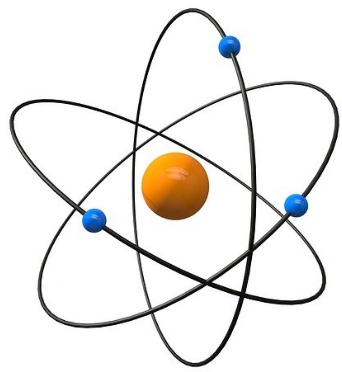
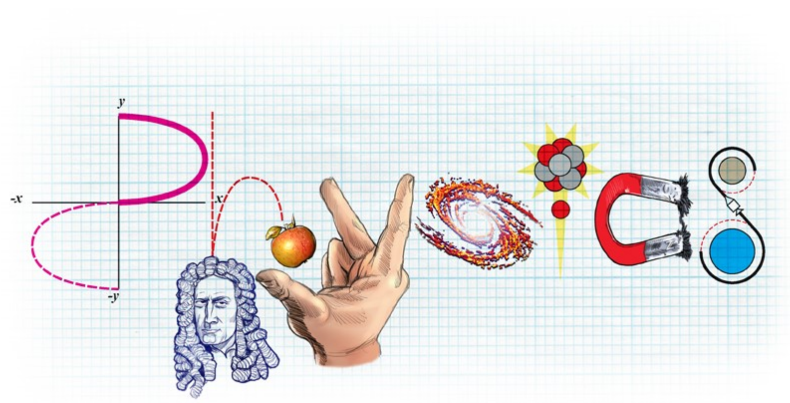


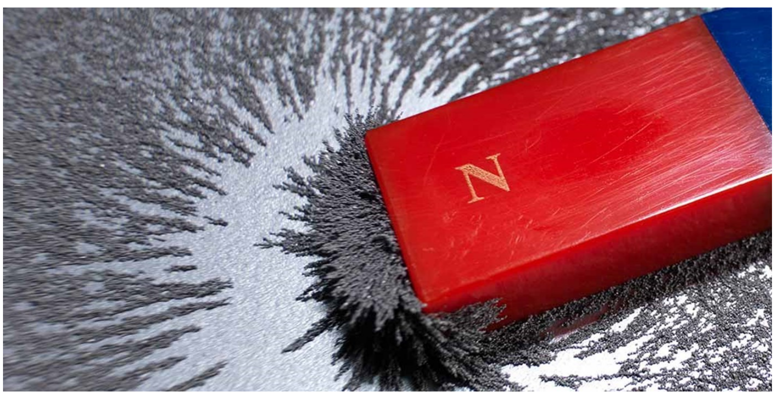
Higher Physics

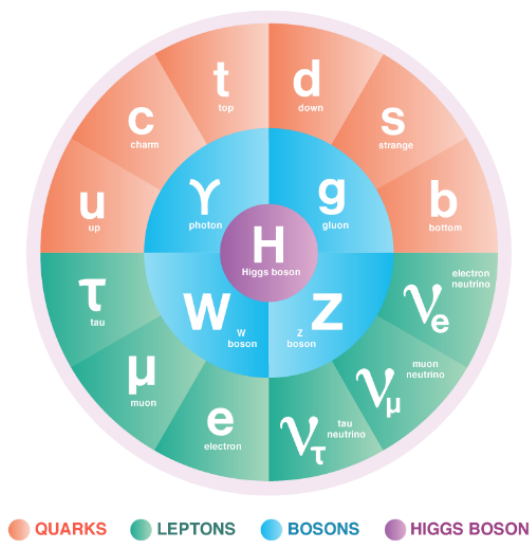
Immersion Day

Challenging past paper questions

Marking Instructions







DATA SHEET

Speed of light in materials

Material	Speed in m s^{-1}
Air	3.0×10^8
Carbon dioxide	3.0×10^8
Diamond	1.2×10^8
Glass	2.0×10^8
Glycerol	2.1×10^8
Water	2.3×10^8

Gravitational field strengths

	Gravitational field strength on the surface in N kg^{-1}
Earth	9.8
Jupiter	23
Mars	3.7
Mercury	3.7
Moon	1.6
Neptune	11
Saturn	9.0
Sun	270
Uranus	8.7
Venus	8.9

Specific latent heat of fusion of materials

Material	Specific latent heat of fusion in J kg^{-1}
Alcohol	0.99×10^5
Aluminium	3.95×10^5
Carbon Dioxide	1.80×10^5
Copper	2.05×10^5
Iron	2.67×10^5
Lead	0.25×10^5
Water	3.34×10^5

