrust is more than the total weight of the balloon, the air in the envelope and the passengers.

Deduce whether the balloon can take off.

volume of air at 120°C in inflated envelope = 2800 m^3
density of air at 20°C = 1.2 kg m^{-3}
mass of balloon = 380 kg
mass of passengers = 340 kg
upthrust when the envelope is full = 33 000 N **(6)**

17(a)	• Use of $pV = NkT$	(1)	<u>Example of calculation</u> $p_1 V_1 = NkT_1$ $p_1 V_1 / T_1 = NkT_1 = p_2 V_2 / T_2$ V_1 / 293 K = 2800 m^3 / 393 K Volume of gas before heating, V_1 = 2087 m^3 mass of air in balloon = 1.2 kg m^{-3} × 2087 m^3 = 2505 kg Total mass with 5 passengers = (2505 + 340 + 380) kg = 3225 kg W = 3225 kg × 9.81 N kg^{-1} = 31 637 N 31 600 N < 33 000 N
	• Conversion of T in K	(1)	
	• Use of $\rho = m/V$ to determine mass of air in the balloon	(1)	
	• Calculation of total mass = mass of air at 120 °C + passengers + balloon	(1)	
	• Use of $W = mg$	(1)	
	• W = 31 600 N, which is less than 33 000 N, so the balloon can take off	(1)	

Example 1

~~$W = (380 + 340)g$~~ ~~$W = (380 + 340 + 2800(1.2\times10^{-3}))g$~~

~~$= 7096$~~

$273 + 20 = 293$ $\quad V \propto T$

$273 + 120 = 393$

$393 \div 293 = 1.341\ldots$

$2800 \div 1.341 = 2087.5\ldots\ m^3$ at $20^\circ C$

$m = \rho V = 2087.5\ldots \times 1.2$

$= 2505.03\ldots$ kg

$340 + 380 + 2505.03\ldots = 3225.03$ kg

$W = mg = 3225.03\ldots \times 9.81 = 31\,600$ N (3sf)

$31\,600 < 33\,000$ ∴ The balloon can take off as $U > W$

Example 2

upthrust = ~~weight~~ displaced weight

weight = drag + mg?

when upthrust > total weight.

people + balloon:

$W = mg$

$(340 \times 9.81) + (380 \times 9.81) = 7063.2$ N

upthrust:

$\rho = \frac{m}{V}$

$1.2 = \frac{m}{2800}$ $\qquad 33000 - 32961.6 = 38.4$ N

$1.2 \times 2800 = m = 3360$ kg $\rightarrow 3360 \times 9.81 = 32961.6$

32961.6 N > 7063.2 N

upthrust is more than the downwards weight of the balloon and people so the hot air balloon rises.

Paper 3, Q12b

(b) One type of chocolate melts at a temperature of 32°C.

The energy released when 65 g of this chocolate is digested is 345 kcal.

It is suggested that the energy used to melt a piece of this chocolate is at least 15% of the energy released when the chocolate is digested.

Assess the accuracy of this suggestion.

initial temperature of chocolate = 15°C
specific heat capacity of chocolate = 3.9×10^3 J kg^{-1} K^{-1}
specific latent heat of chocolate = 1.50×10^5 J kg^{-1}
1 kcal = 4200 J

(6)

• Use of $\Delta E = mc\Delta\theta$	**(1)**	<u>Example of calculation</u> $\Delta E = 0.065 \text{ kg} \times 3900 \text{ J kg}^{-1} \text{ K}^{-1} \times (32 - 15) \text{ K} = 4.31 \times 10^3 \text{ J}$
• Use of $\Delta E = mL$	**(1)**	
• $\Delta E_{total} = \Delta E_c + \Delta E_L$	**(1)**	$\Delta E = 0.065 \text{ kg} \times 1.50 \times 10^5 \text{ J kg}^{-1} = 9.75 \times 10^3 \text{ J}$
• Conversion between kcal and J	**(1)**	Energy to melt chocolate = $(4.31 \times 10^3 + 9.75 \times 10^3)$ J = 1.41×10^4 J [3.4 kcal]
• Use of 15% to give 2.2×10^5 J **Or** energy required = 1%	**(1)**	Energy released from chocolate = 345×4200 J = 1.45×10^6 J 15% of energy released = $0.15 \times 1.45 \times 10^6$ J = 2.17×10^5 J [52 kcal]
• Conclusion consistent with comparison of calculated values of energy released and 15% of energy required.	**(1)**	So energy required to melt chocolate is much less than 15% of energy released.

