Paper 2 Mark scheme

Question Number	Acceptable answers	Additional guidance	Mark
1	C		**1**
2	C		**1**
3	D		**1**
4	A		**1**
5	C		**1**
6	B		**1**
7	A		**1**
8	C		**1**
9	C		**1**
10	D		**1**

(Total for Multiple Choice Questions = 10 marks)

Question Number	Acceptable answers	Additional guidance	Mark
11 (a)	• The energy equivalent to the mass deficit **(1)** • When nucleons bind together to form an atomic nucleus **(1)**		**2**
11 (b)	• Calculation of mass difference in kg **(1)** • Use of $E = c^2 \Delta m$ **(1)** • $E = 2.77 \times 10^{-11}$ J **(1)**	Example of calculation: (235.0439 + 1.008665) u – (140.9144 + 91.9262+ (3×1.008665)) u = 0.186u (0.1860 u × 1.66×10^{-27} kg) × (3×10^8 m s^{-1})^2 = 2.77×10^{-11} J	**3**

(Total for Question 11 = 5 marks)

Question Number	Acceptable answers	Additional guidance	Mark
12 (a)	• Use of $L = \lambda/2$ **(1)** • Use of $v = f\lambda$ **(1)** • $f = 180$ Hz **(1)**	Example of calculation: $\lambda = 2 \times 0.45$ m $= 0.90$ m $f = v/\lambda = 160$ m s^{-1}/0.9 m $= 178$ Hz	**3**
12 (b)	An explanation that makes reference to: **Either** • The oscillating frame causes the lead spheres to deform plastically **(1)** • And this removes energy from the oscillating frame **(1)** • So the amplitude of oscillations decrease with time as shown by the graph **(1)** **OR** • Spheres collide/vibrate **(1)** • Hence energy dissipated **(1)** • So the amplitude of oscillations decrease with time as shown by the graph **(1)**		**3**

(Total for Question 12 = 6 marks)

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>13 *</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
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(continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.

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</table>
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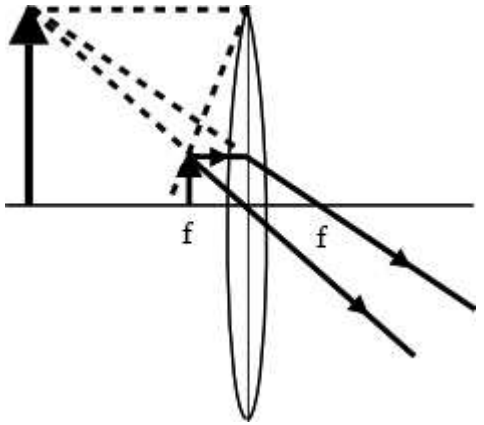
</table>

Question Number	Acceptable answers	Additional guidance	Mark
13* (continued)	**Indicative content** • Sound waves incident upon surfaces within the concert hall will be reflected. • Some frequencies will arrive from different directions with a phase difference of (any odd multiple of) π radians **(1) OR** path difference is odd number of half wavelengths • Destructive superposition/interference will occur, causing the waves with those frequencies to be quieter than others. • Other frequencies arrive with a phase difference of zero or (any multiple of) 2π radians **(1) OR** a whole number of wavelengths • Constructive superposition/interference will occur, causing waves with those frequencies to be louder than others. • Problem arises due to reflections from walls, so use absorbing material on surfaces to reduce reflections.		**6**

Question Number	Acceptable answers	Additional guidance	Mark
13* (continued)	**Alternative approach based on standing waves:** • Sound waves incident upon surfaces within the concert hall will be reflected. • Reflections from walls set up standing waves (in room) • Nodes and antinodes are formed for certain frequencies of sound • Nodes are areas of zero/low amplitude so the frequencies of those sound waves will be quieter than others • Antinodes are areas of maximum amplitude so the frequencies of these sound waves will be louder than others • Problem arises due to reflections from walls, so use absorbing material on surfaces to reduce reflections		

(Total for Question 13 = 6 marks)

Question Number	Acceptable answers	Additional guidance	Mark
14 (a)	• Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ **(1)** • $c = 67^\circ$ **(1)** • Determines the angle of incidence is 70° **(1)** • so i > c so the ray does totally internally reflect **(1)**	Example of calculation: $1.56 \times \sin c = 1.44 \times \sin 90^o$ $c = 67.4^o$	**4**
14 (b)(i)	Two construction rays from: • ray from tip of object parallel to principal axis drawn then refracted through the focal point **(1)** • ray drawn from tip of object through centre of lens **(1)** • ray drawn from focal point through tip of object and then refracted parallel to the principal axis **(1)** **And** • rays extended back to locate tip of image on the same side as the object **(1)**	Example of diagram:  	**3**