Specific latent heat of vaporisation of materials

Material	Specific latent heat of vaporisation in J kg^{-1}
Alcohol	11.2×10^5
Carbon Dioxide	3.77×10^5
Glycerol	8.30×10^5
Turpentine	2.90×10^5
Water	22.6×10^5

Speed of sound in materials

Material	Speed in m s^{-1}
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Specific heat capacity of materials

Material	Specific heat capacity in J kg^{-1} °C^{-1}
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Melting and boiling points of materials

Material	Melting point in °C	Boiling point in °C
Alcohol	−98	65
Aluminium	660	2470
Copper	1077	2567
Lead	328	1737
Iron	1537	2737
Water	–	100

Radiation weighting factors

Type of radiation	Radiation weighting factor
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3
X-rays	1

$d = vt$

$d = \overline{v}t$

$s = vt$

$s = \overline{v}t$

$a = \frac{v-u}{t}$

$F = ma$

$W = mg$

$E_w = Fd$

$E_p = mgh$

$E_k = \frac{1}{2}mv^2$

$Q = It$

$V = IR$

$V_2 = \left(\frac{R_2}{R_1 + R_2}\right)V_S$

$\frac{V_1}{V_2} = \frac{R_1}{R_2}$

$R_T = R_1 + R_2 + ...$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + ...$

$P = \frac{E}{t}$

$P = IV$

$P = I^2R$

$P = \frac{V^2}{R}$

$E_h = cm\Delta T$

$E_h = ml$

$p = \frac{F}{A}$

$p_1V_1 = p_2V_2$

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$\frac{pV}{T} = \text{constant}$

$f = \frac{N}{t}$

$v = f\lambda$

$T = \frac{1}{f}$

$A = \frac{N}{t}$

$D = \frac{E}{m}$

$H = Dw_r$

$\dot{H} = \frac{H}{t}$

1. B
2. A
3. A
4. D
5. A
6. E
7. D
8. E
9. A
10. C
11. D
12. E
13. E
14. A
15. E
16. C
17. B
18.

(a)		$F = ma$ (1) $125-(15+45)=(28+85)\times a$ (1) $a = 0.58\ \text{m s}^{-2}$	2	SHOW Must show how both total mass and unbalanced force are arrived at.
(b)		$F = ma$ (1) $F = 28\times 0.58$ (1) $(F = Tension + Friction)$ $28\times 0.58 = Tension + (-15)$ (1) $Tension = 31\ \text{N}$ (1)	4	Accept: 30, 31.2, 31.24 $T = ma$ on its own - 0 marks.
(c)		(Tension) increases (1) (Friction increases but) unbalanced/ resultant force remains the same. (1)	2	JUSTIFY Must be clear it is the unbalanced force that remains constant. Accept: 'F' for unbalanced force Can be justified by calculation.

19.	(a)		$m_x u_x + m_y u_y = m_x v_x + m_y v_y$ (1) $(760 \times 12.0) + (840 \times 4.0)$ $= (760 \times v_x) + (840 \times 8.5)$ (1) $v_x = 7.0 \text{ m s}^{-1}$ (1)	3	Accept: 7, 7.03, 7.026 Equating the <u>total</u> momenta before and after (1) All substitutions (1) Final answer (1) If a direction is stated it must be to the right otherwise MAX 2 marks.
	(b)		$E_k = \frac{1}{2}mv^2$ *Before* $E_k = \frac{1}{2}m_x u_x^2 + \frac{1}{2}m_y u_y^2$ $E_k = (\frac{1}{2} \times 760 \times 12.0^2) + (\frac{1}{2} \times 840 \times 4.0^2)$ $E_k = 61440$ (J) *After* $E_k = \frac{1}{2}m_x v_x^2 + \frac{1}{2}m_y v_y^2$ $E_k = (\frac{1}{2} \times 760 \times 7.0^2) + (\frac{1}{2} \times 840 \times 8.5^2)$ $E_k = 48965$ (J) (Total) E_k before is greater than (total) E_k after, (the collision is inelastic).	4	Or consistent with (a) 1 mark for relationship 1 mark for <u>all</u> substitutions 1 mark for <u>both</u> total kinetic energies 1 mark for correct final statement Suspend significant figure rule for calculated values of total kinetic energies in this question. <u>Kinetic</u> energy is lost. (Therefore inelastic.) E_k before ≠ E_k after is insufficient.
	(c)		$Ft = mv - mu$ (1) $F \times 0.82 = (840 \times 8.5) - (840 \times 4.0)$ (1) $F = 4.6 \times 10^3$ N (1)	3	Accept: 5, 4.61, 4.610 Accept: Impulse = $mv - mu$ u and v must be substituted correctly If the force that car Y exerts on car X is calculated, then there must be a statement that the forces have equal magnitude for final mark, otherwise MAX 2 marks. For this method - Accept: 5, 4.63, 4.634 (when v = 7.0) Or consistent with (a)
	(d)		(During a collision the tyre wall will) increase the time of contact (between the car and the wall). (1) (this will) reduce the (magnitude of the) force (experienced by the driver). (1)	2	INDEPENDENT MARKS Accept: time/duration of collision Accept: 'rate of change in momentum' for force.

