2019 Preliminary Examinations H2 Physics Paper 2 Solutions

1 **(a)** Speed is a quantity and cannot be defined by a unit (seconds). B1
Speed is distance travelled per unit time. B1

(b) **(i)** $7.5 = 15\cos\theta$

$\theta = 60^\circ$ B1

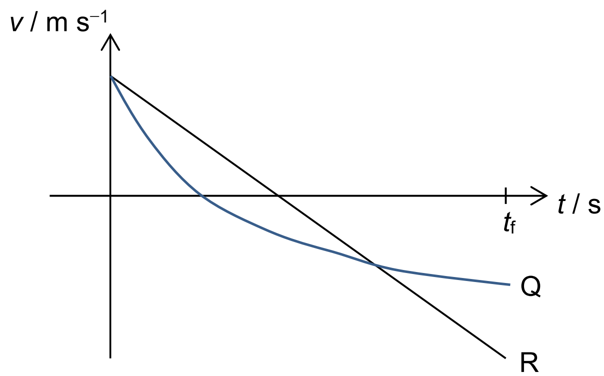
(ii) $u_y = 15\sin 60^\circ = 12.99$ C1

$s_y = u_y t + \frac{1}{2}a_y t^2$

$-2.0 = 12.99t + \frac{1}{2}(-9.81)t^2$ M1

$t = 2.79$ or -0.146 (rej) A1

(c) **(i)**
(ii)



(i) Straight line (negative area larger than positive area)

(ii) Correct shape B1
negative area larger than positive area B1
Gradient at x-intercept is *g* B1

<u>Markers' Comments</u>

(a) Most candidates were able to define speed correctly. A common mistake was to define speed as "the rate of change of distance travelled per unit time".

The next part of the question was poorly attempted. Most explanations stated that the incorrect definition referred to an average value rather than an instantaneous value, or that there were alternative units to seconds but failed to mention that <u>units are generally not stated in definitions</u>. Many candidates stated that "seconds" are not the only units of time, which implies that speed can be defined in terms of other units of time, which is incorrect.

(b) **(i)** Most students answered this question correctly.

(ii) Most candidates who did not get full credit assumed the ball returned to its height above the ground after the motion or failed to include their sign conventions.

(c) **(i)** Most students answered this question correctly.

(ii) Some graphs had kinks in them. Mathematically, the gradient at a kink is undefined and cannot be the case on a v-t graph.

2 **(a)** $h = 2(15 - 15\cos 40°) = 7.0$ m M1

(b) By Principle of the Conservation of Energy,

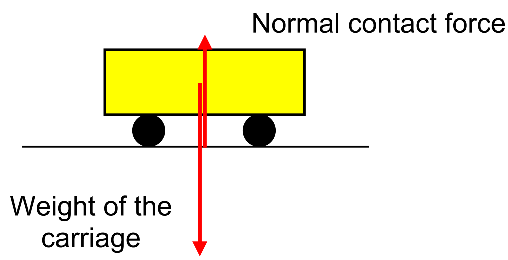
Loss in GPE $=$ Gain in KE

$$mg(7.0) - mg(3.5) = \frac{1}{2}mv_B^{\,2} + \frac{1}{2}mu^2$$ M1

$$v_B = \sqrt{2(9.81)(3.5) + (1)^2}$$ A1

$$= 8.35 \text{ m s}^{-1}$$

(c)



Correct direction of arrows and correct label. Arrow of weight should start from the centre of the body and arrow of the normal contact force should start from the ground. B1

Arrow of the weight is longer than the arrow of the normal contact force. B1

One mark is deducted for any additional force or mistake.

(d)

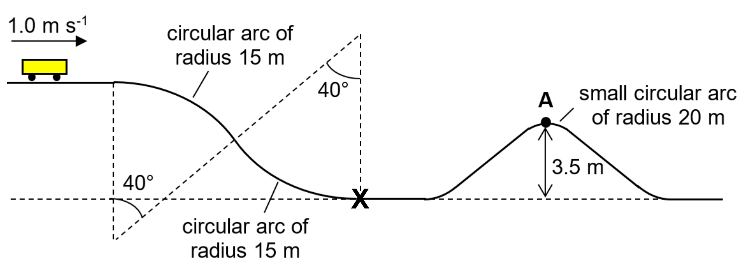
$$mg - N = \frac{mv^2}{r}$$ M1

$$N = mg - \frac{mv^2}{r}$$

$$= 450(9.81) - \frac{450(8.35)^2}{20}$$

$$= 2850 \text{ N}$$ A1

(e) **(i)**



B1

(ii) At 'X', (normal force – weight) provides the centripetal force. Hence the normal force is equals to the weight + centripetal force which is the largest during the entire journey. B1

