Answers – Turning Points in Physics 3

1.

(a)

Answers	Additional Comments/Guidelines	Mark
(for Proper time, t_0 = 31,536,000 s / 365 days) Dilated time, t = 31,561,259 s ✓ Time dilation is 25,259 s / 421 minutes / 7.0 hours / 0.29 days ✓ The recorded time will be longer (as predicted) ✓ The recorded time will be less than several days longer (as predicted) ✓	Accept answers in other units (e.g. 365.3 days) Accept an answer of 31582876 seconds / 365.5 days where a proper time of 365.25 days has been used.	4

(b)

Theory of Special Relativity requires no acceleration ✓ (The spacecraft/frame of reference is) accelerating ✓ Alternative answer: Theory of Special Relativity requires inertial reference frame ✓ (The spacecraft/frame of reference is) not an inertial reference frame ✓	Accept change in direction / speed / velocity as alternatives for accelerating.	2

2.

Conversion of 3.7×10^9 eV to 5.9×10^{-10} J✓ Correct use of $$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$ including correct substitution ✓ 0.97(c) ✓	Accept substitution of $3.7 \times 10^9 \times 1.6 \times 10^{-19}$	3

3.

<table>
<tr><th>Answers</th><th>Additional Comments/Guidance</th><th>Mark</th></tr>
<tr>
<td>
The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.
<table>
<tr><th>Mark</th><th>Criteria</th><th>QoWC</th></tr>
<tr><td>6</td><td><u>A thorough and well communicated</u> discussion using most of the statements in bullets 1 2 and 3</td><td rowspan="2">The student presents relevant information coherently, employing structure, style and SP&G to render meaning clear. The text is legible.</td></tr>
<tr><td>5</td><td><u>A explanation that includes</u> discussion using most of the statements in bullets 1 , 2 and 3 but may contain minor errors or omissions</td></tr>
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<td>
The following statements are likely to be present:
Bullet point 1 in question
(Explanation of how shift expected)
1. PM_2 lies in the direction of the Earth's velocity.
2. Speed of light different in the two directions
3. The time taken for light to travel from P to M_2 and back to P would be greater than the time taken from P to M_1 and back to P
4. If the speed of light depends on the Earth's velocity through the ether.
5. Rotating the apparatus through 90° would cause the time difference to reverse/change,
6. When rotated there would be a change in the phase difference between the waves (at each point in the fringe pattern)

Bullet point 2 in the question
(Results compared with prediction)
7. The apparatus was capable of detecting shifts of 0.05 fringe,
8. No shift was detected then or in later experiments when apparatus rotated

Bullet point 3 in the question
(Conclusions)
9. The experiment showed that there is no absolute motion
10. Ether did not exist so light travels without the need for a material medium,
11. The Earth was dragging the ether with it.
</td>
<td>6</td>
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</table>

(b)

Answers	Additional Comments/Guidance	Mark
Correct postulate invariance of the speed of light in free space/vacuum. speed of light the same in free space		1

(c)

Laws of physics have the same form in all inertial frames Laws of physics unchanged from one inertial frame to another	The same laws of physics are obeyed/apply/hold in (all) inertial frames of reference/non accelerating frames of reference/frames moving at a constant velocity Not Allowed All laws of physics Laws of physics are the same Laws of physics are constant…. Mention of Newton's laws being obeyed Allow 1 here if both 4.2 and 4.3 are correct but reversed	1

(d)

Time of flight is found to be 4.41×10^{-6} s ✓ $t_o = t\sqrt{1-\frac{v^2}{c^2}}$ or $t_o = 4.41 \times 10^{-6}\sqrt{1-0.99^2}$ ✓ (Proper time t_0 is) 6.22×10^{-7} s ✓ Percentage remaining is (found from the graph) 82 +/– 1 OR In muon reference frame $L = 1310\sqrt{1-0.99^2}$ ✓ 185 m✓ $t = \frac{185}{0.99 \times 3\times10^8} = 6.23 \times 10^{-7}$ s✓ allow ecf for incorrect length calculation 82 +/– 1%✓	May do Number of half lives = $6.22 \times 10^{-7}/2.2 \times 10^{-6}$ fraction remaining = $0.5^{0.283}$=0.82 185 m seen scores 2 <u>Must see this stage with speed = 0.99 x 3 x 10^8</u> Final answer in range can be awarded even if 0.99 omitted in MP3 Allow <u>minor</u> differences in time (3rd sf) due to rounding in processing	4

4.

(a)

Answers	Additional Comments/Guidance	Mark
Unchanged Changed		1

(b)

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer.

Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.

Mark	Criteria	QWC
6	All 3 areas A B and C covered Only allow minor omissions	The student presents relevant information coherently, employing structure, style and SP&G to render meaning clear. The text is legible.
5	2 complete descriptions with one partial from A, B and C	
4	Full description of one area, with partial description of other two	The student presents relevant information and in a way which assists the communication of meaning.

The following statements are likely to be present.