20.

(a)	(i)	$f_o = f_s\left(\frac{v}{v \pm v_s}\right)$ (1) $f_o = 440\left(\frac{340}{340-31}\right)$ (1) $f_o = 480$ Hz (1)	3	Accept: 500, 484, 484.1 Accept: $f_o = f_s\left(\frac{v}{v - v_s}\right)$
	(ii)	Less than (1) Statement that there are fewer wavefronts per second. OR The wavefronts are further apart OR The wavelength increases OR diagram showing wavefronts closer together ahead of the car and further apart behind it. (1) or any similar response	2	MUST JUSTIFY Accept: "It is less than" Do not accept: "Sound is less than" on its own. Accept: Waves or wave crests in place of wavefronts. Can be justified by calculation. Significant figure rule suspended for this calculation. Can be justified by explaining the use of the '+' version of the relationship. In a diagram, there must be an implication of direction of travel. Do not accept: Any answer that implies that the frequency/wavelength of the sound produced by the siren itself is changing.
(b)	(i)	T = 0.5 s	1	
(b)	(ii)	When the red LEDs are forward biased the blue LEDs are reverse biased (or vice versa). (1) LEDs (only) light when forward biased (1)	2	INDEPENDENT MARKS Accept: The red and blue LEDs are connected the opposite way round. LEDs will (only) conduct in one direction OR Red LEDs conduct during one half of the cycle the blue LEDs conduct during the other half of the cycle. Do not accept: 'different direction' alone.

20.

(b)	(iii) (A)	$v = f\lambda$ $3.00\times10^{8} = f\times625\times10^{-9}$ (1) $E = hf$ both relationships anywhere (1) $E = 6.63\times10^{-34}\times\left(\frac{3.00\times10^{8}}{625\times10^{-9}}\right)$ (1) $E = 3.18\times10^{-19}$ J (1)	4	Accept 3.2, 3.182, 3.1824 1 mark for both relationships 1 mark for each substitution 1 mark for final answer Alternative method: $E = \frac{hc}{\lambda}$ (1) $E = 6.63\times10^{-34}\times\left(\frac{3.00\times10^{8}}{625\times10^{-9}}\right)$ (1),(1) $E = 3.18\times10^{-19}$ J (1) Do not accept: $E_2 - E_1 = hf$
	(iii) (B)	The (energy) band gap in a blue LED is greater. (1) The photons of blue light have more energy (than the photons of red light). (1)	2	Accept: Converse arguments. If no mention of band gap, 0 marks. Accept: The photons of blue light have a higher frequency (than the photons of red light). OR The photons of blue light have a smaller wavelength (than the photons of red light).

21.

