GCE

Physics B

H557/02: Scientific literacy in physics

Advanced GCE

Mark Scheme for Autumn 2021

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

1. Annotations available in RM Assessor

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
✗	Incorrect response
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
TE	Transcription error
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
SF	Error in number of significant figures
✓	Correct response
?	Wrong physics or equation

2. Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	**Meaning**
/	alternative and acceptable answers for the same marking point
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
Ignore	Statements which are irrelevant
Allow	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Question			Answer	Marks	Guidance
1	a	i	Gravitational energy per kg (at a position in a gravitational field) ✓.	1	Or work required per unit mass to bring a body from infinity to that point AW Or energy required per kg to travel to infinity.
		ii	Gravitational potential is (set at) zero for bodies at infinite distance apart ✓. It takes work to separate bodies therefore at distances less than infinity the potential must be negative. AW ✓	2	Explanation in terms of potential well can gain both marks. (negative potential at mass going to zero at infinity) Second mark does not depend on the first.
		iii	Electrical charges can attract each other (giving a negative potential) or repel each other (giving a positive potential)/ When two like charges interact energy is stored. AW ✓	1	Accept that electrostatic force can be both positive and negative. Reference to charge only is not enough.
	b		Value = (+)6.3 $\times 10^7$ J ✓. K.E. + G.P.E. = 0 for this value ✓ AW Assuming no energy transfer through atmosphere/ No work done against frictional forces ✓	3	When all KE has been transferred to PE, PE = zero so the body is out of the potential well. Allow KE greater than or equal to PE. Allow 'energy losses' if 'in atmosphere' specified
	c		k.e. = 1.0×10^{11} J ✓ g.p.e. = -4.37×10^9 J ✓ total energy = 1.0×10^{11} J ✓ Total energy is positive – Voyager will continue to move further from Sun ✓	4	1.04×10^{11} J to 3 s.f. Must have negative sign 9.97×10^{10} J to 3 s.f. Allow variations due to different numbers of sf used in calculations One mark for correct total energy from incorrect E_k and/ E_P Accept 'will leave Sun's gravitational field'
			Total	**11**	

Question			Answer	Marks	Guidance
2	a	i	$V = 9.0 \times e^{-3.5/(4700 \times 10\text{^}-6 \times 1400)}$ ✓ = 5.29 V ✓	2	Must give own value.
	a	ii	$\Delta E = ½\ C\,(9.0^2 - 5.3^2) = 0.124$ J ✓ Power = 0.036 W ✓ Current through/ p.d. across component not constant ✓	3	3rd mark independent
	b		p.d. across capacitor when E = 300 J, $V_{300\ J} = \sqrt{(2E/C)} = \sqrt{(2 \times 300\ J/120\ F)} = \sqrt{5}\ V = 2.24$ V ✓ p.d. across capacitor when E = 50 J, $V_{50\ J}$ = 0.91 V ✓ time = $-\ln(0.91/2.24) \times 30 \times 10^{-3} \times 120 = 3.2$ s ✓ minimum value because no external load ✓	4	Other routes may be used. Bald correct answer gains all three marks for the calculation.
			Total	**9**	
3	a		Energy gained by block = 541 J ✓ Power per m^2 = 541/(600 × 0.0013) = 690 W m^{-2} ✓	2	Accept 540 J No s.f. penalty. Accept range of answers due to sf choice. Allow 700 W m^{-2}
	b		Power output of Sun = $1.4 \times 10^3 \times 4 \times \pi \times (1.5 \times 10^{11})^2$ ✓ = 3.96×10^{26} W ✓	2	1 mark for correct calculation of area of sphere = 2.83×10^{23} m^2. Need own value
	c	i	Identification of positron as anti-lepton, neutrino as lepton ✓ Lepton number on LHS = zero, lepton number on RHS = zero ✓	2	
	c	ii	Mass loss from one three-stage reaction, Δm = 0.0265 u ✓ Energy released per reaction = Δmc^2 =(0.0265× 1.661×10^{-27}) kg × 9 × 10^{16} m^2s^{-2}= 3.96 × 10^{-12} J ✓ Number of reactions s^{-1}= 3.8 × 10^{26}J/(3.96 × 10^{-12}J × 0.98) ✓ = 9.8 × 10^{37} ✓	4	Or 4.4 x 10^{-29} kg Ecf within question throughout 3 marks maximum for 9.6 or 9.4 × 10^{37} Correct bald answer gains four marks
			Total	**10**	

