Marking notes for M19 HL paper 2

Question			Answers	Notes
1.	a	i	$F = \frac{\Delta mv}{\Delta t}$ / $m\frac{\Delta v}{\Delta t}$ / $\frac{0.058 \times 64.0}{25 \times 10^{-3}}$ ✓ $F = 148$ «N» ≈ 150 «N» ✓	*Award **[2]** for a bald correct answer.* *MP1 may be awarded for a numerical expression that allows for calculation of change in momentum or acceleration.*

1ai) If the answer is not correct MP1 can be awarded for an expression which would calculate either the change in momentum or the acceleration.

ii	***ALTERNATIVE 1*** $P = \frac{\frac{1}{2}mv^2}{t}$ / $\frac{\frac{1}{2} \times 0.058 \times 64.0^2}{25 \times 10^{-3}}$ ✓ $P = 4700 / 4800$ «W» ✓ ***ALTERNATIVE 2*** $P =$ average Fv / $148 \times \frac{64.0}{2}$ ✓ $P = 4700 / 4800$ «W» ✓	*Do not award BCA. Check working.* *Allow ECF from (a)(i)* *Award **[1]** for omitting to divide v by 2 which gives 9500 «W»*

1aii) A common answer is to calculate Fv and forget to divide v by 2 to calculate the average. This will give an answer of 9500/9600 <<W>>. ECF for 1 mark can be awarded for this.

b	i	horizontal component of velocity is $64.0 \times \cos 7^\circ = 63.52$ «m s^{-1}» ✓ $t =$ «$\frac{11.9}{63.52}$ =» $0.187 / 0.19$ «s» ✓	*Do not award BCA. Check working.* *Do not award ECF from using 64 m s^{-1}.*

1bi) Radian mode on calculator gives 48.25m/s, 0.247s

1b) In general, beware answers that use Pythagoras to get a straight line distance and then assume that the ball travels along that line at a constant speed. Ex incorrect to say s=12.22m (Zero marks)

ii	***ALTERNATIVE 1*** $u_y = 64 \sin 7 / 7.80$ «m s^{-1}» ✓ decrease in height $= 7.80 \times 0.187 + \frac{1}{2} \times 9.81 \times 0.187^2 / 1.63$ «m» ✓ final height = «$2.80 - 1.63$» $= 1.1 / 1.2$ «m» ✓ «higher than net so goes over» ***ALTERNATIVE 2*** vertical distance to fall to net «$= 2.80 - 0.91$» $= 1.89$ «m» ✓ time to fall this distance found using «$1.89 = 7.8t + \frac{1}{2} \times 9.81 \times t^2$» $t = 0.21$ «s» ✓ 0.21 «s» > 0.187 «s» ✓ «reaches the net before it has fallen far enough so goes over»	*Award **[3]** for a bald correct answer of final height.* *Allow use of g = 10 m s^{-2}.* *Allow ECF from (b)(i).* *Allow ECF from MP1 and 2 for MP3.* *Allow use of g = 10 m s^{-2}.* *Other alternatives are possible*

1bii) Alternative 1. Look for vertical component of v, decrease in height and then conclusion based on relative heights of ball and net. There are a number of ways that the final heights can be treated. Make sure they are comparing distance fallen to distance needed to fall to reach net OR height from ground and height of net. Radian mode gives 42.05m/s

Alternative 2. This requires students to solve a quadratic to calculate time to fall to net (0.21 s) and the compare this to the time to reach the net calculated in bi). It wasn't envisaged that students would take this route as a quadratic is involved.

iii	***ALTERNATIVE 1*** Initial KE + PE = final KE / $\frac{1}{2}\times 0.058\times 64^2 + 0.058\times 9.81\times 2.80 = \frac{1}{2}\times 0.058\times v^2$ ✓ $v = 64.4$ «ms^{-1}» ✓ ***ALTERNATIVE 2*** $v_v = «\sqrt{7.8^2 + 2\times 9.81\times 2.8}» = 10.8$ «ms^{-1}» ✓ «$v = \sqrt{63.5^2 + 10.8^2}$» $v = 64.4$ «ms^{-1}» ✓	*Do not award BCA. Check working.* *Allow use of g = 10 m s^{-2}.* *Do not award BCA. Check working.* *Allow use of g = 10 m s^{-2}.*