(a)		Apparatus (1) Method used to collect data (1)	2	Any mention of laser - 0 marks. INDEPENDENT MARKS Must have either name or a labelled diagram of all measuring instruments. Do not accept: light sensor on its own for instrument to measure irradiance. Ignore any mention of analysis of data.
(b)	(i)	The power per unit area (incident on a surface)	1	Accept: power per square metre/power per metre squared/(m^2) Do not accept: watts per square metre
(b)	(ii)	$142 \times 0.200^2 = 5.68$ $63.1 \times 0.300^2 = 5.68$ $35.5 \times 0.400^2 = 5.68$ $22.7 \times 0.500^2 = 5.68$ $15.8 \times 0.600^2 = 5.69$ (2) statement of $I \times d^2 = \text{constant}$ OR $I \propto \frac{1}{d^2}$ (1)	3	If only 4 sets of data used correctly then maximum 2 marks. If only 3 sets of data used correctly then maximum 1 mark (for relationship). If only 1 or 2 sets of data used correctly, award 0 marks. Must be clear how the candidate has used the data to obtain the relationship. Accept: $I \times d^2 = 5.68$ Ignore inappropriate averaging in this case. The 'statement' mark is only available if consistent with the calculations shown. $I_1 d_1^2 = I_2 d_2^2$ is insufficient on its own for statement of relationship. $I \times d^2 = k$ is insufficient on its own for statement of relationship. Graphical method: Graph drawn correctly (1) Line of best fit through origin (1) Statement of relationship. (1) A sketch graph is not acceptable.
(c)		Area increases (1) Power remains the same (1)	2	'light spreads out' is insufficient for 'area increases' Accept alternative explanation, provided the candidate refers to irradiance on light detector: Area remains the same (1) (Incident) power decreases (1)

22. (a)		A (central) positively charged nucleus. OR When an electron moves from one state to another, the energy lost or gained is done so ONLY in very specific amounts of energy. OR Each line in a spectrum is produced when an electron moves from one energy level/orbit/shell to another.	1	Do not accept: Atom is mainly empty space. Nucleus is small compared to size of atom. Any statement referring to photons and photon frequency is a consequence, not a feature.
(b)	(i)	If an electron is in an excited state it can return to a lower energy level. When it does this, it emits a photon. (1) Different transitions produce different lines/ frequencies (of photons). (1)	2	Accept: When an electron drops down a level it releases energy. If absorption described - 0 marks.
	(ii)	(For the brighter lines) more electrons are making those transitions (per second). (1) (Therefore), there are more <u>photons</u> (per second) emitted (of that specific energy and so produce brighter lines). (1)	2	INDEPENDENT MARKS Do not accept: greater brightness due to greater frequency/energy of the photons. 'More electrons release more photons' on its own - MAX 1 mark
(c)	(i)	10	1	
	(ii)	$E_2 - E_1 = hf$ (1) $-0.871\times10^{-19} - (-5.45\times10^{-19}) = 6.63\times10^{-34}\times f$ (1) $f = 6.91\times10^{14}$ Hz (1)	3	Accept: 6.9, 6.906, 6.9065 Accept: $(\Delta)E = hf$ OR $E_4 - E_1 = hf$ Note: $\Delta E = 4.579\times10^{-19}$ (J) Accept: $5.45\times10^{-19} - 0.871\times10^{-19} = 6.63\times10^{-34}\times f$ for energy substitution mark If $0.871\times10^{-19} - 5.45\times10^{-19}$ is shown for ΔE, maximum (1 mark) for relationship.
	(ii) (B)	486 nm (1)	1	Accept: 4.86×10^{-7} m

(c)	(ii) (C)	$z = \frac{v}{c}$ (1) $z = \frac{4.52\times10^{6}}{3.00\times10^{8}}$ (1) $z = \frac{\lambda_o - \lambda_r}{\lambda_r}$ (1) $\frac{4.52\times10^{6}}{3.00\times10^{8}} = \frac{\lambda_o - 486\times10^{-9}}{486\times10^{-9}}$ (1) $\lambda_o = 4.93\times10^{-7}$ m (1)	5	Or consistent with (c)(ii)(B) Accept: 4.9, 4.933, 4.9332 $z = \frac{v}{c}$ anywhere, 1 mark $z = \frac{\lambda_o - \lambda_r}{\lambda_r}$ anywhere, 1 mark substitution of 486 × 10^{-9} (1) Accept: 486 Alternative method: $\frac{v}{c} = \frac{\lambda_o - \lambda_r}{\lambda_r}$ $\frac{4.52\times10^{6}}{3.00\times10^{8}} = \frac{\lambda_o - 486}{486}$ $\lambda_o = 4.93\times10^{-7}$ m Equating formula, (2) Substitution of v and c (1) Substitution of λ_r (1) Final answer (1)

