SCIENCE TEACHERS ASSOCIATION VICTORIA 2023

TRIAL EXAMINATION

SOLUTIONS BOOK

PHYSICS

UNITS 3 & 4

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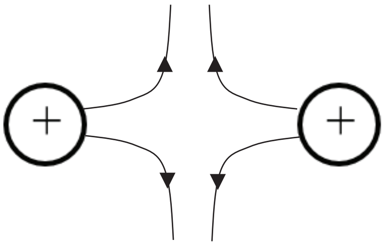
Use this page as an overlay for marking the multiple choice answer sheets. Simply photocopy the page onto an overhead projector sheet. The correct answers are open boxes below. Students should have shaded their answers. Therefore, any open box with shading inside it is correct and scores 1 mark.

	ONE ANSWER PER LINE		ONE ANSWER PER LINE
1	■ ■ ■ ☐	11	■ ■ ☐ ■
2	■ ☐ ■ ■	12	■ ■ ■ ☐
3	☐ ■ ■ ■	13	☐ ■ ■ ■
4	■ ☐ ■ ■	14	■ ☐ ■ ■
5	■ ■ ☐ ■	15	■ ☐ ■ ■
6	■ ☐ ■ ■	16	■ ☐ ■ ■
7	■ ■ ■ ☐	17	■ ■ ■ ☐
8	■ ■ ■ ☐	18	■ ■ ■ ☐
9	■ ☐ ■ ■	19	■ ■ ■ ☐
10	■ ■ ☐ ■	20	■ ■ ■ ☐

SECTION A – Multiple-choice questions

Q	Marks	Answer	Solution
1	1	D	Using the right hand grip rule, the thumb is the current directed up the page. The fingers are the magnetic field which on the right of the wire is directed into the page.
2	1	B	The smallest scale is 1 cm. The uncertainty is half the smallest scale = ±0.5 cm. The measurement cannot be more accurate than the scale allows so 8 cm is a valid measurement whereas 8.1 cm is not.
3	1	A	The students may or may not have started and stopped the stopwatches correctly for each event. That makes their measurements subject to random error.
4	1	B	The electric field is directed away from a positive charge and towards a negative charge. The field lines will point away from each charge; to the right from the left hand charge and to the left from the right hand charge. These add as vectors to equal zero net field at the midpoint. 
5	1	C	Using the right hand slap rule, the fingers are the magnetic field directed into the page. The palm is the force on the radiation which is initially down the page when it first enters the magnetic field. The thumb is the direction a positive charge would move which is to the left, but since the radiation is travelling to the right when it first enters the magnetic field, it must have a negative charge. An electron or a beta particle has a negative charge.
6	1	B	Applying the Doppler Effect, the siren will appear to have a higher frequency when it travels towards the student and a lower frequency when it travels away from the student. Since the apparent frequency is lower in this case it must be travelling away from the student.