Question Number	Acceptable answers	Additional guidance	Mark
14 (b)(ii)	• Use of $m = v/u$ **(1)** • Use of $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ and substituting for v or u **(1)** • $u = 6.1$ cm **(1)**	Example of calculation: $\frac{v}{u} = -3.5 \quad \therefore v = -3.5u$ $\frac{1}{u} + \frac{1}{-3.5u} = \frac{1}{8.5} \qquad \therefore \frac{3.5-1}{3.5u} = \frac{1}{8.5}$ $\therefore \frac{3.5u}{2.5} = 8.5$ $u = \frac{8.5 \times 2.5}{3.5} = 6.07$ cm	**3**

(Total for Question 14 = 10 marks)

Question Number	Acceptable answers	Additional guidance	Mark
15	• Use of $pV = NkT$ **(1)** • Conversion of temperature to Kelvin **(1)** • p = 95.4 kPa **(1)** • Calculation of excess pressure **(1)** • Use of $p = F/A$ **(1)** • ΔF = 995 N **(1)** • Sensible comment, e.g. this is a large force so could make the door hard to open **(1)**	Example of calculation: $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ $p_2 = p_1 \times \frac{T_2}{T_1} = 102 \times 10^3\,\text{Pa} \times \frac{(273 + 3.3)\text{K}}{(273 + 22.5)\text{K}}$ $= 95.37 \times 10^3\,\text{Pa}$ Δp = (102 –95.37) kPa = 6.63 kPa $\Delta F = A\Delta p = 0.15\,\text{m}^2 \times 6.63 \times 10^3\,\text{Pa} = 994.5\,\text{N}$	**7**

(Total for Question 15 = 7 marks)

Question Number	Acceptable answers	Additional guidance	Mark
16	• Use of $F = k\,\Delta x$ **(1)** • $k = 14.4$ N m^{-1} **(1)** • Use of $T = 2\pi\sqrt{\frac{m}{k}}$ **(1)** • Use of $f = 1/T$ **(1)** • $f = 2.4$ Hz **(1)**	Example of calculation: $k = mg/\Delta x = 66\times 10^{-3}$ kg $\times$ 9.81m s^{-2})/4.5×10^{-2} m = 14.4 N m^{-1} $T = 2\pi(0.066/14.4.0)^{1/2} = 0.425$ s $f=1/T = 1/0.425 = 2.35$ Hz	**5**

(Total for Question 16 = 5 marks)

Question Number	Acceptable answers	Additional guidance	Mark
17 (a)	An explanation that makes reference to: • the temperature is constant when the puree boils because the average kinetic energy of the molecules in the puree is constant. **(1)** • when boiling occurs, the thermal energy supplied increases the potential energy of the molecules causing the molecules to move further apart (producing steam) **(1) OR** when boiling occurs, the thermal energy supplied increases the potential energy of the molecules breaking molecular bonds. **(1)**		**2**
17 (b)	• Use of $\Delta E = mc\Delta\theta$ with a temperature change of 80°C **(1)** • $c = 3.94\times10^{3}\,\text{J kg}^{-1}\,\text{C}^{-1}$ **(1)**	Example of calculation: Temperature rise = $(101 - 21)^{\circ}\text{C}$ $175000\text{J} = 0.444\text{kg}\times c\times(101-21)\text{C}$ $c = 3.94\times10^{3}\,\text{J kg}^{-1}\,\text{C}^{-1}$	**2**
17 (c)	• Use of $\Delta E = m\,L$ **(1)** • Convert peak voltage and current to r.m.s. values (230 V and 8.77 A) **(1) OR** use $P=I_{peak}V_{peak}/2$ **(1)** • Use of $E = VI\,t$ **(1)** • t = 264 s **(1)**	Example of calculation: $\Delta E = m\,L = 0.225\text{kg}\times2.37\times10^{6}\,\text{J kg}^{-1} = 5.33\times10^{5}\,\text{J}$ V = 325 V/√2 = 230 V and I = 12.4 A/√2 = 8.77 A $t = \frac{E}{VI} = \frac{5.33\times10^{5}\,\text{J}}{230\,\text{V}\times8.75\,\text{A}} = 264\text{s}$	**4**

(Total for Question 17 = 8 marks)

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>18 (a)*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

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If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
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18 (a)* (continued)

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure of answer and sustained line of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkages between points and is unstructured	0

Question Number	Acceptable answers	Additional guidance	Mark
18 (a)* (continued)	**Indicative content** • a polarising filter restricts the (electric field) vibrations of the (transverse) light wave to a single plane • including the direction of propagation of the light • the light incident on the filter must be plane polarised • when the angle of rotation is a multiple of π rad (including zero), the plane of polarisation of the incident light is perpendicular to the transmission axis of the polarising filter hence the intensity of the transmitted light is zero • when the angle of rotation is an odd multiple of π/2 rad the plane of polarisation of the incident light is the same as that of the transmission axis of the polarising filter hence maximum light is transmitted • the intensity of the transmitted light varies from a minimum to a maximum as the angle of rotation varies as shown by the graph		