23.	(a)	(i)	$n = \frac{\sin\theta_1}{\sin\theta_2}$ (1) $1.53 = \frac{\sin 36.0}{\sin\theta_2}$ (1) $\theta_2 = 22.6°$ (1)	3	Accept: 23, 22.59, 22.592 Accept: $\frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2}$ (1) $\frac{1.53}{1} = \frac{\sin 36.0}{\sin\theta_2}$ (1) $\theta_2 = 22.6°$ (1)
		(ii)	$180 - 60 - [90 - 22.6]$ (1) $(= 52.6°)$ $(90 - 52.6 = B)$ $B = 37.4°$ (1)	2	Or consistent with (a)(i) Value must be given to 1 decimal place or consistent with the number of decimal places in answer to (a)(i)
	(b)	(i)	The angle of incidence that produces an angle of refraction of 90°.	1	Accept a description of the incident ray as an alternative to the word 'incidence'. Do not accept: The minimum angle of incidence that causes total internal reflection.
		(ii)	$\sin\theta_c = \frac{1}{n}$ (1) $\sin\theta_c = \frac{1}{1.53}$ (1) $\theta_c = 40.8°$ (1)	3	Accept: 41, 40.81, 40.813

	(c)		Emergent ray drawn at an angle greater than angle B (1) $\left(n = \frac{\sin\theta_1}{\sin\theta_2}\right)$ $1.53 = \frac{\sin\theta_1}{\sin 37.4}$ (1) $(\theta_1 = 68.3°)$ calculated angle correctly shown on diagram (1)	3	or consistent with (a)(ii) and/or (b)(ii) Accept: 68, 68.32, 68.324 Ignore any partially reflected rays. If (a)(ii) has a greater angle than (b)(ii) then the total internal reflection would be correct Internally reflected ray drawn (1) Angle of reflection approximately equal to angle B (1) Value for angle of reflection shown on diagram consistent with (a)(ii) (1) Ignore any further refraction at other glass-air boundaries.

24.

(a)		Axes appropriately labelled (quantity and units) and axes linearly scaled (1) [Allow for axes starting at zero or broken axes or an appropriate value] Data points plotted accurately (1) Appropriate line of best-fit (1)	3	If the origin is shown the scale must either be continuous, or the axis must be 'broken'. Otherwise, maximum 2 marks. If non-linear scale is used over the range of the data on either axis eg values from the table are used as the scale points. (0) marks Do not penalise if candidates plot *frequency* against *switch on voltage*. Accuracy of plotting should be easily checkable with the scale chosen. An appropriate scale to allow the accuracy of plotting to be checked must be linear over the range of the data.
(b)		Choosing 2 points on their line (1) Calculate gradient: (1) (min 1 sig fig, max 4 sig figs) (Gradient works out as approx. 5.0×10^{-15})	2	Must be consistent with graph drawn for (a). Candidates are asked to calculate the gradient of their graph. Tolerance required depending upon best fit line drawn by the candidate. If candidates use values from the table, these points must lie on their line. If ($\times 10^{14}$) is not accounted for in the final answer, maximum 1 mark unless this being omitted is consistent with the graph drawn in (a). A unit is not required in the final answer, but if stated it must be correct. If candidate has a non-linear scale over the range of the values used in the substitution, (0) marks. If candidate has drawn a 'dot to dot' graph or no line, (0) marks.

(c)		$(h = e \times gradient)$ $h = 1.60\times10^{-19}\times5.0\times10^{-15}$ (1) $h = 8.0\times10^{-34}$ Js (1)	2	Must be consistent with (b) Must substitute the gradient of their graph, and not a single data point. If a single data point is substituted into in the calculation, award (0) marks Accept: correct alternative units If candidate has plotted frequency against switch on voltage, the formula becomes $\left(h = \frac{e}{gradient}\right)$ $h = \frac{1.60\times10^{-19}}{2.0\times10^{14}}$ (1) $h = 8.0\times10^{-34}$ Js (1)
(d)		Repeat the measurements and take the mean. OR Use a greater range of colours/ frequencies of LEDs. OR Carry out experiment in a dark room/use a viewing tube to see when LED first emits light. OR Use a photodiode to detect when the LED lights/use an ammeter to detect when the circuit conducts.	1	Accept: 'Average' for 'mean' Do not accept: 'Repeat the experiment and take the mean' on its own. Accept: Use more colours/frequencies of LEDs. Do not accept: Use more LEDs take more measurements on its own.