Example 1

$345(4200) = 1449000$ J

~~W~~ $32 - 15 = \Delta\theta = 17$

~~*~~ $\Delta E = (0.065)(3.9 \times 10^3)(17) = 4309.5$ J

$\Delta E = (0.065)(1.5 \times 10^5) = 9750$ J

$9750 + 4309.5 = 14060$ J

$\frac{14060}{1449000} \times 100 = 0.97\%$

$0.97\% < 15\%$ ∴

suggestion inaccurate

Example 2

(b) One type of chocolate melts at a temperature of 32°C.

The energy released when 65 g of this chocolate is digested is 345 kcal.

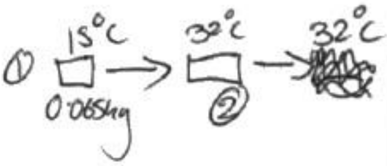
It is suggested that the energy used to melt a piece of this chocolate is at least 15% of the energy released when the chocolate is digested.

Assess the accuracy of this suggestion.

initial temperature of chocolate = 15°C
specific heat capacity of chocolate = 3.9×10^3 J kg^{-1} K^{-1}
specific latent heat of chocolate = 1.50×10^5 J kg^{-1}
1 kcal = 4200 J

(6)

0·15×345
= 51·75kcal



ΔE = mcΔθ
ΔE = LΔm

① ΔE = 0·065 × 3·9×10³ × (32−15)
= 4309·5 J

② ΔE = 1·5×10⁵ × 0·065
= 9750 J

ΣΔE = 14059·5 J

345×4200 = 1449000 J
× 0·15 = 217350 J
217350 − 14059·5 = 203290·5 J
∴ suggestion is incorrect

Example 3

ΔE = mcΔθ   ΔE = LΔm

15 → 16 = 0.065 × 3.9×10³ × 1 = 253.5 J

15 → 32 = 253.5 ×17 = 4309.5 J

1.5×10⁵ × 0.065 = 9750

4309 + 9750 = 14059.5 J

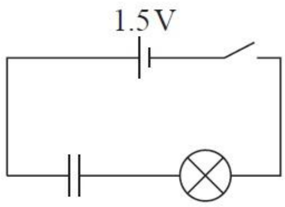
345 ×4200 = 1449000 J

(14059.5 / 1449000) ×100 = 0.97

Feedback strand 3: explanation questions
Paper 1, Q16c

(c) The student connects the filament bulb in the circuit shown below. The capacitor is initially uncharged and has a capacitance of 1.2 F.

The resistance of the filament bulb is 5 Ω.



Explain how the brightness of the filament bulb will vary as the switch is closed.

(4)

• Initial p.d. across the capacitor is zero **Or** Initial p.d. across bulb will be 1.5 V/maximum **Or** initial current is maximum	**(1)**	
• Bulb will be bright/lit initially	**(1)**	
• As capacitor charges the brightness of bulb decreases	**(1)**	Accept pd across capacitor increasing so brightness of bulb decreases
• Exponential decrease **Or** The time constant is 6.0 s (so the process will be of the order of 25 – 35 s)	**(1)**	MP4 for correct calculation of time constant Example of calculation $RC = 5.0\ \Omega \times 1.2\ \text{F} = 6.0\ \text{s}$

Example 1

Explain how the brightness of the filament bulb will vary as the switch is closed.

(4)

· WHEN THE SWITCH IS CLOSED, THE CAPACITOR WILL BEGIN CHARGING EXPONENTIALLY.

· ~~THIS MEANS~~ INITIALLY, WHEN THE SWITCH IS CLOSED, THE BULB WILL BRIEFLY BE BRIGHT DUE TO IT RECEIVING A CURRENT AND THE CAPACITOR BEING UNCHARGED.