The speed of the carriage is the highest at the bottom of the circular arc. B1

(f)

$$mg - N = \frac{mv^2}{r}$$

N = 0 when the carriage just loses contact,

$$mg = \frac{mv^2}{r}$$

$$v = \sqrt{rg}$$

$$= \sqrt{(20)(9.81)}$$ M1

$$= 14.0 \text{ m s}^{-1}$$ A1

Markers' Comments

(a) This part proves to be mathematically challenging for many students who left this part blank.

(b) Several students forgot to consider the initial kinetic energy of the carriage.

(c) At **A**, the resultant force is towards the centre of the circle which is downwards. Hence the length of arrow for weight should be longer than the normal contact force.
When you are required to draw and label forces acting on a body, it is important to spell out the forces instead of giving your own notations.

(f) Generally well done.

3 **(a)** A transverse wave is one in which its particles oscillate in a direction perpendicular to the direction of energy transfer. B1
A longitudinal wave is one in which its particles oscillate in a direction parallel to the direction of energy transfer. B1

(b) polarisation B1

(c) **(i)** $I = \dfrac{k}{r^2}$

$1.2 \times 10^{-5} \times 1.5^2 = I_6 \times 6.0^2$ M1

$I_6 = 7.50 \times 10^{-7}$ W m^{-2} A1

(ii) $P = I \times A = 7.50 \times 10^{-7} \times 1.3 \times 10^{-3} = 9.75 \times 10^{-10}$ W B1

(iii) $I = kA^2$

$\dfrac{1.2 \times 10^{-5}}{84^2} = \dfrac{7.50 \times 10^{-7}}{x_0^{\ 2}}$ M1

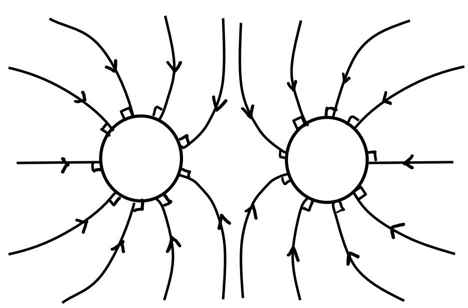
$x_0 = 21\ \mu$m A1

Markers' Comments

This question is generally well done.

4 **(a)** The electric field strength at the point is the <u>electric force</u> exerted B1
<u>per unit positive charge</u> placed at that point. B1

(b) **(i)**



- smooth lines with correct field direction (at least 8 for each sphere), lines originate from spheres perpendicularly. B1
- Lines not touching and not crossing, symmetrical and null space in centre of both spheres. B1

Zero credit when field lines between spheres act through direction of P.

(ii) Distance of X from centre of sphere A = (0.08 + 14.0) = 14.08 m

Taking rightwards as positive,

electric field strength

$$= \frac{-0.0400 \times 10^{-9}}{4\pi(8.85 \times 10^{-12})(14.08)^2} - \frac{-0.0400 \times 10^{-9}}{4\pi(8.85 \times 10^{-12})(60.0 - 14.08)^2} \quad \text{M1}$$

$$= -1.814268 \times 10^{-3} - (-1.70570 \times 10^{-4})$$

$$= -1.64 \times 10^{-3}\ \text{N C}^{-1}$$

$$= 1.64 \times 10^{-3}\ \text{N C}^{-1} \quad \text{A1}$$

Towards sphere A B1

(c) (i)