Section B

Question			Answer	Marks	Guidance
4	**a**		E = 3.43 N × 3.951 m / (5.9 × 10^{-8} m^2 × 0.002 m) ✓ = 1.15 × 10^{11} Pa ✓	**2**	Or via ε = 5.062×10^{-4} & σ = 5.814×10^{7} Pa Bald correct answer gains two marks. Accept two s.f. answer of 1.1 x 10^{11} Pa
	b	**i**	area occupied by one atom = (2.3 × 10^{-10} m)^2 = 5.29 × 10^{-20} m^2 ✓ Number of atoms in 5.9 × 10^{-8} m^2 = 5.9 × 10^{-8} m^2/5.29 × 10^{-20} m^2 = 1.115 × 10^{12} ✓ Tension = 3.43 N/1.115 × 10^{12} = 3.1 × 10^{-12} N ✓	**3**	Bald correct answer gains three marks. Allow use of π r^2 giving area = 4.15 x 10^{-20} m^2 and / 1.42 x 10^{12} atoms per layer. 3rd marking point available as ecf from number of atoms. (3.075 × 10^{-12} N to 4 s.f.)
	b	**ii**	$x = FL/AE$ = 3.43 N × 2.3 x 10^{-10} m/(5.9 × 10^{-8} m^2 ×1.15 × 10^{11} Pa) ✓ = 1.163 × 10^{-13} m = 1.2 × 10^{-13} m ✓	**2**	Ecf from (a) if this method used. (precise value of E gives 1.16 × 10^{-13} m) Alternative methods possible, e.g. simple ratio: x = 0.002 m × 2.3 × 10^{-10} m/3.591 m ✓ = 1.16 × 10^{-13} m ✓ Or $x = \varepsilon L$= 5.062×10^{-4} × 2.3 x 10^{-10} m ✓ = 1.16 × 10^{-13} m ✓
	b	**iii**	Force constant = 3.1 × 10^{-12} N/1.16 × 10^{-13} m ✓ = 26.7 N m^{-1} = 27 N m^{-1}✓	**2**	Ecf from b(i) and b(ii). No credit if 3.43 N used. Unrounded answers give acceptable 26 N m^{-1} to two s.f.

Question			Answer	Marks	Guidance
	c		**Level 3 (5–6 marks)** Clear explanation of yield stress; clear explanation of the limitations of the model; clear explanation of the effect of mobile dislocations in materials and its effect on yield stress. (can be helped by a correct diagram) Clear explanation of the effects of adding alloying atoms to the metal. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear explanation of yield stress. Gives a clear explanation of either the limitations of the model or the effect of mobile dislocations and considers the effect of alloying atoms. The explanations are correct but lack either breadth or depth. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Description/explanation of yield stress; Gives a superficial description of either the limitations of the model or the effect of mobile dislocations. Mentions the role of alloying atoms. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit	6	**Indicative scientific points may include:** • Description/explanation of term 'yield stress' • Model suggests perfect (crystal) structure • Better model includes missing atoms/dislocations in layers of atoms. • Dislocations in metals are mobile • (Dislocations allow) bonds to be broken one at a time rather than the whole plane failing at once • (dislocations) reduce stress required for material to yield • Dislocations can be 'pinned' by alloying atoms • Dislocations can be pinned (tangled together) by work hardening • Alloying/work hardening (usually) leads to a harder material • Alloying/work hardening (usually) leads to a more brittle material • Diagrams of dislocations • Effect of grain size/rate of cooling
			Total	**15**	