1biii) For alternative 2 some students are calculating the time to fall to the ground and then the vertical component of velocity. There is no mark for calculating the time, but for your information to help the marking it is 0.3 s.

c		so horizontal velocity component at lift off for clay is smaller ✓ normal force is the same so vertical component of velocity is the same ✓ so bounce angle on clay is greater ✓	*The question says 'predict' so MP3 can be awarded for a plain answer "clay" without any correct justifying argument.*

1c) We would not normally award a mark for a fifty-fifty choice (clay or grass) but we are allowing it in this case for MP3 as the command term is 'predict'.
Many candidates are talking about forces, it must be velocity components that are considered for MP1 & 2. MP1 awarded for "Velocity of ball decreases more on clay surface"

2.	**a**		$\frac{1}{2}mv^2 = \frac{3}{2}kT$ / $v = \sqrt{\frac{3kT}{m}}$ / $\sqrt{\frac{3\times 1.38\times 10^{-23}\times 320}{6.6\times 10^{-27}}}$ ✓ $v = 1.4\times 10^3$ «ms^{-1}» ✓	*Award **[2]** for a bald correct answer.*

2a)Ek=6.62E-21

b			$N = \frac{pV}{kT}$ / $\frac{5.1\times 10^5\times 3.2\times 10^{-6}}{1.38\times 10^{-23}\times 320}$ *OR* $N = \frac{pVN_A}{RT}$ / $\frac{5.1\times 10^5\times 3.2\times 10^{-6}\times 6.02\times 10^{23}}{8.31\times 320}$ ✓ $N = 3.7\times 10^{20}$ ✓	*Answer must be given to at least one more sf than the show that value.* *Award **[1]** for n = 6.14 x 10^{-4}* «moles»

2b) It is common to see number of moles calculated and then number of atoms, which is fine. Watch out for candidates who work backwards from the answer. i.e divide 4 x 10^{20} by N_A to get a number of moles without showing the working and then show us that number multiplied by N_A to get 3.9…… very close to 4.

c	**i**	«$\frac{4\times 10^{20}\times 4.9\times 10^{-31}}{3.2\times 10^{-6}}$ =» 6×10^{-5} ✓	

2ci) Two correct answers are possible are possible here depending on whether the candidate uses their value or the 'show that' value from 2b). Both round to 6 x 10^{-5}.

ii	«For an ideal gas» the size of the particles is small compared to the distance between them/size of the container/gas *OR* «For an ideal gas» the volume of the particles is negligible/the volume of the particles is small compared to the volume of the container/gas *OR* «For an ideal gas» particles are assumed to be point objects ✓ calculation/ratio/result in (c)(i) shows that volume of helium atoms is negligible compared to/much smaller than volume of helium gas/container «hence assumption is justified» ✓	*For MP1 look for one of these general statements about an ideal gas.* *For MP2 there needs to be some reference to (c)(i).*

2cii) We are not awarding credit for kinetic theory assumptions that are not directly related to volume e.g no intermolecular forces.

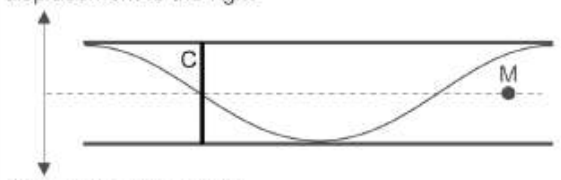
3.	a		Expression or statement showing acceleration is proportional to displacement ✓ so «$7.9 \times \frac{2.3}{3.2}$» = 5.7 «$ms^{-2}$» ✓	*Award [2] for a bald correct answer.*