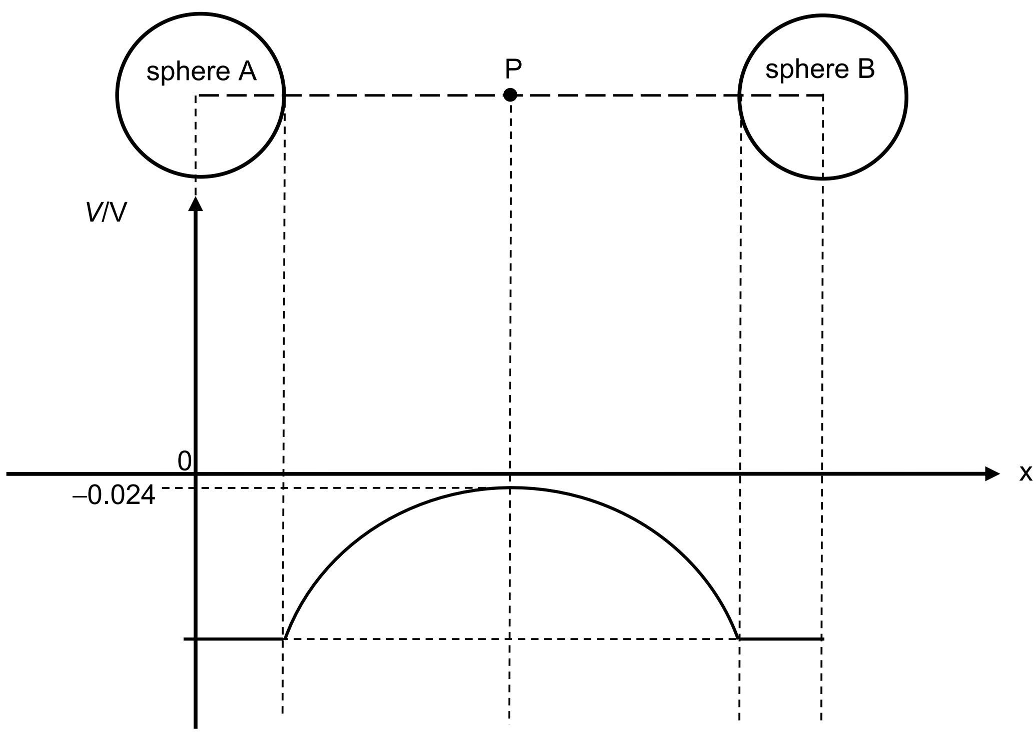
$$\text{Potential at P} = \frac{Q_A}{4\pi\varepsilon_0 r} + \frac{Q_B}{4\pi\varepsilon_0 r}$$

$$= -\frac{(0.040 \times 10^{-9})}{4\pi(8.85 \times 10^{-12})(30.0)} + \left(-\frac{(0.040 \times 10^{-9})}{4\pi(8.85 \times 10^{-12})(30.0)}\right)$$

$$= -0.023978$$

$$= -0.0240\ \text{V} \quad \text{A1}$$

(ii)



- symmetrical curve about P, value higher than potential within spheres. (values must match convention of (c)(i). B1
- Potential is a constant value within both spheres B1

Markers' Comments

(a) Many student miss out the terms 'electric' force, 'per unit' and 'positive' in their definition. Statements often read as the electrical force, (N) as the subject and acting on (unit charges) which is not the same as electric force per unit positive charge (NC^{-1}).

A handful mention 'masses' and even moving charges from infinity to the point.

(b) **(i)** Very badly done.
Sketching of field lines has been tested before, but most students totally ignore feedback. It is hard to sketch lines going perpendicularly into the surface of the sphere. Little right angles can easily settle this issue, but only a handful adopted that technique. Many are totally clueless of how field lines ought to look like.

(ii) Very badly done. Many overlooked the fact that the distance should be taken from the centre of the spheres, and that the spheres have **diameter** of 0.16 m.
Many probably forgot that that electric field strength is a **vector**, giving us a scalar sum instead, this arises from students not sketching diagrams to guide their thought processes.

(c) **(i)** Horribly done. Many assumed that at the null point, no field lines are sketched and hence potential is zero. This is **NOT** true! Potential is a scalar and they add up.
Many students get confused (with gravitational potential) and put in the negative sign for the equation. For electric fields, the polarities will take care of themselves when you substitute the proper (positive or negative) charges into the equation!!!!

Note that potential gradient = 0 does not mean that potential is also 0. (Potential at infinity is taken as zero, and the point P is nowhere near infinity)

Equation for electric potential is given in the data sheet!!

Many students did not read the question and though that we were asking for the potential at point X.

(ii) Well done (except for the flipping of the graph which stemmed from the error in (c)(i).
Note that the sign convention for this graph has to follow that of part (i).
No credit awarded if the correctly shaped graph extends into both the positive and negative axes.