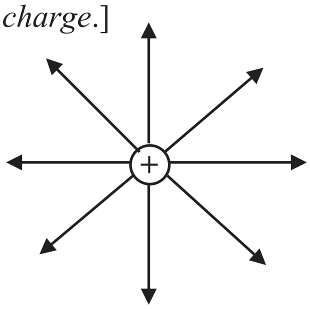
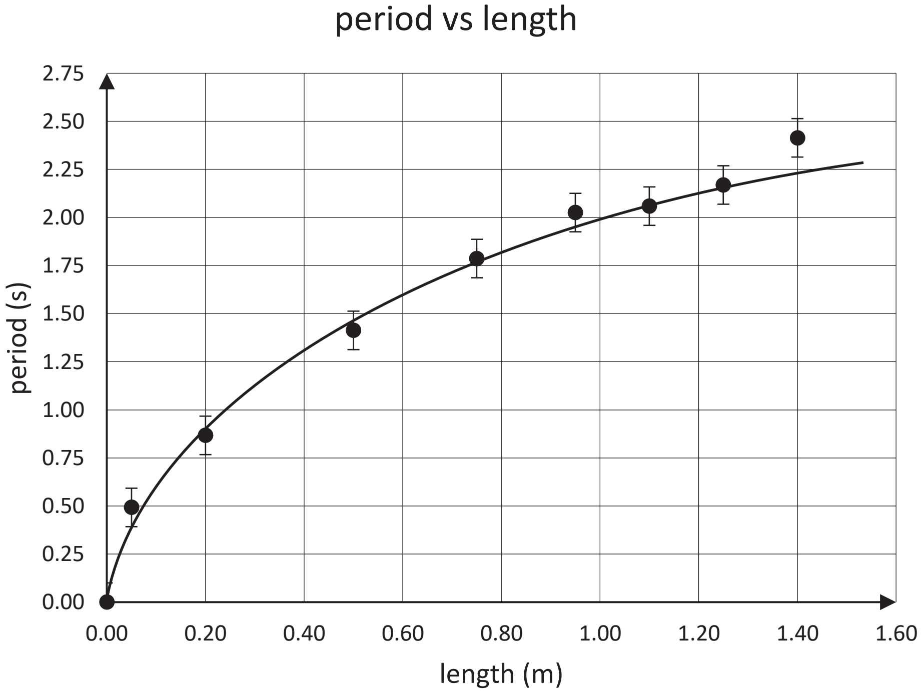
Q	Marks	Answer	Solution
7	**1**	**D**	radius = ½ × diameter = ½ × 6.78 × 10^6 m = 3.39 × 10^6 m $g = \frac{G\,m}{r^2}$ $g = \frac{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}{(3.39 \times 10^6)^2} = 3.7\text{ N kg}^{-1}$
8	**1**	**D**	To be correct, D should state: Gravitational fields exist in the space around every mass.
9	**1**	**B**	The smallest scale is 1 V. Although the reading is approximately 4.2 V, the uncertainty is half the smallest scale = ±0.5 V.
10	**1**	**C**	$m_1\,u_1 + m_2\,u_2 = (m_1 + m_2)\,v$ $3500 \times 5.0 + 1500 \times 2.0 = (3500 + 1500) \times v$ $v = \frac{20\,500}{5000} = 4.1\text{ m s}^{-1}$
11	**1**	**C**	Newton's Third Law states that objects exert equal and opposite forces on each other. Therefore the forces between the truck and the car are equal in magnitude.
12	**1**	**D**	distance travelled = area under the speed-time graph $s = 24 \times 0.5 + ½ \times 3.0 \times 24$ $s = 48$ m
13	**1**	**A**	$u = 24,\ v = 0,\ t = 3.0,\ a = ?$ $v = u + a\,t$ $a = \frac{0-24}{3.0} = -\,8.0\text{ m s}^{-2}$ $F = m\,a = 1200 \times -8.0$ $F = -9600$ N or 9.6 × 10^3 N in magnitude
14	**1**	**B**	area of loop = 0.05 × 0.04 = 2 × 10^{-3} m^2 $\Phi = B \times A$ $\Phi = 0.06 \times 2 \times 10^{-3} = 1.2 \times 10^{-4}$ Wb