3.	b		$\sin\theta = \frac{340}{6010} \times \sin 54^0$ ✓ $\theta = 2.6^0$ ✓	*Award [2] for a bald correct answer.*

c		λ = «$\frac{340}{250}$» = 1.36 ≈ 1.4 «m» ✓	

d	i	horizontal arrow «at M» pointing left ✓	

Must be left ← on the diagram

d	ii	any point labelled C on the vertical line shown below ✓ *eg:* displacement to the right  displacement to the left	

e	i	$f' = 2500 \times \frac{340}{340+280}$ ✓ $f' = 1371 \approx 1400$ «Hz» ✓	*Award [2] for a bald correct answer.*

e	ii	$\lambda' = \frac{340}{1371} \approx 0.24 / 0.25$ «m» ✓	*Allow ECF from (e)(i).*

3eii) ex: ECF for 340/1130=0.30m

4.	a		total resistance of circuit is 8.0 «Ω» ✓ $P = \frac{12^2}{8.0} = 18$ «W» ✓	*Award [2] for a bald correct answer.*

4a) ECF can be awarded from an incorrect **total** resistance.

b	i	«a resistor is now connected in parallel» reducing the total resistance *OR* current through YZ unchanged and additional current flows through X ✓	

b	ii	evidence in calculation or statement that pd across Y/current in Y is the same as before ✓ so ratio is 1 ✓	*Award [2] for a bald correct answer.*

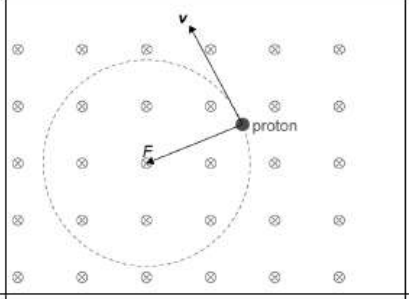
4bii) In a calculation when looking for evidence that the pd is the same across Y it should be 6 V not 12 V as many candidates use.

c		E = «$\frac{1}{2}CV^2 = \frac{1}{2} \times 6 \times 10^{-6} \times 12^2$» = 4.3×10^{-4} «J» ✓	

d	i	*ALTERNATIVE 1* capacitance doubles and voltage halves ✓ since $E = \frac{1}{2}CV^2$ energy halves ✓ so change is «–»2.2×10^{-4} «J» ✓ *ALTERNATIVE 2* $E = \frac{1}{2}CV^2$ and $Q = CV$ so $E = \frac{Q^2}{2C}$ ✓ capacitance doubles and charge unchanged so energy halves ✓ so change is «–»2.2×10^{-4} «J» ✓	*Allow ECF from (c)* *Award [1] ECF for change in energy* $= 4.3 / 4.4 \times 10^{-4}$ «J».

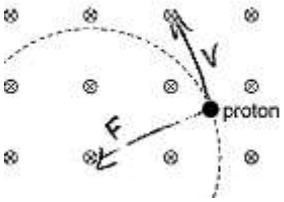
4di) If a candidate halves the capacitance and keeps the pd the same the answer will give 2.2 x 10⁻ <<J>>. Watch for this.

d	ii	it is the work done when inserting the dielectric into the capacitor ✓	

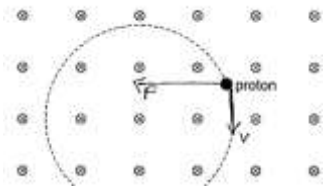
5.	a	i	*F* towards centre ✓	*Judge by eye. Be lenient.*
5.	a	ii	*v* tangent to circle and in the direction shown in the diagram ✓	

5ai) and ii) Here are some examples to consider when deciding on whether to award the marks.

For v look for the arrow being drawn to the left or through the field line shown below.



