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This document consists of **13** printed pages.

Mark categories

B marks	These are <u>independent</u> marks, which do not depend on other marks. For a **B** mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer.
M marks	These are <u>method</u> marks upon which **A** marks later depend. For an **M** mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer. If a candidate is not awarded an **M** mark, then the later **A** mark cannot be awarded either.
C marks	These are <u>compensatory</u> marks which can be awarded even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known them. For example, if an equation carries a **C** mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C** mark is awarded. If a correct answer is given to a numerical question, all of the preceding **C** marks are awarded automatically. It is only necessary to consider each of the **C** marks in turn when the numerical answer is not correct.
A marks	These are <u>answer</u> marks. They may depend on an **M** mark or allow a **C** mark to be awarded by implication.

Annotations

✓	Indicates the point at which a mark has been awarded.
X	Indicates an incorrect answer or a point at which a decision is made not to award a mark.
XP	Indicates a physically incorrect equation ('incorrect physics'). No credit is given for substitution, or subsequent arithmetic, in a physically incorrect equation.
ECF	Indicates 'error carried forward'. Answers to later numerical questions can always be awarded up to full credit provided they are consistent with earlier incorrect answers. <u>Within</u> a section of a numerical question, ECF can be given after AE, TE and POT errors, but **not** after XP.
AE	Indicates an arithmetic error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
POT	Indicates a power of ten error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.

TE	Indicates incorrect transcription of the correct data from the question, a graph, data sheet or a previous answer. For example, the value of 1.6×10^{-19} has been written down as 6.1×10^{-19} or 1.6×10^{19}. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
SF	Indicates that the correct answer is seen in the working but the final answer is incorrect as it is expressed to too few significant figures.
BOD	Indicates that a mark is awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done ('benefit of doubt').
CON	Indicates that a response is contradictory.
I	Indicates parts of a response that have been seen but disregarded as irrelevant.
M0	Indicates where an A category mark has not been awarded due to the M category mark upon which it depends not having previously been awarded.
^	Indicates where more is needed for a mark to be awarded (what is written is not wrong, but not enough). May also be used to annotate a response space that has been left completely blank.
SEEN	Indicates that a page has been seen.

Question	Answer	Marks
1(a)(i)	wavelength = 8.5×10^{-5} m	**A1**
1(a)(ii)	$f = v / \lambda$ **or** c / λ	**C1**
	$= 3.0 \times 10^8 / 8.5 \times 10^{-5}$ $(= 3.5 \times 10^{12})$ $= 3.5$ THz	**A1**
1(a)(iii)	infrared	**B1**
1(b)	(implied) percentage uncertainty in I = 4% **or** (implied) fractional uncertainty in I = 0.04	**C1**
	percentage uncertainty in E = 5% + (4% $\times$ 2) = 13%	**A1**

Question	Answer	Marks
2(a)	point where (all) the weight (of the body)	**M1**
	is considered/seems to act	**A1**
2(b)(i)	horizontal component of force = 38 cos 60° **or** 38 sin 30° = 19 N	**A1**
2(b)(ii)	$(T \times 1.2)$ **or** (19×0.9) **or** 17	**C1**
	$(T \times 1.2) = (19 \times 0.9)$ $T = 14$ N	**A1**
2(b)(iii)	$F = 45 + 38 \sin 60°$ = 78 N	**A1**

Question	Answer	Marks
3(a)	$s = \frac{1}{2}at^2$	**C1**
	$57 = \frac{1}{2} \times 9.81 \times t^2$ **and** $t = 3.4$ (s)	**A1**
3(b)	horizontal distance $= 41 \times 3.4$	**A1**
	$= 140$ m	
3(c)	(displacement)^2 $= 57^2 + 140^2$	**C1**
	displacement $= (57^2 + 140^2)^{0.5}$	**A1**
	$= 150$ m	
3(d)	straight line from the origin with positive gradient	**B1**
3(e)	$(1480 - m) \times 0.340 = m \times 41.0$	**C1**
	$m = 12.2$ kg	**A1**
	or	
	$m_c\, 0.34 = m_b\, 41$ **and** $m_c + m_b = 1480$	**(C1)**
	$m_c = (41 / 0.34)m_b$	**(A1)**
	$(41 / 0.34)m_b + m_b = 1480$	
	$m_b = 12.2$ kg	
3(f)	acceleration (of free fall) is unchanged/is not dependent on mass	**M1**
	(so) no change (to the graph)	**A1**