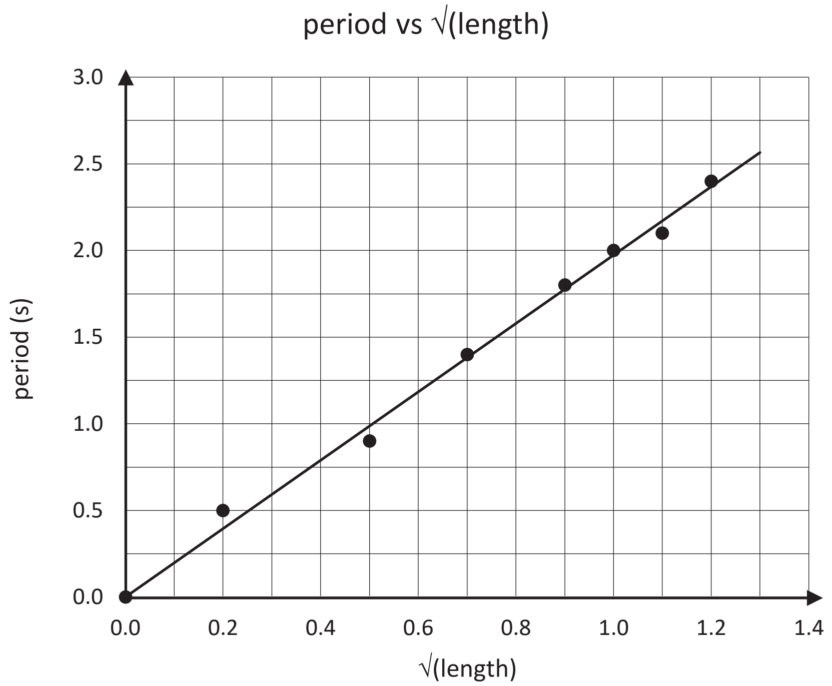
Q	Marks	Answer	Solution
15	**1**	**B**	When the switch is closed current will flow from the positive terminal of the battery (long line) through the switch and around the left coil, creating a magnetic field to the left. A magnetic field will be induced in the right coil to counteract this field so will be to the right. Using the right hand grip rule this creates a current that flows from Y to X through the milliammeter. The current will be momentary as the change in flux in the left hand coil is only momentary over the fraction of time it takes to close the switch.
16	**1**	**B**	$\frac{N_1}{N_2} = \frac{V_1}{V_2}$ $\frac{2000}{80} = \frac{V_1}{12}$ $V_1 = 300$ V
17	**1**	**D**	Radio signals travel at the speed of light. The speed of light, *c*, is absolute and does not change despite the source travelling away from the Earth.
18	**1**	**D**	Light waves can also undergo the Doppler Effect, such as the red shift and blue shift from starlight.
19	**1**	**D**	Constructive and destructive interference causes the loud and quiet regions between the two speakers.
20	**1**	**D**	The energy and hence wavelength of the electrons determines the number of standing waves and hence the energy of a particular energy level.