25.	(a)	(i)	$\Delta mv = mv - mu$ (1) $\Delta mv = (0.25 \times 1.80) - (0.25 \times 0.40)$ (1) $\Delta mv = 0.35 \text{ kg m s}^{-1}$ (1)	3	Accept: 0.4, 0.350, 0.3500 Accept: $\Delta p = m\Delta v$ $Ft = mv - mu$ $p = mv$ Do not accept: $p = mv - mu$ - 0 marks For alternative methods: Acceptable relationship (1) all substitutions including subtraction (1) Final answer (1) Sign convention must be consistent within this part of the question. v and u must have same sign. Accept N s
		(ii)	$Ft = mv - mu$ (1) $6.25 \times t = 0.35$ (1) $t = 0.056$ s (1)	3	OR consistent with (a)(i) Accept: 0.06, 0.0560, 0.05600 Alternative method: $F = ma$ $6.25 = 0.25 \times a$ $v = u + at$ $1.80 = 0.40 + \left(\frac{6.25}{0.25}\right) \times t$ $t = 0.056$ s Both relationships (1) Both substitutions (1) Final answer (1)

(b)		(total momentum before = total momentum after) $m_x u_x + m_y u_y = m_x v_x + m_y v_y$ (1) $(0.50 \times 0.40) + (0.25 \times 0.40)$ $= (0.50 v_x) + (0.25 \times 1.80)$ (1) $v_x = -0.30 \text{ m s}^{-1}$ (1) OR $(m_x + m_y)u = m_x v_x + m_y v_y$ (1) $(0.50 + 0.25) \times 0.40$ $= (0.50 v_x) + (0.25 \times 1.80)$ (1) $v_x = -0.30 \text{ ms}^{-1}$ (1) (Accept '0.30 m s^{-1} to the left')	3	Accept: -0.3, -0.300, -0.3000 Equating the <u>total</u> momenta before and after (1) All substitutions (1) Final answer (1) Sign convention must be consistent. Do not accept: 'v_x = −0.30 m s^{-1} to the left' Alternative methods: $\Delta mv = mv - mu$ $-0.35 = (0.50v) - (0.50 \times 0.40)$ $v = -0.30 \text{ m s}^{-1}$ Δmv and u must have opposite signs $Ft = mv - mu$ -6.25×0.056 $= (0.50v) - (0.50 \times 0.40)$ $v = -0.30 \text{ m s}^{-1}$ F and u must have opposite signs $F = ma$ $-6.25 = 0.50 \times a$ $v = u + at$ $v = 0.40 + \left(\left(\frac{-6.25}{0.5}\right) \times 0.056\right)$ $v = -0.30 \text{ m s}^{-1}$ F and u must have opposite signs Both relationships (1) Both substitutions (1) Final answer (1)

(c)		Calculate/compare the <u>total</u> <u>kinetic</u> energy before and (<u>total</u> <u>kinetic</u> energy) after. (1)
		
		If (total) kinetic energy before is equal to (total) kinetic energy after, the interaction is elastic. (1)
		
		OR
		
		If (total) kinetic energy is conserved, the interaction is elastic.
			2	Accept: E_k for 'kinetic energy'.
				
				Look for a statement relating to calculating/finding the <u>total</u> E_k before and after first, otherwise (0) marks.
				
				There must be an indication of total kinetic energy or equivalent term.
				
				Accept:
				Can show by calculation but would still require a statement for the second mark.
				
				Do not accept:
				If (total) kinetic energy is not conserved, the interaction is inelastic, on its own.

(d)	(i)	Photovoltaic (effect)	1	
	(ii)	Electrons gain/absorb energy from photons/light (1) Electrons move from <u>valence band</u> to <u>conduction band</u> (1) Electrons move towards n-type semiconductor (producing a potential difference). (1)	3	Look for reference to both conduction and valence band first, otherwise (0) marks. Bands must be named correctly, e.g. do not accept 'valency' or 'conductive'. Third statement is dependent on second statement. The direction the electrons move must be clear.

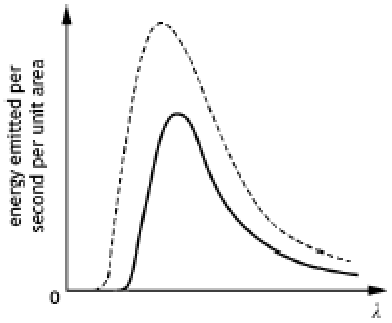
26.

