PHYSICS
Unit 4
Trial Examination

SOLUTIONS BOOK

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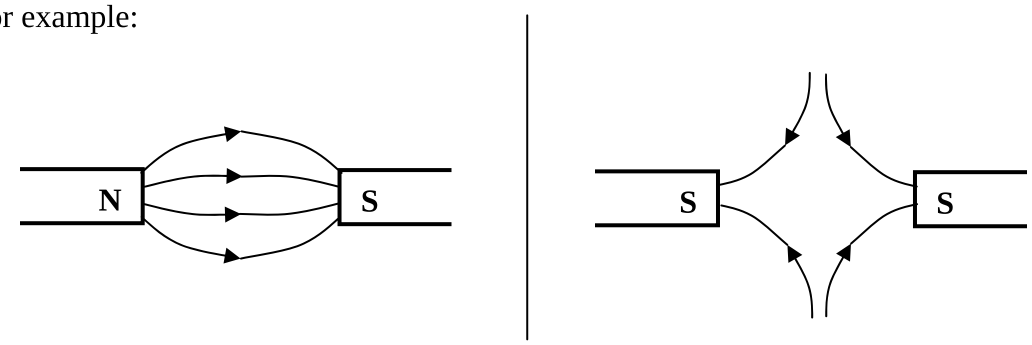
AREA 1 – ELECTRIC POWER

<table>
<tr><th>Q</th><th>Marks</th><th>Answer</th><th>Solution</th></tr>
<tr><td>1</td><td>4</td><td colspan="2">Any four correct field lines that also show the correct direction (from north to south).
For example:

</td></tr>
<tr><td>2</td><td>2</td><td>F</td><td>The field at Q due to current A will be directed into the page (right hand curl rule). The field at Q due to current B will be directed out of the page (right hand curl rule) and will be twice the size of the field due to current A (since $I_B = 2\ I_A$). The resultant field will therefore be directed out of the page, answer F.</td></tr>
<tr><td>3</td><td>2</td><td>E</td><td>The field at P due to current A will be directed into the page (right hand curl rule). The field at P due to current B will also be directed into the page (right hand curl rule). The resultant field will therefore be directed into the page, answer E.</td></tr>
<tr><td>4</td><td>2</td><td>B</td><td>Using the right hand curl rule for a solenoid, the fingers wrap the solenoid in the direction of the current and the thumb gives the north pole of the solenoid, which is end A. Therefore the SOUTH pole of the solenoid is end B.</td></tr>
<tr><td>5</td><td>2</td><td colspan="2">There are three possible methods, only two are required.
Method One: Increase the current flowing in the coils of the solenoid. (Note it is the increase in current NOT the voltage that increases the magnetic field.)
Method Two: Increase the number of coils in the solenoid.
Method Three: Insert an iron core through the centre of the solenoid.</td></tr>
<tr><td>6</td><td>2</td><td>5.5×10^{-6} Wb</td><td>flux = B A
$= 2.3 \times 10^{-3} \times 0.06 \times 0.04$
$= 5.52 \times 10^{-6}$ Wb</td></tr>
<tr><td>7</td><td>2</td><td>B</td><td>Lenz's law says the direction of the induced current will oppose the change that caused it. The change is going from having a flux to having no flux. Reinstating the flux through the coil using the right hand curl rule, the thumb points into the page and the fingers give the current direction as clockwise and therefore from B to A in side A-B.</td></tr>
</table>