· AS THE CAPACITOR CHARGES, THE P.D. ACROSS THE BULB EXPONENTIALLY DECREASES TO 0V. $V \propto I$, SO THE BRIGHTNESS EXPONENTIALLY DECREASES UNTIL THERE IS NO LIGHT (CAPACITOR IS FULLY CHARGED)

(Total for Question 16 = 12 marks)

Example 2

Explain how the brightness of the filament bulb will vary as the switch is closed.

(4)

When the switch is closed, the capacitor will start to charge. The p.d at the capacitor increases exponentially as time goes on as charge builds up on the plates. Therefore, at the start the brightness of the bulb will be at it's maximum however, as p.d increases at the capacitor, due to the share of voltage in a series circuit, the p.d at the bulb will decrease exponentially. Therefore the power at the bulb will also decrease, until when the capacitor is fully charged, the p.d at the bulb would be 0, so the power and brightness at the bulb would be 0.

(Total for Question 16 = 12 marks)

Example 3

Explain how the brightness of the filament bulb will vary as the switch is closed.

(4)

- Initially as the switch is closed maximum current flows, V=IR and the bulb is at maximum brightness.
- As the potential difference across the capacitor increases the current decreases exponentially to zero.
- As the current decreases exponentially the p.d across the bulb decreases => the brightness decreases.
- At the maximum p.d. across the capacitor, the current is zero and the brightness of the bulb is at a minimum (zero).

(Total for Question 16 = 12 marks)

Feedback strand 4: linkage questions
Paper 2, Q18a

18 In 1864, William Huggins and William Miller used dark lines in the spectrum of the Sun to identify elements in the Sun's atmosphere.

*(a) Explain how gases in the Sun's atmosphere cause dark lines in the spectrum corresponding to different elements.

(6)

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content:

IC1 Electrons are in (discrete) energy levels

IC2 Absorption of (a single) photon causes an electron to move to a higher energy level

IC3 Photon energy = hf
Or photon energy is proportional to frequency

IC4 Energy of (absorbed) photon must equal difference in energy levels

IC5 The (changes in) energy levels are specific to each element

IC6 Different wavelengths/frequencies of light are absorbed

Example 1

Electrons of atoms of different elements in the suns atmosphere have discrete energy levels. When they absorb a photon, they become excited and move to a higher energy level. The energy of ~~the a~~ one photon is equal to the change in energy between an electron energy levels. Hence As the range of photon energy is limited and $E = hf$, only a limited range of frequencies and ~~ab~~ in turn wavelengths can be seen as dark lines in a spectrum. When the electrons de-excite and drop down energy levels, photons are released.

Example 2

- The sun emits light with wavelengths ~~equivalent to the whole range of wavele~~ ~~that tw~~ of all wavelengths within the visible light spectrum, (and electromagnetic spectrum). The gases in the Sun's atmosphere has ~~elements~~ which have electrons at discrete energy levels. The Photon energy is proportional to frequency and inversely proportional to wavelength. ~~Each element will have different discrete energy levels~~. The light emitted by the Sun ~~will have~~ will have photon E = hf. If the photon energy is equivalent to ~~an~~ energy level difference in an element, at then one photon will be absorbed by that one electron. ~~There~~ Each element has its own discrete energy levels, ~~and therefore~~ and therefore discrete energy level differences. Since E = hf, f = c/λ, if the λ ~~is~~ within the visible light spectrum, when it has been absorbed by an electron, a dark line will be seen in the spectrum. ~~Since each element has their own~~ ~~These dark lines~~, ~~Elements~~ ~~The elements can therefore be~~

→ These dark lines will be specific to the elements which are in the Sun's gases.