Question			Answer	Marks	Guidance
5	a		$k = 4\pi^2 \times 0.84$ kg/(1.3 s)^2 ✓ = 19.62 N m^{-1} = 20 (N m^{-1}) ✓	2	Bald answer of 19.62/19.6/20 gains two marks.
	b		k.e.$_{max}$ = ½ kx^2 = 0.5 × 19.6 N m^{-1} × (0.24 m)^2 ✓= 0.565 J v_{max} = (2 × [0.5 × 19.6 N m^{-1} × {0.24 m}^{2}] J /0.84 kg)$^{1/2}$ ✓ = 1.16 m s^{-1} ✓	3	One mark for correct k.e. (0.56 J) Ecf from (a) OR v_{max} = 2 π f A ✓ = 2 × π × (1.3 s)$^{-1}$ × 0.24 ✓ = 1.16 m s^{-1} ✓ 1.2 m s^{-1}
	c		p.e. is proportional to x^2 so p.e. will fall to half maximum value when $x^2 = (x_{max})^2/2$ so p.e. is half maximum value when $x = x/(2)^{1/2}$ ✓ AW Total energy = k.e. + p.e. so when p.e. = ½ p.e.$_{max}$ so is kinetic energy AW ✓	2	Or via p.e. = 0.565 J/2 = 0.2865 J 0.2865 J = ½ kx^2✓ x = √(0.565 J/19.62 N m$^{-1)}$ = 0.170 m and 0.24 m / √2 = 0.170 m ✓
	d		1/(2$^{1/2}$) = cos (2 π t/1.3 s) ✓ t = 0.163 s ✓	2	Or via 0.170 m = 0.24 m cos (2 π t/1.3 s)
	e		Changing flux/magnetic field in metal sheet ✓ Emf generated ✓ Current driven by emf ✓ (I^2r) heating effect of current ✓	4	'Changing flux generates emf' gains 2 marks. Or work done against Lenz force AW – need work done/energy transferred rather than just 'against force' 4th mark can be independent.
	f		Pendulum will resonate with (wind-induced) oscillations of the tower ✓ Energy of movement of tower is transferred to pendulum ✓ Energy of pendulum transferred to internal energy of block ✓	3	AW throughout
			Total	**16**	

Question			Answer	Marks	Guidance
6	a		Any two from: • Heating effect of current • Changes resistance of wire • Higher current will lead to higher equilibrium temperature	**2**	Accept 'maintain constant temperature of wire'
	b	i	Non-zero p.d. intercept ✓ Contact resistance ✓	**2**	Accept low resistance voltmeter/ systematic error in length measurement/zero error on meter
	b	ii	Method of establishing gradient clearly shown, $\Delta L \geq 0.5$ m ✓ Gradient 1.8 (V m^{-1}) to 2 s.f. ✓	**2**	
	b	iii	$\sigma = GL/A = I/V \times L/A = I/A \div [V/L]$ ✓ $= 0.30$ A/{$\pi \times (2.8 \times 10^{-4}m)^2$} $\div$ 1.8 V m^{-1} ✓ $= 6.8 \times 10^5$ (S m^{-1}) ✓	**3**	Bald answer of 6.8/6.77/6.767 × 10^5 gains two marks. e.c.f. own gradient from (b)(ii) If using specific *I* and *V* values (instead of gradient) two marks max.
	c		Any two from: • same current will require greater p.d. across wire • greater heating effect • higher resistance therefore lower conductance (therefore lower conductivity	**2**	Or same I & larger R ✓gives larger I^2R ✓
	d		• metals have free electrons/electron cloud/sea of free electrons/metallic bonding allows electrons to migrate through lattice under potential difference • insulators have far fewer free electrons/electrons are bound to individual atoms in insulators • more electrons (therefore more charge) flow under given potential difference in metals so conductivity far higher	**3**	
			Total	**14**	