Area A
Description of corpuscular explanation of refraction

i)Light is made up of particles/corpuscles

ii)Force acts attracting them to the water.

iii)Attraction only affects motion at the interface/boundary.

iv)Only one component of velocity / momentum (vertical) changes at the interface.

v)The (vertical component of) velocity / momentum increases which causes the change in direction.

Partial answers may be missing idea of Force (ii) or component AND boundary (iv)(iii)

6

	OR Full descriptions of two areas with very little on third or nothing at all	The text is legible. SP&G are sufficiently accurate not to obscure meaning.	**Area B** **Description of wave explanation of refraction** i)Wave front is incident on interface ii)Huygens secondary <u>wavelets</u> at wave fronts. iii)Wavelets travel more slowly in the water. iv)The slowing down of the waves / wavelets causes the change in direction. A partial answer may have no reference to <u>wavelets</u> **Area C** **Acceptance of wave theory** Discussion of speed: (Newton's theory required light to travel faster in the water. And Huygens' theory required light to move more slowly in the water.) When the speed of light was measured in water, the value found supported Huygens' prediction. Discussion of wave properties Light was observed to show interference	
3	A full description of one area and a partial description of one area OR A partial discussion of all three areas			
2	A full discussion of one area OR A partial discussion of two areas	The student presents some relevant information in a simple form. The text is usually legible. SP&G allow meaning to be derived although errors are sometimes obstructive.		
1	Only one area covered, and that partially.			
0				

	effects that cannot be explained using corpuscular theory.) Interference effects in Young's double slit experiment can be explained by Huygens' wave theory but not by Newton's corpuscular theory. A partial answer will refer to only one piece of evidence.	

(c)

(vibrations of) the <u>electric wave/field</u> and <u>magnetic wave/field</u> are: perpendicular to each other ✓ perpendicular to the labelled direction of motion ✓ in phase with each other ✓	Names of both waves needed for first mark But condone missing labels (E and B) on diagram if mentioned in text Condone single arrow unlabelled to represent direction of travel But Reward unlabelled arrow on axis only if no arrows on other axes Credit writing over poor diagram	3

5.

(a)

Answers	Additional Comments/Guidance	Mark
Calculation of constant of proportionality for at least two data sets ✓ Allow conversion to J	Alternative methods of calculation: Calculation of constant of proportionality and then using to calculate other E, v, v^2 and comparing with table. Checking ratio of $\frac{E_m}{E_n} \neq \frac{v_m^2}{v_n^2}$ 1 mark for any calculation that shows KE ≠ $1/2mv^2$ ✓	2
Calculation of at least three data sets and conclusion to the effect that as the constants differ, the classical prediction is not true ✓	If more than 3 calculations shown, reward any three correct	

(b)

Answers	Additional Comments/Guidance	Mark
v has upper limit as Ek increases✓ Explanation: As v increase mass increases✓ As v approaches c, mass approaches infinity/increase in mass significant✓ Near c, increases in Ek are due to increase in mass/Ek tends to infinity✓	For MP1 allow comment on their calculations from 4.1 e.g. Ek/v2 increases Do not reward references to 'constant increases' Treat 'exponentially' as neutral Condone energy/total energy for Ek	4

(c)

$E_0 = m_0c^2 = 8.2 \times 10^{-14}$ J $E = \frac{m_0c^2}{\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}}} = 2.6 \times 10^{-13}$ J ✓ $E_k\ (= E - E_0) = 2.6 \times 10^{-13} - 8.2 \times 10^{-14}$ ✓ 1.8×10^{-13} J ✓	If no marks are scored 1 mark can be given for *seeing* 8.2×10^{-14} J Allow ecf from MP1 for incorrect m_o eg use of proton Give all 3 marks for correct answer	3

6.

(a)

Answers	Additional Comments/Guidance	Mark
(All matter particles) have a wave-like nature/wave-like properties✓ (and an associated) wavelength/λ = $\frac{h}{\text{momentum of the particle}}$ ✓	Condone named particle e.g. electron Condone 'particles have a wavelength Condone mv for momentum Do not allow p unless defined (eg p=mv) Do not allow 'inversely proportional	2

(b)

Use of de Broglie equation $\lambda = h / \sqrt{2meV}$ to give 0.021 nm ✓	Allow reverse calculation to give **3800V** Allow 0.02 if substitution of 3500 V **seen** **If no other mark given allow mp1 for substitution of 3500 into equation**	2
(Comparison of calculated value of λ to given value) and consistent conclusion ✓	Allow ecf in MP2 only for POT error.	

(c)

First Change One statement ✓ Relevant explanation✓ Second Change One statement✓ Relevant explanation✓ Statement 1 Use target with greater spacing between atoms	Condone Statement: use particles of bigger mass (e.g. protons) smaller wavelength (at same speed) If no other marks are awarded, give 1 mark for stating that any one of the following could change but do not allow physics errors The target/spacing of atoms	Max 4
Explanation Larger separation gives rise to narrower fringes Statement 2 Increase the p.d. Explanation Reduces wavelength (which gives rise to narrower fringes) Statement 3 Decrease distance between foil and film Explanation for same angles, maxima closer together.	Potential difference Velocity of electrons Wavelength of electrons. Do not allow 'does not spread out as much'	