OK for F and v. Any further to right would be incorrect for v



Unacceptable for F and wrong direction for v

b	i	«$qvB = \frac{mv^2}{R}$ ⇒» $R = \frac{mv}{qB}$ / $\frac{1.673 \times 10^{-27} \times 2.16 \times 10^6}{1.60 \times 10^{-19} \times 0.042}$ ✓ $R = 0.538$ «m» ✓ $R = 0.54$ «m» ✓	*Award [3] for a bald correct answer to 2sf and award [2] for a bald correct answer to any other number of sf.* *Award MP3 for any answer to 2sf.*

b	ii	$T = \frac{2\pi R}{v}$ / $\frac{2\pi \times 0.54}{2.16 \times 10^6}$ ✓ $T = 1.6 \times 10^{-5}$ «s» ✓	*Award [2] for a bald correct answer.* *Allow ECF from (b)(i).*

6.	a		proton / $^{1}_{1}H$ / p ✓	

b	i	«3 × 2.78 – 2 × 2 × 1.12» See 3 × 2.78 / 8.34 *OR* 2 × 2 × 1.12 / 4.48 ✓ 3.86 «MeV» ✓	*Award **[2]** for a bald correct answer.* *Do not allow negative sign.*

b	ii	the deuterium nuclei are positively charged/repel ✓ high KE/energy is required to overcome «Coulomb/electrostatic» repulsion /potential barrier *OR* high KE/energy is required to bring the nuclei within range of the strong nuclear force ✓ high temperatures are required to give high KEs/energies ✓	

c	i	–1 / -e ✓	
c	ii	–3 ✓	

6ci) 'Negative' is not sufficient, there must be a magnitude as well.

7.	a		$5.67 \times 10^{-8} \times 289^{4}$ *OR* $= 396$ «W m^{-2}» ✓ «≈ 400 W m^{-2}»	

7a) The mark can be awarded for either the substitution or the 396 figure.

b		«most of the radiation emitted by the oceans is in the» infrared ✓ «this radiation is» absorbed by greenhouse gases/named greenhouse gas in the atmosphere ✓ «the gases» reradiate/re-emit ✓ partly back towards oceans/in all directions/awareness that radiation in other directions is also present ✓	*Do not allow "gases in the atmosphere" without qualification.* *Do not award MP4 if the answer is based on radiation being 'reflected' by the atmosphere or directed away from the ocean.*

7b) Do not allow 'trapped' instead of 'absorbed' or 'returned' instead of 're-emitted'.

c	i	water loses 396 – 330 / 66 «W m^{-2}» ✓ extra intensity that must be lost is «170 – 66» = 104 ≈ 100 W m^{-2}» ✓ *OR* absorbed by water 330 + 170 / 500 «W m^{-2}» ✓ extra intensity that must be lost is «500 – 396» = 104 ≈ 100 W m^{-2}» ✓	*Award **[2]** for a bald correct answer.*

ii	conduction to the air above *OR* «mainly» evaporation *OR* melting ice at the poles *OR* reflection of sunlight off the surface of the ocean ✓	*Do not accept convection or radiation.*

8.	a		there is constructive interference at M *OR* the amplitude doubles at M ✓ intensity is «proportional to» amplitude^2 ✓ 88 «W m^{-2}» ✓	*Reasoning must be shown.*	3

Should show each marking point clearly, not just 22*4=88

8.	b		«$s = \frac{\lambda D}{d} \Rightarrow$» $\lambda = \frac{sd}{D}$ / $\frac{0.12\times10^{-3}\times7.0\times10^{-3}}{1.5}$ ✓ $\lambda = 560$ «nm» ✓	*Award **[2]** for a bald correct answer.* *Accept e.g. 5.60 x 10^{-7} m. Power of 10 must match unit.*	2

8b) If no unit is given we assume the candidate means nm as that is the instruction in the question. If any other figure is given the unit must be included e.g 5.6 x 10^{-7} **m.**

8.	c	i	«the interference pattern will be modulated by» single slit diffraction ✓ «envelope and so it will be less»		1