5 **(a)** Faraday's law of electromagnetic induction states that the
<u>induced e.m.f. is proportional to the rate of change of magnetic flux linkage</u>. B1

(b) **(i)** From Fig. 5.2, the current at t = 0.070 s is 1.500 A. M1

$$n = \frac{3000}{0.15} = 20000$$ M1

$$B = \mu_0 n I = 4\pi \times 10^{-7} \times 20000 \times 1.500 = 3.7699 \times 10^{-2}\ \text{T} = 3.77 \times 10^{-2}\ \text{T}$$ A1

(ii) Using points (0.070, 1.500) and (3.80, 0.550) on the line in Fig. 5.2,

$$\frac{dI}{dt} = \frac{0.550 - 1.500}{0.380 - 0.070} = -3.0645 = -3.06$$ M1

According to Faraday's law,

$$\text{e.m.f.} = -\frac{d\Phi}{dt} = -\frac{d}{dt}(N_c B_s A_s)$$

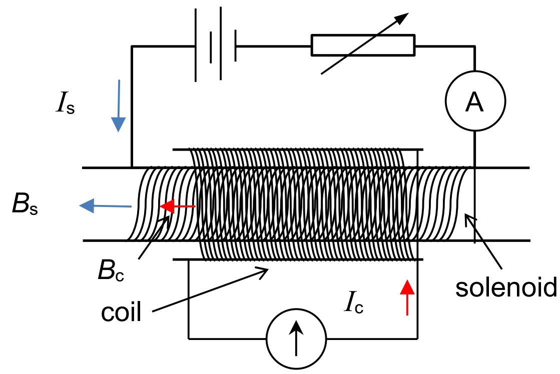
$$= -N_c A_s \frac{d}{dt}(\mu_0 n I)$$

$$= -N_c A_s \mu_0 n \frac{dI}{dt}$$

$$= -1500 \times 2.5 \times 10^{-4} \times 4\pi \times 10^{-7} \times 20000 \times (-3.0645)$$ M1

$$= 2.8882 \times 10^{-2} = 2.89 \times 10^{-2}\ \text{V}$$ A1

(iii)



The current I_s in the solenoid flows from the positive terminal of the battery. By right-hand-grip rule, the magnetic flux density B_s produced points to the left. — M1

Since I_s decreases, B_s also decreases (because $B = \mu_0 n I$) — M1

By Lenz's law, the induced magnetic flux density B_c in the coil must point to the left. By right-hand-grip rule, the induced current I_c in the coil flows from left to right through the galvanometer. — A1

Markers' Comments

(a) Many students included extra phrases such as "the magnitude of" and "in a conductor/coil" in their answers. These are not part of Faraday's law, hence are penalized accordingly. Some students switched the order by saying 'the rate of change of flux linkage is proportional to the emf induced', which is also wrong. Instead of 'proportional to', some said 'equal to' or 'is', neither of which is accepted.

(b) **(i)** The most common mistake was to misinterpret the 'n' in $B=\mu_0 nI$ as the total number of turns, instead of the number of turns per unit length. A few used a wrong formula.

(ii) Many students were penalized for omitting the negative sign in Faraday's law equation, and subsequently ignoring the negative sign in the calculated gradient. Some students used the modulus sign excessively, for which BoD were given (if they were used correctly and consistently). But these students should know that it is still a dangerous practice. The meaning of the negative sign in Faraday's law equation is not easy to understand or explain within the H2 syllabus, but that does not mean it can be omitted, especially if another negative sign (in the gradient) is involved.

(iii) The most common and most serious mistake was on the misunderstanding of Lenz's law. Lenz's law says that 'the change in flux linkage' will be opposed by 'induced flux density', or 'motion' will be opposed by 'the magnetic force on the induced current', respectively. Instead, some students misinterpreted Lenz's law as saying the changing current (which induces a current in the secondary coil) will be opposed by the induced current in direction, which is wrong. Some students specified the direction of the current in a solenoid simply as 'from left to right', not realizing that different wiring of the solenoid can yield flux densities in opposite directions (as determined by the right-hand-grip rule) for the same 'from left to right' current. Some students, instead of specifying the direction of current in the galvanometer, specified the direction in which the galvanometer would be deflected. The direction of deflection and the direction of the current need not be the same in a galvanometer. The BoD were given for these students, but they should refrain from doing so in the future. Still some students said that 'the coil cuts the flux due to the solenoid', which is wrong but ignored when marking. There is no cutting of field lines in the setup. Some students used 'induced' and 'generated/produced' interchangeably, which is wrong. 'Induced' is to be used only if the flux density is due to an induced current.