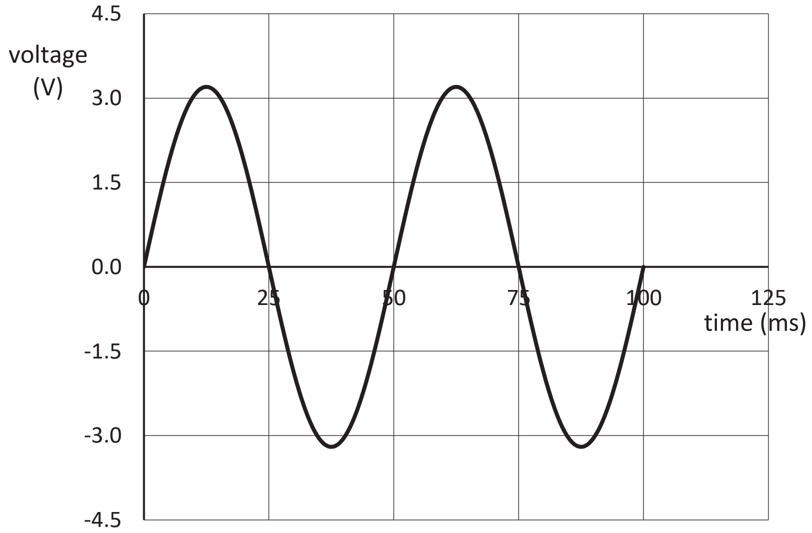
SECTION B

Q	Marks	Answer	Solution
1a	3	[✓ inelastic]	$E_{\text{k initial}} = \frac{1}{2} \times 20 \times 10^3 \times 5.0^2 + \frac{1}{2} \times 10 \times 10^3 \times 2.0^2$ $= 2.7 \times 10^5$ J $E_{\text{k final}} = \frac{1}{2} \times 30 \times 10^3 \times 4.0^2 = 2.4 \times 10^5$ J $E_{\text{k final}} \neq E_{\text{k initial}}$ so collision is inelastic.
b	3	**1.7 s**	for truck Y: $\Delta v = 4 - 2 = 2$ m s^{-1} $I = m\,\Delta v = 10 \times 10^3 \times 2.0 = 2.0 \times 10^4$ kg m s^{-1} $I = F \times t \rightarrow t = \frac{I}{F} = \frac{2 \times 10^4}{12 \times 10^3} = 1.67$ s
2a	3	**13 m**	vertically with up as positive: $u = 30 \sin 30° = 15,\ v = 0,\ a = -9.8,\ s = ?$ $v^2 = u^2 + 2as \quad 0^2 = 15^2 + 2 \times -9.8 \times s$ $s = \frac{225}{19.6} = 11.48$ m height above ground level = 11.48 + 1.2 = 12.7 m
b	4	**3.1 s** **NO WIND RESISTANCE**	vertically to top: $u = 30 \sin 30° = 15,\ v = 0,\ a = -9.8,\ t = ?$ $v = u + at \rightarrow 0 = 15 - 9.8t \rightarrow t = \frac{15}{9.8} = 1.53$ s then down: $u = 0,\ s = -12.7,\ a = -9.8,\ t = ?$ $s = ut + \frac{1}{2}at^2 \rightarrow 4.9t^2 = 12.7 \rightarrow t = \sqrt{\frac{12.7}{4.9}} = 1.61$ s $t_{\text{total}} = 1.53 + 1.61 = 3.14$ s [*conseq on answer Q2b*] OR $u = 15,\ s = -1.2,\ a = -9.8,\ t = ? \rightarrow 4.9t^2 - 15t - 1.2 = 0$ this is a quadratic and can be solved to give $t = 3.14$ s Assumption: **NO WIND RESISTANCE**
c	2	[✓ YES]	horizontally: $u = 30 \cos 30° = 26.0,\ a = 0,\ t = 3.14,\ s = ?$ $s = ut + \frac{1}{2}at^2$ $s = 26.0 \times 3.14 = 81.64$ m [*conseq on answer Q2b*]