Question	Answer	Marks
4(a)	compression/extension is proportional to force (provided limit of proportionality is not exceeded)	**B1**
4(b)	$(E) = \frac{1}{2}Fx$ **or** $\frac{1}{2}kx^2$ **or** area under graph	**C1**
	$= \frac{1}{2} \times 8 \times 16 \times 10^{-2} = 0.64$ (J) **or** $= \frac{1}{2} \times 50 \times (16 \times 10^{-2})^2 = 0.64$ (J)	**A1**
4(c)(i)	$(E) = \frac{1}{2}mv^2$	**C1**
	$0.64 = \frac{1}{2} \times 0.076 \times v^2$ $v = 4.1\,\mathrm{m\,s^{-1}}$	**A1**
4(c)(ii)	$(\Delta)(E) = mg(\Delta)h$	**C1**
	$= 0.076 \times 9.81 \times 0.24$ $(= 0.18$ (J)$)$	**C1**
	kinetic energy $= 0.64 - 0.18$ $= 0.46$ J	**A1**
4(c)(iii)	$v = 4.1\,\mathrm{m\,s^{-1}}$	**A1**
4(d)	$W = Fs$	**C1**
	$d = 0.30 + (2\pi \times 0.12) + 0.25\ (= 1.3\,\mathrm{m})$	**C1**
	$F = 0.23 / 1.3$ $= 0.18\,\mathrm{N}$	**A1**

Question	Answer	Marks
5(a)(i)	$T = 2.0 \times 10^{-5} \times 6.0$ $(= 1.2 \times 10^{-4} \, \text{s})$	C1
	$f = 1 / (2.0 \times 10^{-5} \times 6.0)$ $= 8300 \, \text{Hz}$	A1
5(a)(ii)	new trace shows the same period	B1
	new trace shows amplitude of 10 small squares	B1
5(a)(iii)	(trace is a) vertical line	B1
5(b)(i)	$n\lambda = d \sin \theta$	C1
	$\lambda = (3.4 \times 10^{-6} \times \sin 16°) / 2$ $= 4.7 \times 10^{-7} \, \text{m}$	A1
5(b)(ii)	$n = 3.4 \times 10^{-6} \, (\times \sin 90°) / 4.7 \times 10^{-7}$ or $2 \, (\times \sin 90°) / \sin 16°$ $(= 7.2 \text{ or } 7.3)$	C1
	highest order = 7	A1

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Question	Answer	Marks
6(a)	$\dfrac{\text{work (done) / energy (transferred from electrical to other forms)}}{\text{charge}}$	**B1**
6(b)	$R = \rho L / A$	**B1**
	$V = LA$ **and** (so) $R = \rho V / A^2$ (with ρ and V constant)	**B1**
6(c)	$E = IR + Ir$ **or** $E = I(R + r)$ **or** $E - Ir = IR$ **and** $R = (E / I) - r$	**A1**
6(d)(i)	$P = I^2R$ **or** $P = IV$ **or** $P = V^2 / R$	**C1**
	$R = 5.4 \, (\Omega)$ **or** $V = 10.8 \, (\text{V})$	**C1**
	$P = 2.0^2 \times 5.4$ $= 22 \, \text{W}$	**A1**
6(d)(ii)	**1.** $r = 0.60 \, \Omega$	**A1**
	2. $E = \text{gradient}$	**C1**
	$= \text{e.g. } 5.4 / 0.45$ $= 12 \, \text{V}$	**A1**

Question	Answer	Marks
7(a)(i)	electric field strength = V / d	**B1**
7(a)(ii)	force = Vq / d	**B1**
7(a)(iii)	kinetic energy = Vq	**B1**
7(b)(i)	no change	**B1**
7(b)(ii)	no change	**B1**
7(c)(i)	nucleon number = 14 **and** proton number = 7	**A1**
7(c)(ii)	(electron) antineutrino	**B1**