6 (a) (i) Nuclear binding energy is <u>the energy required to separate to infinity all the nucleons of a nucleus.</u> B1

(ii) mass defect, Δm

$= \left(79 \times 1.672648 \times 10^{-27}\right) + \left[\left(197 - 79\right) \times 1.674954 \times 10^{-27}\right] - 3.269645 \times 10^{-25}$ M1

$= 2.819264 \times 10^{-27}$ kg $= 2.8193 \times 10^{-27}$ kg

$\therefore \text{BE} = \Delta mc^2 = \dfrac{2.819264 \times 10^{-27} \times \left(3.0 \times 10^8\right)^2}{1.60 \times 10^{-13}}$ M1

$= 1590$ MeV (accept 1580 MeV) A1

(b) (i) ${}^{198}_{79}\text{Au} \rightarrow {}^{198}_{80}\text{Hg} + {}^{0}_{-1}\text{e} + \bar{\nu}$ (symbol for neutrino or anti-neutrino to be stated) B1

(ii) The half-life of a radioactive nuclide is the time taken for the **number of undecayed nuclei** to be **reduced to half** its original number. B1

(iii) $A = A_0 e^{-\lambda t} \Rightarrow \dfrac{A}{A_0} = e^{-\lambda t} \Rightarrow \ln\left(\dfrac{A}{A_0}\right) = -\dfrac{\ln 2}{t_{1/2}} t$ M1

$\therefore \quad t = \dfrac{1}{\lambda}\ln\left(\dfrac{A_0}{A}\right) = \dfrac{t_{1/2}}{\ln 2}\ln\left(\dfrac{A_0}{A}\right) = \dfrac{2.7}{\ln 2}\ln\left(\dfrac{1}{0.15}\right) = 7.39$ days A1

OR $\dfrac{A}{A_0} = \left(\dfrac{1}{2}\right)^{\frac{t}{t_{1/2}}} \rightarrow 0.15 = \left(\dfrac{1}{2}\right)^{\frac{t}{2.7}}$ M1

$\lg(0.15) = \dfrac{t}{2.7}\lg(0.5)$

$t = 7.3898 = 7.39$ days A1

(iv)

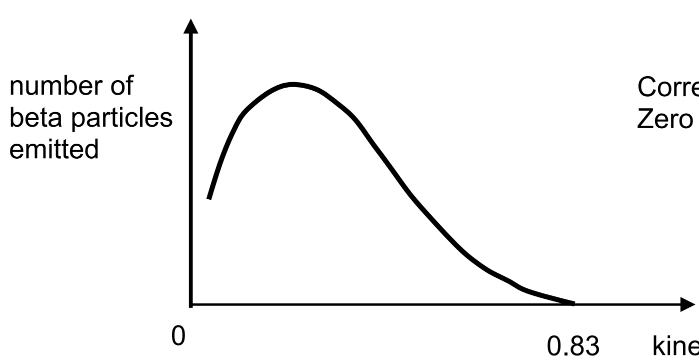


Fig. 6.1

Correct shape B1
Zero at 0.83 MeV B1

Markers' Comments

(a) **(i)** Some students described the combining of nucleons to form a nucleus but failed to mention that in this case, the energy **released** is the binding energy.

(ii)
- There was a misconception that mass defect is *numerically* equal to binding energy. This is wrong as mass defect is the difference in mass (unit = kg) and binding energy is usually presented in Joules or MeV.
- MeV = 10^6 eV and not 10^9 eV

(b) **(i)**
- Many students left out the anti-neutrino
- Many students also wrote that Gold decayed into Gold (Au) or Magnesium (Mg) despite the question stating that it was Mercury (Hg)
- A number thought that it was an alpha decay instead of beta.

(ii) There seems to be confusion over the terms
1. Nucleon: a collective term for protons and neutrons
2. Nucleus/Nuclei: a very dense region at the centre of an atom, containing protons and neutrons
3. Nuclide: an atomic species characterised by a unique value of Z and N, also commonly referred to as an isotope

When defining half-life, we are concerned with the <u>number (not amount or size or concentration) of undecayed nuclei</u> of a particular nuclide, and not the decaying of nuclide**s** per se.

The term "decay" here does not refer to "rotting", hence any equivalent meaning word was not accepted.