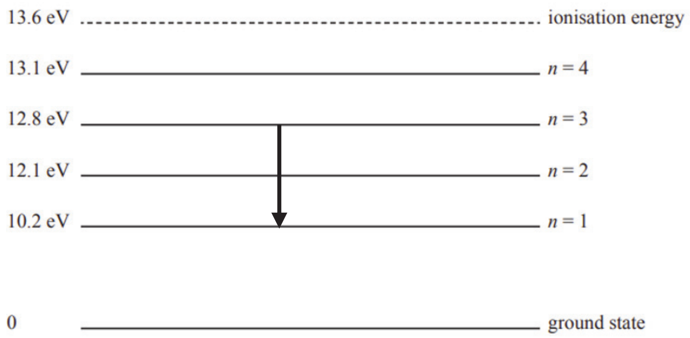
Q	Marks	Answer	Solution
3a	**1**	**6.87×10^6 m**	$r_{\text{orbit}} = 6.37 \times 10^6 + 500 \times 10^3 = 6.87 \times 10^6$ m
b	**3**	**5.7×10^3 s**	$\frac{4\pi^2 r}{T^2} = \frac{GM}{r^2} \rightarrow T = \sqrt{\frac{4\pi^2 r^3}{GM}}$ $T = \sqrt{\frac{4\pi^2 (6.87 \times 10^3)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}} = 5665$ s [*conseq on answer Q3a*]
c	**3**	**accept** **5.4 to 5.5** **$\times 10^8$ J**	ΔE_g = area under the graph × mass of the satellite $= ½ (9.8 + 8.4) \times 500 \times 10^3 \times 120$ $= 5.46 \times 10^8$ J
4a	**2**	**2.6×10^3 W**	$P = VI = 260 \times 10 = 2600$ W
b	**2**	**2 Ω**	$\Delta V = 260 - 240 = 20$ V lost along the transmission wires $\Delta V = IR \rightarrow R = \frac{\Delta V}{I} = \frac{20}{10} = 2\ \Omega$ OR can calculate P_{lost} and use $I^2 \times R$ to find R
c	**2**	**200 W**	$P_{\text{lost}} = I^2 R = 10^2 \times 2 = 200$ W [*conseq on answer Q2b*] OR $P_{\text{lost}} = \Delta V \times I = 20 \times 10 = 200$ W [*conseq on answer Q2b*]
d	**3**	**0.5 W**	Since the turns ratio is 1:20 the voltage will increase by a factor of 20 and the current will reduce by a factor of 20 from 10 A to 0.5 A. Resistance remains constant at 2 Ω. $P_{\text{lost}} = I^2 R = 0.5^2 \times 2 = 0.5$ W [*conseq on answer Q2b*]
5a	**1**	**0 N**	Box Y is stationary so $F_{\text{net}} = 0$ (otherwise it would accelerate).
b	**2**	**2.2×10^3 N**	$F_{\text{floor on Y}}$ = mass of Y × g + mass of X × g $= 150 \times 9.8 + 75 \times 9.8$ $= 1470 + 735 = 2205$ N
c	**2**	**7.4×10^2 N**	$F_{\text{X on Y}}$ = mass of X × g = $75 \times 9.8 = 735$ N
d	**1**	The gravitational force acting on Box Y is the gravitational force of the Earth on Y so the reaction is the gravitational force of Y on the Earth.	

<table>
<tr><th>Q</th><th>Marks</th><th>Answer</th><th colspan="2">Solution</th></tr>
<tr><td>6a</td><td>2</td><td colspan="3">[<i>At least 6 electric field lines must be shown, equally spaced and directed away from the positive charge</i>.]

 </td></tr>
<tr><td>b</td><td>2</td><td>1.2×10^{-4} V m^{-1}</td><td colspan="2">$E = \frac{k\,q}{r^2} = \frac{8.99 \times 10^9 \times 4.8 \times 10^{-19}}{(6.0 \times 10^{-3})^2}$
$E = 1.1987 \times 10^{-4} = 1.2 \times 10^{-4}$ V m^{-1}</td></tr>
<tr><td>7a</td><td>1</td><td colspan="3">To reduce the uncertainty in coordinating the release of the pendulum and starting the stopwatches and allow the pendulum to steady in its motion.</td></tr>
<tr><td>b</td><td>1</td><td colspan="3"><i>Any one of the following</i>:
mass of the pendulum rod, angle of release, height of release, how many periods to time, any other reasonable variable.</td></tr>
<tr><td>c</td><td>1</td><td>0.49 & 2.06</td><td colspan="2">$\frac{9.8}{20} = 0.49$ s $\frac{41.2}{20} = 2.06$ s</td></tr>
<tr><td>d</td><td>2</td><td colspan="3">
 </td></tr>
<tr><td>e</td><td>2</td><td>1.6 s</td><td>±0.1</td><td>[<i>consequential on the student's value of the period for a length of 0.60 m on their graph</i>]</td></tr>
</table>