Section C					
Question			**Answer**	**Marks**	**Guidance**
7	**a**		0.0119 m ✓	**1**	no s.f. penalty (so 0.011935 is OK, as is 0.012))
	b		Number of waves in pulse = $1 \times 10^{-6} \times 3.5 \times 10^{6} = 3.5$ ✓ Wavelength = 4.4×10^{-4} m ✓ Resolution = $4.4 \times 10^{-4} \times 3.5/2 = 7.7 \times 10^{-4}$ ✓	**3**	Ecf from number of waves in a cycle Or pulse duration x velocity/2. 1.54×10^{-3} credited two marks
			Total	**4**	
8	**a**		Width of Fig 8 = 53 mm Number of pixels along length = (25/53) × 920 = 434 ✓ Resolution = 39/434 = 0.090 mm ✓	**2**	Expect to see one stage calculation. Allow horizontal length or length along arrow ECF from length of image. Range: rounds to 0.09 mm to 1 s.f.
	b		1 bit per pixel so only choice of 2 possibilities (0 & 1) ✓ Density of white pixels in image ✓	**2**	'one bit per pixel' on its own is not enough for mark
			Total	**4**	

Question			Answer	Marks	Guidance
9	a	i	The value of the variable concerned falls by a factor of the square of the distance between the source and detector ✓ Intensity will have fallen to $1/R^2$ at the object (this now acts as the source) this reflected intensity falls by a factor of $1/R^2$ again; intensity of reflection signal at source= $1/R^2 \times 1/R^2 = 1/R^4$ ✓	2	AW – clear explanations gain the mark A complete and clear statement required.
	a	ii	Calculation of intensity ratio $= 1/(2.4)^4$ ✓ $= 0.03014 = 0.030$ ✓ Power difference in dB = $10 \log_{10} 0.030$ = (-) 15 dB ✓	3	$10 \log_{10} 0.03014$ = (-) 15.2 dB
	b	i	ln 0.93 = -0.07257 = $-\alpha \times 0.1$ ✓ α = 0.07257/0.1 = 0.726 ✓	2	Evaluation needed for second mark
	b	ii	$P = \frac{P_0\ e^{-\alpha(2R)}}{R^4} \Rightarrow R^4 \times \frac{P}{P_0} = e^{-\alpha(2R)}$ ✓ $\ln\left(3.0^4 \times \frac{P}{P_0}\right) = \ln 3.0^4 + \ln\frac{P}{P_0} = -2\ \alpha\ R = -6.0\alpha$ ✓ Using α = 0.7 m^{-1} $\Rightarrow$ P/P_0 = 0.000186 ✓ 10 log (0.000186) = -37.3 dB ✓	4	Bald correct answer gains all the marks. Ecf own value of α. If the factor of two left out in the attenuation expression, leading to an answer of – 28.2 dB (α = 0.7 m^{-1}) or –28.5 dB (α = 0.726 m^{-1}), three marks. Using α = 0.726 m^{-1} $\Rightarrow$ P/P_0 = 0.000158 & ΔP = -38.0 dB Ecf from third to fourth mark.
			Total	**11**	

Question			Answer	Marks	Guidance
10			**Level 3 (5–6 marks)** Superposition: Clear explanation of the principle of superposition including the concept of in phase superposition producing highest amplitude resultant and the link between amplitude and power. Bats: Clear explanation of superposition from the two sources and explanation/description of energy distribution of the sound in front of the bat. Medical ultrasound: Clear explanation of delaying pulses so that they meet in front of the transducer in phase at a (chosen) depth. Link between amplitude and intensity/power of beam at given depth and why this is important. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Gives a clear explanation principle of superposition and its relevance to the beam from bats or medical ultrasound. Or a superficial explanation of all three sections attempted. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Gives a superficial description of any two of the three areas of interest. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit	6	**Indicative scientific points may include:** • Credit clear diagram showing waves from two sources meeting in phase. • Principle of superposition clearly stated • Waves from two sources will always meet in phase along the line at right angles to the sources at the midpoint of the sources. • Energy ‘focused’ /redistributed along line where waves meet in phase • Relationship between amplitude and power • More intense beam will have same **proportion** of energy at ‘target’ but **greater** value of energy. • Medical ultrasound concentrates energy at a depth • Concentrating energy in this fashion means greater energy reflected • Greater return energy delivers more detail/information • Concentrating energy in this manner allows greater depths to be imaged
			Total	6	

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