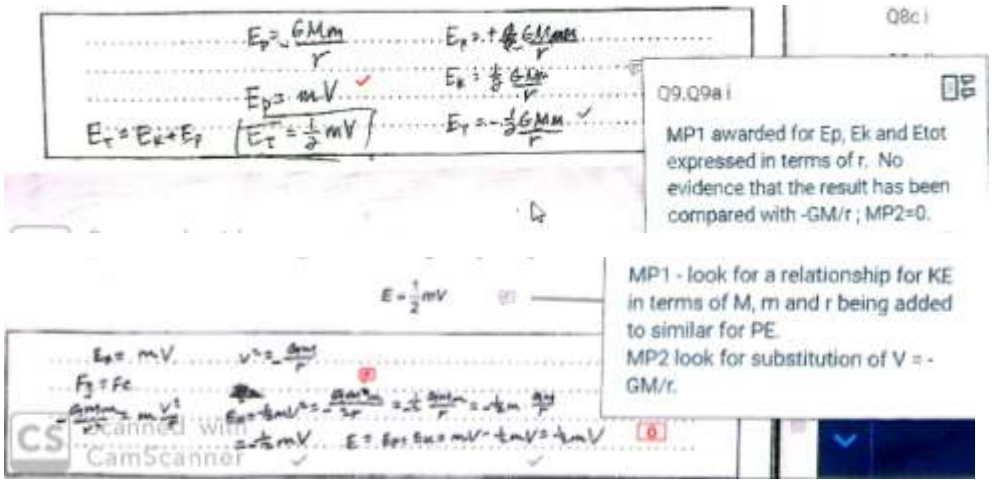
8ci) Must mention single slit

8.	c	ii	***ALTERNATIVE 1*** the angular position of this point is $\theta = \frac{28\times10^{-3}}{1.5} = 0.01867$ «rad» ✓ which coincides with the first minimum of the diffraction envelope $\theta = \frac{\lambda}{b} = \frac{560\times10^{-9}}{0.030\times10^{-3}} = 0.01867$ «rad» ✓ «so intensity will be zero» ***ALTERNATIVE 2*** the first minimum of the diffraction envelope is at $\theta = \frac{\lambda}{b} = \frac{560\times10^{-9}}{0.030\times10^{-3}} = 0.01867$ «rad» ✓ distance on screen is $y = 1.50\times0.01867 = 28$ «mm» ✓ «so intensity will be zero»	*Accept use of sin or tan.* *ECF can be awarded for their value from b) / 0.030 x 10^{-3}.*	2

8cii) The use of tan or sin is acceptable here. Path difference formula *2dn=m or (m+1/2)* **not** okay. Substitution of numbers needed for Alt2 MP2, not just d=θD

9.	a	i	$E = \frac{1}{2}m\frac{GM}{r} - \frac{GMm}{r} = -\frac{1}{2}\frac{GMm}{r}$ ✓ comparison with $V = -\frac{GM}{r}$ ✓ «to give answer»		2

9ai) **Award one mark if unsure** Give Et in terms of r. Allowing missing – sign as long as substitution is performed correctly? Must show final Et. Can show substitution of –GM/r for V. It is useful to look for KE in terms of G, M, m, r when marking this. Must link V to r for MP2



$K.E = \frac{GmM}{2r} = \frac{m(-V)}{2}$; $P.E = mV$

Where $V = \frac{GM}{r}$ so $T.E = \frac{-mV}{2} + mV = \frac{mV}{2} = \frac{1}{2}mV$

Orbital $= \sqrt{\frac{GM}{r}}$ $E_T = \frac{1}{2}mv^2 - \frac{GM}{r}m$

$V = -\frac{GM}{r}$ $= \frac{1}{2}m\frac{GM}{r} - \frac{GM}{r}m$

$= -\frac{1}{2}mV + Vm$

$= \frac{1}{2}mV$

9.	a	ii	*ALTERNATIVE 1* «at the position of the planet» the potential depends only on the mass of the star /does not depend on the radius of the star ✓ the potential will not change and so the energy will not change ✓ *ALTERNATIVE 2* r / distance between the centres of the objects / orbital radius remains unchanged ✓ since $E_{Total} = -\frac{1}{2}\frac{GMm}{r}$, energy will not change ✓		2

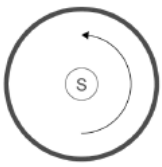
9aii) Alt 1 MP1 and MP2 must match, not mix and match. Must mention both potential and energy for Alt1 MP2. No marks when stating energy changes.