Q	Marks	Answer	Solution
f	3		
g	2	2	the constant of proportionality is the gradient gradient $= \frac{\text{rise}}{\text{run}} = \frac{2.5}{1.27} = 1.97$ or 2 [*conseq on graph*]
h	2	2.8 s	$T = 2 \times \sqrt{L} = 2 \times \sqrt{2.0} = 2.8$ s [*conseq on answer Q7g*]
8a	1	120 m	The length of the spaceship does not change in the frame of reference of the astronaut who is stationary relative to the spaceship. It only changes for a stationary observer.
b	2	5.7 years	time taken $= \frac{\text{distance}}{\text{speed}} = \frac{4.25}{0.600} = 7.08$ years $t = t_o \gamma \rightarrow t_o = \frac{t}{\gamma} = \frac{7.08}{1.25} = 5.67$ years
c	1	Yes, proper time is measured at rest relative to the event, which is the spaceship's journey to Proxima Centauri, measured by the astronaut.	
9a	3	8.8 m	$E_{g\,A} + E_{k\,A} = E_{g\,B} + E_{k\,B}$ $75 \times 9.8 \times 12 + ½ \times 75 \times 1.0^2 = 75 \times 9.8 \times \boldsymbol{x} + ½ \times 75 \times 8^2$ $8820 + 37.5 = 735\,\boldsymbol{x} + 2400$ $\boldsymbol{x} = 8.8$ m

Q	Marks	Answer	Solution
b	**2**	**1.1×10^3 N**	$F_{\text{seat on passenger}} = F_{\text{centripetal}} + F_{\text{gravitational}}$ $F_{\text{seat on passenger}} = \frac{m\,v^2}{r} + mg = \frac{75 \times 8.0^2}{12} + 75 \times 9.8$ $F_{\text{seat on passenger}} = 400 + 735 = 1135$ N
c	**3**	**6.3 m s^{-1}**	$E_{\text{g A}} + E_{\text{k A}} = E_{\text{g C}} + E_{\text{k C}}$ $8820 + 37.5 = 75 \times 9.8 \times 10 + \tfrac{1}{2} \times 75 \times \boldsymbol{v}^2$ $8857.5 = 7350 + 37.5\,\boldsymbol{v}^2$ $\boldsymbol{v} = 6.34 \text{ m s}^{-1}$
10a	**1**	**20 Hz**	$f = \frac{1}{T} = \frac{1}{50 \times 10^{-3}} = 20$ Hz
b	**1**	**2.3 V**	$V_{\text{RMS}} = \frac{V_{peak}}{\sqrt{2}} = \frac{3.2}{\sqrt{2}} = 2.26$ V
c	**3**	At the starting vertical position the flux through the coil is a maximum and the rate of flux change is minimal so according to Faraday's Law, the emf or voltage in the coil is minimal. As the coil turns, the flux decreases, and the rate of flux change (and voltage) increases to a maximum when the coil is horizontal after ¼ of a period (12.5 ms). As it again comes to the vertical after ½ a period (25 ms), the flux becomes maximum in the opposite direction and the rate of flux change is minimal again, so is the voltage. The pattern then inverts while the coil completes the first cycle. The second cycle is the same as the first, taking 2 periods or 100 ms. The graph could also be inverted.  	

Q	Marks	Answer	Solution
d	**2**	*Any two of the following*: use stronger magnets, use a coil of larger area, rotate the coil at a faster rate, add more loops to the coil.	
11a	**1**	[✓ **X to Y**]	Using the right hand slap rule, the fingers are the magnetic field from N to S, the palm is the upwards force and the thumb is the current which points towards Y.
b	**2**	**2.5×10^{-3} N**	$F = n\, I\, l\, B = 1 \times 2.5 \times 50 \times 10^{-2} \times 2.0 \times 10^{-3}$ $F = 2.5 \times 10^{-3}$ N
c	**2**	**1.0×10^{-4} Wb**	$\Phi = B\, A = 2.0 \times 10^{-3} \times 50 \times 10^{-2} \times 10 \times 10^{-2}$ $\Phi = 1.0 \times 10^{-4}$ Wb
12a	**2**	[✓ **B**]	The current flows from the positive terminal of the battery from points J to K. The Right hand slap rule gives the force down on JK which is indicated by the arrow B.
b	**2**	When side KL is vertical there is no force on the coil as the splits in the commutator line up with the brushes and no current flows momentarily in the coil. However, the momentum of the coil keeps it rotating.	
13a	**2**	**1.2**	$n_1 \sin\theta_1 = n_2 \sin\theta_2$ $n_1 \sin 60° = 1.00 \sin 90°$ $n_1 = \frac{1.00 \sin 90^{\circ}}{\sin 60^{\circ}} = 1.15$
b	**2**	**35°**	$n_1 \sin\theta_1 = n_2 \sin\theta_2$ $1.00 \sin \beta° = 1.15 \sin 30°$ $\beta = \sin^{-1}\left(\frac{1.15 \sin 30^{\circ}}{1.00}\right) = 35.1°$ [*conseq on answer Q13a*]
14a	**i) 1**	**1.70 m**	$\lambda = \frac{v}{f} = \frac{340}{200} = 1.70$ m
	ii) 1	**6.8×10^{-2} m**	$\lambda = \frac{v}{f} = \frac{340}{5000} = 0.068$ m