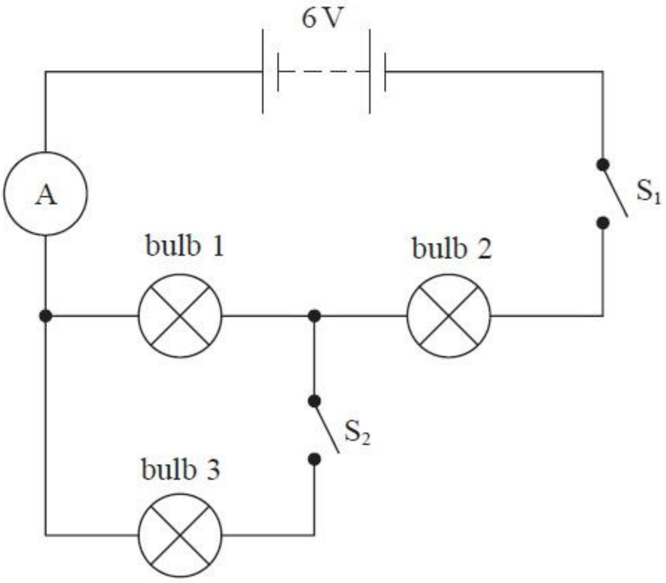
Example 3

As the sun's atmosphere contains different elements, they give off differing levels of light energy, when they are excited ~~this~~ this means differing energy levels will create differing lines on the spectrum.

Differing energy levels correspond to different darkening in the spectrum, due to different wavelengths of light emitted.

Paper 3, Q3

*3 A student connects three identical 3 V bulbs to a 6 V battery of negligible internal resistance. The circuit includes two switches, S_1 and S_2, as shown.



The student closes S_1 and records the brightness of each bulb.

With S_1 still closed, the student closes S_2.

Explain how the brightness of bulb 1 compares with the brightness of bulb 2 before and after S_2 is closed.

IC points	IC mark	Max linkage mark	Max final mark
6	4	2	6
5	3	2	5
4	3	1	4
3	2	1	3
2	2	0	2
1	1	0	1
0	0	0	0

Indicative content:

IC1 Before closing S2, bulb 1 and bulb 2 have the same p.d./current so both bulbs have equal brightness

IC2 Closing switch S2 allows current to flow in bulb 3

IC3 Bulb 1 and bulb 3 are in parallel, so the resistance of the combination decreases
[Allow "resistance halves" for "resistance decreases"]

IC4 The p.d. across bulb 1 (and bulb 3) decreases
Or The p.d. across bulb 2 increases
[Allow a greater proportion of p.d. is across bulb 2. Do not credit if this is based on p.d. being split between bulb 1 and bulb 3]

IC5 The current in circuit/bulb 2 increases so the brightness/power of bulb 2 increases
Or current in bulb 1 decreases so the brightness/power of bulb 1 decreases

IC6 (When S2 closed) bulb 1 is not as bright as bulb 2.

Example 1

The student closes S_1 and records the brightness of each bulb.

With S_1 still closed, the student closes S_2.

Explain how the brightness of bulb 1 compares with the brightness of bulb 2 before and after S_2 is closed.

When S_1 is closed, the circuit will operate as a series circuit, with bulb 1 and bulb 2. This means bulb 1 and bulb 2 will have the same brightness as the bulbs are identical, so they have equal share of resistance, hence aqual brightness. When S_2 is closed, bulb 1 and bulb 3 operate as a parallel circuit and will have the same brightness. However, the parallel circuit means the sum of bulb 1 and 3 resistance is less than before as $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$. This means less p.d is applied so bulb 1 recieves a smaller share of p.d. This means bulb 1 will have less brightness compared to bulb 2. After S_2 is closed, bulb 2 gets brighter and bulb 1 gets dimmer.

(Total for Question 3 = 6 marks)

Example 2

The student closes S_1 and records the brightness of each bulb.

With S_1 still closed, the student closes S_2.

Explain how the brightness of bulb 1 compares with the brightness of bulb 2 before and after S_2 is closed.

With S_1 closed, the brightness of Bulb 1 and Bulb 2 will be the same as they are in series. However when S_2 is closed and S_1 closed, Bulb 1's brightness is dimmer than Bulb 2 as Bulb 1 is now in parallel with Bulb 3, meaning the voltage supplied to them is split. Due to this, Bulb 2 will be the brightest and Bulb 1 and 3 will have the same brightness.

Example 3

The student closes S_1 and records the brightness of each bulb.

With S_1 still closed, the student closes S_2.

Explain how the brightness of bulb 1 compares with the brightness of bulb 2 before and after S_2 is closed.

- Before S_2 is closed there is a p.d. of 3V across both bulb 1 and 2.
- As p.d. $\propto$ brightness they both have the same brightness.
- After S_2 is closed there is still a p.d. of 3V across bulb 2.
- But there is a p.d. of 3V split between bulb 1 and 3.
- Therefore there is a p.d. of 1.5V across bulb 1.
- Therefore bulb 2 is brighter than bulb 1 as $3V > 1.5V$.