Question Number	Acceptable answers	Additional guidance	Mark
18 (a)* (continued)	**Alternative answer** • a polarising filter restricts the (electric field) vibrations of the (transverse) light wave to a single direction • perpendicular to the direction of propagation of the light • the light incident on the filter is plane polarised • when the angle of rotation is a multiple of π rad (including zero), the plane of polarisation of the incident light is perpendicular to the transmission axis of the polarising filter hence the intensity of the transmitted light is zero • when the angle of rotation is an odd multiple of π/2 rad the plane of polarisation of the incident light is the same as that of the transmission axis of the polarising filter hence maximum light is transmitted • the intensity of the transmitted light varies from a minimum to a maximum as the angle of rotation varies as shown by the graph		
18 (b)	• Pass light through one lens of the glasses and view the light through the lens of the second pair of glasses. Rotate one pair of glasses through 90° **(1)** • If the light intensity varies then the glasses use polarising filters **(1)**	Allow full credit for a suitably annotated diagram.	**2**

(Total for Question 18 = 8 marks)

Question Number	Acceptable answers	Additional guidance	Mark
19 (a)(i)	An explanation that makes reference to: • quantisation of energy is the idea that energy is emitted/radiated in discrete packets/photons **(1)** • each photon has an energy which is related to frequency OR suitable reference to $E = hf$ **(1)**		**2**
19 (a)(ii)	• Model A is successful at long wavelengths because the curve for model A follows the experimental curve **(1)** • But model A breaks down for short wavelengths, since it suggests that the intensity tends to infinity as the wavelength gets shorter **(1)** • Model B is successful for short wavelengths because curve B follows the experimental curve **(1)** • But model B indicates higher than expected intensities at larger wavelengths **(1)**		**4**
19 (b)	• Use of $c=f\lambda$ and $E=hf$ **(1)** • Converts eV to J **(1)** • Use of $E = W + KE_{max}$ **(1)** • $KE_{max} = 1.3 \times 10^{-19}$ J **(1)**	Example of calculation: $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\,\text{J s}\times3\times10^{8}\,\text{m s}^{-1}}{2.54\times10^{-7}\,\text{m}} = 7.831\times10^{-19}\,\text{J}$ Work function = 6.51×10^{-19} J $E = W + KE_{\max}$ $KE_{\max} = 7.83\times10^{-19}\text{J} - 6.51\times10\text{-}19\text{J} = 1.32\times10^{-19}\text{J}$	**4**

(Total for Question 19 = 10 marks)

Question Number	Acceptable answers	Additional guidance	Mark
20 (a)	• The wavelength change is bigger the further away the galaxies are **(1)** • The further away galaxies are the faster they are moving, so all distant galaxies are moving away from each other (and the universe is expanding) **(1)** • There is a large amount of scatter in Hubble's original data set. **(1)** • The original data set covers a very small range of distances [only the closest galaxies considered] **(1)** • Hence, on the basis of the original data, the conclusion drawn by Hubble was quite speculative **(1)**		**5**
20 (b)	• Use of $\lambda_{max}T = 2.9\times10^{-3}$ **(1)** • T = 5800 K [accept 5780 K and 6000 K] **(1)** • Use of $L = 4\pi r^2\sigma T^4$ **(1)** • r = 6.9×10^{8} m **(1)**	Example of calculation: $T = \frac{2.9\times10^{-3}\,\text{mK}}{5.02\times10^{-7}\,\text{m}} = 5780\,\text{K}$ $r = \sqrt{\frac{3.85\times10^{26}\,\text{W}}{4\pi\times5.67\times10^{-8}\,\text{Wm}^{-2}\text{K}^{-4}\times(5800\text{K})^4}} = 6.91\times10^{8}\,\text{m}$	**4**

Question Number	Acceptable answers	Additional guidance	Mark
20 (c)(i)	• 8 alpha decays reduce the proton number by 16 **(1)** • proton number decreases by only 10, so there must be 6 β decays **(1)** **OR** • balanced equation written for overall decay **(1)** • explicit solution to give 6 β^- decays **(1)**	Example of calculation: $^{238}_{92}\text{U} \rightarrow {}^{206}_{82}\text{Pb} + 8\times{}^{4}_{2}\alpha + \text{N}\times{}^{0}_{-1}\beta^-$ $92 = 82 + (8\times2) - \text{N}$ $92 = 82 + 16 - \text{N}$ $\text{N} = 98 - 92 = 6$ Proof must be given to obtain these marks.	**2**
20 (c)(ii)	• use of $\lambda t_{1/2} = \ln 2$ **(1)** • use of $N = N_0 e^{-\lambda t}$ **(1)** • $\text{N}/\text{N}_0 = 0.1$ **(1)** • $t = 2.5 \times 10^5$ years **(1)**	Example of calculation: $\lambda = \frac{0.693}{75000} = 9.24\times10^{-6}\,\text{y}^{-1}$ $\lambda t = -\ln\frac{N}{N_0}$ $t = \frac{-\ln(0.1)}{9.24\times10^{-6}\,\text{y}^{-1}} = 2.49\times10^5\,\text{y}$	**4**

(Total for Question 20 = 15 marks)