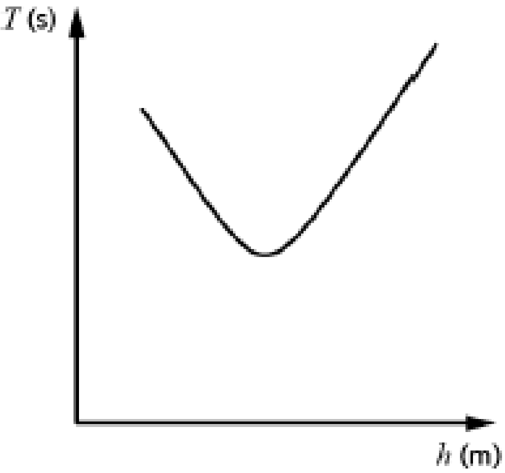
(a)		Protons are (positively) charged (1) Protons experience a <u>force</u> (in the electric field) (1)	2	Must state protons are charged otherwise, maximum (1) mark. Any mention of protons being negatively charged or uncharged - award (0) marks. Charged particles experience a <u>force</u>, on its own, award (1) mark.
(b)	(i)	$E_k = \frac{1}{2}mv^2$ (1) $E_k = \frac{1}{2} \times 1.673 \times 10^{-27} \times (3.8 \times 10^5)^2$ (1) $E_k = 1.2 \times 10^{-16}$ J	2	SHOW question
	(ii)	$W = QV$ (1) $W = 1.60 \times 10^{-19} \times 2.8 \times 10^3$ (1) $W = 4.5 \times 10^{-16}$ J (1)	3	Accept: 4, 4.48, 4.480
	(iii)	$E_k = 1.2 \times 10^{-16} + 4.5 \times 10^{-16}$ (1) ($E_k = 5.7 \times 10^{-16}$ J) $E_k = \frac{1}{2}mv^2$ (1) $(1.2 \times 10^{-16} + 4.5 \times 10^{-16}) = \frac{1}{2} \times 1.673 \times 10^{-27} \times v^2$ (1) $v = 8.3 \times 10^5$ m s^{-1} (1)	4	OR consistent with (b)(ii) Accept: 8, 8.25, 8.255 $E_k = \frac{1}{2}mv^2$ anywhere (1) Must attempt addition of kinetic energy and work done, otherwise maximum (1) mark. Demonstrated arithmetic mistake can be carried forward through the response. If using 4.48×10^{-16} (J), accept: 8, 8.2, 8.24, 8.240
(c)		No effect (1) Work done is the same OR <u>gain in</u> kinetic energy is the same (1)	2	MUST JUSTIFY Look for this statement first - if incorrect or missing then (0) marks. charge and potential difference are unchanged, on its own, is insufficient for second mark. Any mention of magnetic field/force on its own is insufficient for second mark.

27.

(a)		(f_0 =) 7.0×10^{14} Hz	1	Accept: 7×10^{14} Hz Accept: 6.9×10^{14} - 7.1×10^{14} Hz
(b)		$E = hf_0$ (1) $E = 6.63\times10^{-34}\times7.0\times10^{14}$ (1) $E = 4.6\times10^{-19}$ (J) (1) Calcium/Ca (1)	4	OR consistent with (a) Accept: 5, 4.64, 4.641 If calcium is correctly identified with no calculation, maximum (1) mark. If there is a calculation with a value consistent with (a), then the metal chosen must be consistent with their calculation. If this calculated value does not match a value in the table, then maximum (3) marks. A unit is not required but, if a unit is given, it must be correct. If a candidate completes a calculation but does not go on to identify a metal, then a unit is required. In this question, if an incorrect metal or no metal identified, maximum (3) marks. Accept: $E = hf$ Alternative method: $E = hf_0$ (1) $4.6\times10^{-19} = 6.63\times10^{-34}\times f_0$ (1) $f_0 = 6.9\times10^{14}$ (Hz) (1) Therefore calcium (1) Accept: 7, 6.94, 6.938 Where more than one calculation is shown all substitutions must be correct for substitution mark, and all calculated values must be correct for calculated value mark. Accept: $E_k = hf - hf_0$ (1) Substituted values must be consistent with the line or the table, depending on the method chosen.