Feedback strand 5: experimental skills

Paper 3, Q2ai

2 A student made measurements to determine if some gold coins were made from pure gold. The coins that were available to the student are shown below.

(Source: © Bjoern Wylezich/Shutterstock)

(a) The student used digital calipers to measure the thickness t and the diameter d of one of the coins.

(i) Calculate the volume V of the coin, and the percentage uncertainty in V.

$t = 1.54\,\text{mm}$

$d = 22.16\,\text{mm}$

(7)

• Use of $V = \pi r^2 t$	(1)	Allow MP4 for use of full resolution if MP2 was withheld for not using half resolution
• Use of half resolution to calculate % uncertainty in d	(1)	
• % uncertainty in area = 2 × (% uncertainty in d)	(1)	Example of calculation
• Calculation of % uncertainty in t	(1)	$V = \pi\left(\frac{22.16 \times 10^{-3}\,\text{m}}{2}\right)^2 \times 1.54 \times 10^{-3}\,\text{m}$
• % uncertainty in t added to % uncertainty in area	(1)	$\therefore V = 5.94 \times 10^{-7}\,\text{m}^3$
• $V = 5.94 \times 10^{-7}\,\text{m}^3$	(1)	$\%U = \left(2 \times \frac{0.005\,\text{mm}}{22.16\,\text{mm}} + \frac{0.005\,\text{mm}}{1.54\,\text{mm}}\right) \times 100\%$
• $\%U = 0.4\,\%$	(1)	$\%U = 0.36\,\%$

Example 1

(i) Calculate the volume V of the coin, and the percentage uncertainty in V.

$t = 1.54\,\text{mm}$

$d = 22.16\,\text{mm}$

(7)

$t = 0·00154\,\text{m}$

$d = 0·02216\,\text{m}$ $r = 0·01108$

$\pi \times (0·01108)^2 = 3·86 \times 10^{-4}\,\text{m}^2$

$3·86 \times 10^{-4} \times 0·00154 = 5·94 \times 10^{-7}\,\text{m}^3$

$\%U \text{ in } t = \frac{0·5 \times 0·01}{1·54} \times 100 = 0·3247\%$

$\%U \text{ in } d = \frac{0·5 \times 0·01}{22·16} \times 100 = 0·0227\%$

$(0·0227 \times 2) + 0·3247 = 0·37\%$

Example 2

(i) Calculate the volume V of the coin, and the percentage uncertainty in V.

$t = 1.54$ mm → h $= 1.54\times10^{-3}$

$d = 22.16$ mm → r $= 0.02216 \div 2 = 0.01108 = r$

(7)

$V = 2\pi r^2 h$

$V = 2\pi \times (0.01108)^2 \times (1.54\times10^{-3})$

$V = 1.187\times10^{-6} \approx 1.18\times10^{-6}\,m^3$

% uncertainty

uncertainty in t : $0.001 \div 2 = 0.0005 \times 100$

$= 0.05\%$

uncertainty in d : $0.01 \div 2 = 0.005 \div 2$

$r = 2.5\times10^{-3} \times 100$

$r = 0.25\%$ ×2 $r^2 = 0.5\%$

uncertainty in V = $(0.5)\% + 0.5\%$

$= 1\%$

$V = 1.18\times10^{-6}\,m^3$

Percentage uncertainty in V = 1%

Example 3

(i) Calculate the volume V of the coin, and the percentage uncertainty in V.

$t = 1.54$ mm ± 0.01 mm

$d = 22.16$ mm ± 0.01 mm

(7)

$V = \pi\left(\frac{d}{2}\right)^2 \times t$

$= \pi\left(\frac{22.16}{2}\right)^2(1.54) = 594\ mm^3$

Max V: $\pi\left(\frac{22.17}{2}\right)^2(1.55) = 598\ mm^3$

Min V: $\pi\left(\frac{22.15}{2}\right)^2(1.53) = 590\ mm^3$

% Unc (V) $= \frac{598-590}{594} \times 100 = 1.3\%$.