Radioactive nuclei are not "reactants" and do not react with anything. They undergo radioactive decay spontaneously.

Radioactive nuclei are also not referred to as compounds or particles or samples.

(iii) The common mistake here was to take the final activity as 85% of the initial activity. Another common mistake was using $N = N_0 e^{-\lambda t}$, instead of using activity. Benefit of doubt was given.
Many people also thought that the decay constant was equal to the half-life of the nuclide.

7 **(a)** "×" is between 400 to 800 nm. B1

(b) At 1100 K, the intensity in the visible spectrum is negligible except for the longest wavelengths (~ 600 to 750 nm or longer). B1
This corresponds to the wavelength of red light and hence the object will glow in red. B1

(c) **(i)**

T/K	λ_{max} /nm	$T \times \lambda_{max}$/ m K
600	4830	0.00290
700	4140	0.00290
800	3610	0.00289
900	3210	0.00289
1000	2900	0.00290
1100	2630	0.00289

M1 – two values
M1 – > two values

A1

(ii) Value of constant = 2.9 × 10^{-3} m K (or 2.89 × 10^{-3} m K)

$\lambda_{max} \times 1200 = 2.9 \times 10^{-3}$ M1

$\lambda_{max} = \mathbf{2.42 \times 10^{-6}\ m}$ A1

(d) At 900 K, $I_{tot} = 69.4$ W m^{-2}

$\Rightarrow \lg(T/\text{K}) = 2.954,\ \lg(I_{tot}/\text{W m}^{-2}) = 1.841$

(i) Point plotted to an accuracy of ½ the smallest square. B1

(ii) Appropriate line of best-fit. B1

(e) **(i)** Linearise the equation and deduce that *n* is the gradient. B1
lg I read to 2 d.p., lg T read to 3 or 4 d.p. B1
n is between 3.9 to 4.0 A1

(ii)

$I_{1200} = c(1200)^4$

$I_{900} = c(900)^4$

$\frac{I_{1200}}{I_{900}} = \frac{I_{1200}}{69.4} = \left(\frac{1200}{900}\right)^4$ M1

$I_{1200} = \mathbf{219\ W\ m^{-2}}$ A1

(f) Position of peak is at 2420 nm B1
Intensity for all wavelengths is higher than that of 1100 K. B1
Sharper peak, with the peak at least 5 small squares above the second big square. B1

(g) From Fig. 7.3, λ_{max} (or I_{tot}) has a different value for each different temperature. B1
Hence, one can measure λ_{max} (or I_{tot}) of the targeted object and convert it to temperature readings. A1

Markers' Comments

(b) Many students were not careful in their explanation and show no evidence that they know the reason. Eg. some students merely states that red light is emitted with the highest intensity when clearly most of the radiation is in the infra-red range. A complete answer will require students to state that the intensity of the other visible light (less than 600 nm) is close to zero, because if this isn't the case, the object will glow in white instead.

(c) **(i)** Students who wrote "600 × 4830 = 700 × 4140 = 800 × 3610 =…..= 1100 × 2630" are not given any credit because the statement is no difference from repeating the question. There are also some students who carelessly list down all the products as 2.90 × 10^{-3} when clearly some are not so.

(ii) This part is generally well done except that some students were penalised for changing the given unit of metre to nanometre.

(d) **(i)** Generally ok but some students use the same marking to mark out the gradient points (which they are not supposed to) and it was not possible to tell which of the three plots is the intended answer for **(d)(i)**, resulting in them losing the mark.

(ii) Some students mistook the small scatter in the data points as anomalous points. Many of the best-fit lines accepted have room for improvement.

(e) **(i)** Most students were able to linearise the equation correctly and equate n to gradient. However, many of them misread the gradient coordinates and end up getting the wrong answer. Students are also reminded that they need to read the gradient coordinates to the correct dp following the rules in practicals. In this case, the numerator should be 2 dp while the denominator should be 3 or 4 dp.

(ii) The question has stated clearly that students are to use the values in Fig. 7.3 for T = 900 K for calculations, but a handful of students ignored this piece of instruction and used another point instead. These students are not given any credit.

(f) Most students scored at leasr two marks out of three for this part, with the one mark lost because the peak was not high enough.

(g) Many students don’t seem to understand the question and provided answers that are totally irrelevant. A number mistook radiation as radioactive decay and went on to discuss half-life etc.