9.	b		$\frac{kQ}{(0.600+0.820)^2} = \frac{kq}{0.820^2}$ ✓ $\frac{Q}{q} = «\frac{(0.600+0.820)^2}{0.820^2} = 2.9988 \approx» 3$ ✓	*Award [2] for a bald correct answer to 1sf.* *Ignore minus sign if included.*	2

9b) Ignore any negative signs used as the question is about the magnitude of the charges. No ECF for incorrect r or forget to square. MUST BE 1SF!

10.	a		the magnetic field at the position of the ring is increasing «because the magnet gets closer to the ring» ✓		1

10a)field is "felt more" implies increasing magnetic field. Inc. flux/flux linkage not sufficient as flux is in the question stem. Allow for English language learners.

10.	b		the current must be counterclockwise «in diagram 2» ✓ *eg:*  Diagram 2: view from above		1

10b) There may well be annotations on both Diagram 1 and Diagram 2. Look first for a direction shown on Diagram 2. If this is blank, look at Diagram 1.

10.	c		since the induced magnetic field is upwards *OR* by Lenz law the change «of magnetic field/flux» must be opposed *OR* by conservation of energy the movement of the magnet must be opposed ✓ therefore the force is repulsive/upwards ✓	*Allow out of the paper for MP3.*	2

10c)"outwards" too imprecise. Alt 2 must say "change". Must say force direction, not just field. MP1 awarded for mention of Lenz's Law and opposing direction/opposes motion. MP1 not awarded for "keep initial field strength"

11.	a		«de Broglie's hypothesis states that the» electron is represented by a wave ✓ therefore it cannot be localized/it is spread out/it does not have a definite position ✓	*Award MP1 for any mention of wavelike property of an electron.*	2

11a) Note that many candidates answer by restating the 'well defined radius' part of the question. Do not penalise candidates for attributing ideas to the wrong physicist (Heisenberg OK). Position of e has uncertainty OK for MP2. Continuous energy levels not sufficient. Less-well defined too vague for MP2. "Dual nature" too vague for MP1

11.	b	i	«$d \sin\theta = \lambda \Rightarrow$» $d = \frac{1.6\times10^{-15}}{\sin 17^\circ}$ / 5.47×10^{-15} «m» ✓ $R = \frac{d}{2} \approx 2.7$ / 2.8×10^{-15} «m» ✓	*Award **[2]** for a bald correct answer.*	2

11bi) We are looking for the use of λ = d sin θ. MUST HAVE sin theta for MP1

11.	b	ii	this implies that the nucleons are very tightly packed/that there is very little space in between the nucleons ✓ because the nuclear force is stronger than the electrostatic force ✓		2

11bii)Within the range of strong force too vague for MP1. Should refer to nucleons, not holding quarks together. Should compare to electrostatic force for MP2

11.	c	i	number of nuclei is $\frac{28\times10^{-3}}{64}\times6.02\times10^{23}$ / 2.63×10^{20} ✓ $A =$ «$\lambda N = 2.63\times10^{20}\times\frac{5.5\times10^{-2}}{3600}$» $= 4.0\times10^{15}$ «Bq» ✓	*Award **[2]** for a bald correct answer.*	2

11ci)1.45E19 ok if includes units of decays per hour. Don't award ECF if N not calculated

11.	c	ii	$\frac{1}{3} = e^{-\lambda t}$ ✓ $t = 20$ «hr» ✓	*Award **[2]** for a bald correct answer.* *Award MP1 if λ is substituted in s^{-1}.*	2

11cii)Generous on MP1 numbers. Don't award marks for use of A=A0e-lambda t (incorrect formula)