28.	(a)		Appropriate labels and units (1) Suitable scales (1) Plotting and line of best fit (1)	3	Allow for axes starting at zero, or broken axes, or at an appropriate value. Accuracy of plotting should be easily checkable with the scale chosen. An origin is not essential and can be implied by a suitable linear scale. If the origin is shown, the scale must either be continuous or the axis must be 'broken'. Otherwise maximum (2) marks. An appropriate scale must be linear over the range of the data. Accept: graph of L against T^2.
	(b)		$\left(m = \frac{y_2 - y_1}{x_2 - x_1}\right)$ $m = \frac{4-2}{0.96-0.48}$ (for example) (1) $m = 4.2$ ($s^2\ m^{-1}$) (1)	2	Must be consistent with graph drawn for (a). Candidates are asked to calculate the gradient of their graph. Tolerance required depending upon best fit line drawn by the candidate. If candidates use values from the table, these points must lie on their line. A unit is not required in the final answer, but if stated it must be correct. If candidate has a non-linear scale over the range of the values used in the substitution, (0) marks. If candidate has drawn a 'dot to dot' graph or no line, (0) marks.
	(c)		$\left(\frac{T^2}{L} = \frac{4\pi^2}{g} = \text{gradient}\right)$ $\frac{4\pi^2}{g} = 4.2$ (1) $g = 9.4\ N\ kg^{-1}$ (1)	2	Must be consistent with (b) Must substitute the gradient of their graph, and not a single data point. If a single data point is substituted into in the calculation, award (0) marks. The use of 3.14 is acceptable for π. Accept $m\ s^{-2}$. If a candidate has plotted L against T^2, this becomes $\left(\frac{L}{T^2} = \frac{g}{4\pi^2} = \text{gradient}\right)$ $\frac{g}{4\pi^2} = 0.24$ (1) $g = 9.5\ N\ kg^{-1}$ (1)

29.	(a)			2	Peak wavelength less **(1)** Line added should always be above original line **(1)**
	(b)		$7700 \times 3{\cdot}76\times10^{-7} = 2{\cdot}9\times10^{-3}$ $8500 \times 3{\cdot}42\times10^{-7} = 2{\cdot}9\times10^{-3}$ $9600 \times 3{\cdot}01\times10^{-7} = 2{\cdot}9\times10^{-3}$ $12000 \times 2{\cdot}42\times10^{-7} = 2{\cdot}9\times10^{-3}$ **(2)** therefore $T\times\lambda_{peak} = 2{\cdot}9\times10^{-3}$ **(1)**	3	All four calculations correct **(2)** Three correct calculations **(1)** < Three correct calculations **(0)** $7700 \times 3{\cdot}76\times0^{-7} = 2{\cdot}895\times10^{-3}$ $8500 \times 3{\cdot}42\times10^{-7} = 2{\cdot}907\times10^{-3}$ $9600 \times 3{\cdot}01\times10^{-7} = 2{\cdot}890\times10^{-3}$ $12000 \times 2{\cdot}42\times10^{-7} = 2{\cdot}904\times10^{-3}$ therefore $T \times \lambda_{peak} = 2{\cdot}9\times10^{-3}$ **(1)** This 'conclusion' mark is only available if consistent with the calculations shown. For 'finding the constant' method, accept restatement of relationship for final mark. Alternative methods: Can calculate the temperatures or wavelengths using the relationship. Final mark is given for a statement that the calculated temperatures or wavelengths match values in the table. Graphical method: Graph drawn correctly **(1)** Gradient calculated **(1)** restatement of relationship **(1)**

30.	(a)		Measure the total time over a number of swings (1) Divide total time by number of swings (1)	2	
	(b)	(i)		3	Appropriate labels and units (1) Suitable scales (1) Plotting and curve of best fit (1) Allow for axes starting at zero or broken axes or at an appropriate value. Accuracy of plotting should be easily checkable with the scale chosen If the origin is shown the scale must either be continuous or the axis must be 'broken'. Otherwise maximum **(2 marks).** Do not penalise if the candidate plots h against T.
		(ii)	0·21 and 0·42 m	1	must be consistent with candidate's graph
		(iii) (A)	1·53 s	1	must be consistent with candidate's graph
		(B)	Use smaller increments around the 'turning point'. **OR** Take more measurements about the 'turning point'. **OR** Take more measurements over the whole range.	1	Accept: More readings around/close to turning point or smaller 'steps' in h. Do not accept: 'Repeat experiment' on its own.
	(c)		$T^2h = \frac{4\pi^2h^2}{g} + C$ $1{\cdot}53^2 \times 0{\cdot}30 = \frac{4\times\pi^2\times 0{\cdot}30^2}{9{\cdot}8} + C$ (1) $C = 0{\cdot}34$ (1)	2	Accept: 0·3, 0·340, 0·3397 If candidate uses 3·14 for π, accept 0·3401. Ignore any unit given.