Q	Marks	Answer	Solution
b	3	**200 Hz**	The amount of diffraction depends on the $\frac{\lambda}{d}$ ratio. Since the ratio is larger for the 200 Hz sound it will diffract more than the 5000 Hz sound and more of the 200 Hz sound will reach point Y sounding louder than the small amount of the 5000 Hz sound that will reach point Y. *(ratios may be calculated but are not necessary)* *For the 200 Hz sound* $\frac{\lambda}{d} = \frac{1.7}{4.0} = 0.425$ *For the 5000 Hz sound* $\frac{\lambda}{d} = \frac{0.07}{4.0} = 0.0175$
15a	**2**	**405 nm**	$\lambda = \frac{v}{f} = \frac{3.0 \times 10^{8}}{7.4 \times 10^{14}} = 4.05 \times 10^{-7}\text{ m} = 405\text{ nm}$
b	2	According to the wave model, increasing the light intensity produces waves of higher amplitude and more energy but the same frequency. Without a higher energy no photoelectrons are released from the aluminium.	
c	2	**0.83 eV**	$E_{\text{k max}} = hf - W = 4.14 \times 10^{-15} \times 7.50 \times 10^{14} - 2.28$ $E_{\text{k max}} = 3.105 - 2.28 = 0.825\text{ eV}$
d	1	**0.83 V**	$V_0 = \frac{E_{k\,max}}{q} = \frac{0.825}{1} = 0.825\text{ V}$ [*conseq on answer Q16c*]
16a	**2**	**4.8 × 10^{-7} m**	$\lambda = \frac{h\,c}{E} = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^{8}}{2.6}$ $\lambda = 4.78 \times 10^{-7}\text{ m}$
b	1	2.6 eV is the difference between 12.8 eV at $n = 3$ and 10.2 eV at $n = 1$ 	
c	3	**12.1 eV** **1.9 eV** **10.2 eV**	$n = 2 \rightarrow n = 0$ 12.1 – 0 = 12.1 eV $n = 2 \rightarrow n = 1$ 12.1 – 10.2 = 1.9 eV $n = 1 \rightarrow n = 0$ 10.2 – 0 = 10.2 eV

Q	Marks	Answer	Solution
17a	**3**	**1.0×10^2 keV**	Assumption: The diffraction patterns are very similar so the electron and the X-rays have similar wavelengths. $\lambda_{\text{electron}} = 0.0123$ nm $E = \frac{h\,c}{\lambda} = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^{8}}{0.0123 \times 10^{-9}}$ $E = 100\ 976$ eV $= 101$ keV
b	**2**	Since the electrons undergo very similar diffraction to the X-rays in this experiment, electrons (matter) can behave like waves in certain circumstances. Electrons usually behave like particles so this experiment shows they can have a wave-particle dual behaviour depending on the circumstances.	

END OF SUGGESTED SOLUTIONS