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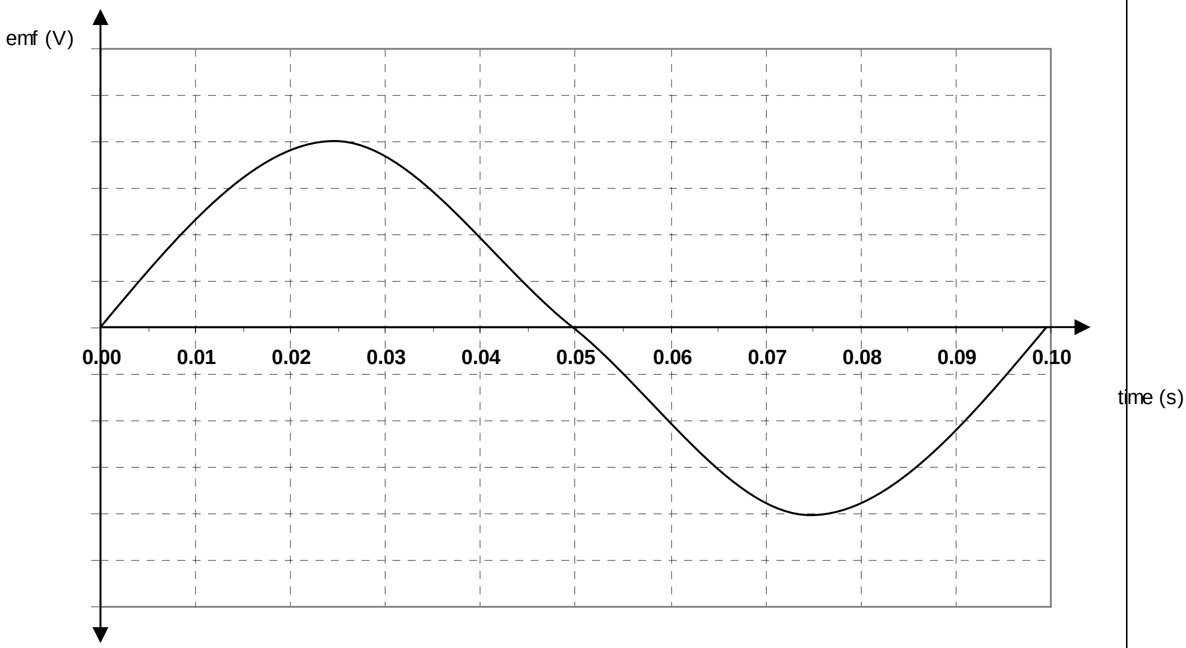
Q	Marks	Answer	Solution
8	**2**	**B**	$emf = N\dfrac{\Delta\Phi}{\Delta t} = \dfrac{1\times 5.52\times 10^{-6}}{0.1}$ = 5.52×10^{-5} V = $5.52 \times 10^{-5} \div 10^{-6}$ μV = 55 μV
9	**2**	 The *emf* graph is the negative rate of change of the flux-time graph. Flux goes from a maximum at the starting position, to zero, to a reverse maximum to zero and back to a maximum again in one full revolution. The negative rate of change of this flux graph gives the graph above or a reflection in the x-axis.	
10	**4**	<table><tr><td>Quantity</td><td>Change</td><td>Factor of change</td></tr><tr><td>Amplitude</td><td>Increase</td><td>× 20</td></tr><tr><td>Period</td><td>Decrease</td><td>÷ 2 or × ½</td></tr></table>	
11	**2**	**17 V**	$V_{RMS} = \dfrac{1}{\sqrt{2}}V_{peak}$ $\therefore\ V_{peak} = \sqrt{2} \times V_{RMS} = \sqrt{2} \times 12 = 16.97$ V
12	**1**	**iron**	Iron is usually used for the core of a transformer as it is easily magnetised.

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Q	Marks	Answer	Solution
13	**2**	The purpose of the core of a transformer is to form a magnetic link between the primary and secondary coils. As the primary AC changes, the core carries the changing magnetic field to the secondary coils where the scondary AC is induced.	
14	**2**	**100 turns**	$\frac{N_S}{N_P} = \frac{V_S}{V_P} \rightarrow N_S = \frac{N_P \times V_S}{V_P} = \frac{2000 \times 12}{240} = 100$
15	**2**	**18 W**	For 100% efficiency → power in primary = power in secondary $P = I \times V = 1.5 \times 12 = 18$ W
16	**2**	**20 A**	$P = I\,V \rightarrow I = \frac{P}{V} = \frac{100{,}000}{5000} = 20$ A
17	**3**	**9.8×10^4 W** **or** **98,000 W**	$P_{lost} = I^2 R = 20^2 \times 5 = 400 \times 5 = 2000$ W $\therefore$ P delivered to factory = 100,000 – 2000 = 98,000 W
18	**2**	**4.9×10^3 V** **or** **4900 V**	$P = I\,V \rightarrow V = \frac{P}{I} = \frac{98{,}000}{20} = 4900$ V OR $V_{lost} = I\,R = 20 \times 5 = 100$ V $\therefore$ V delivered to factory = 5000 – 100 = 4900 V

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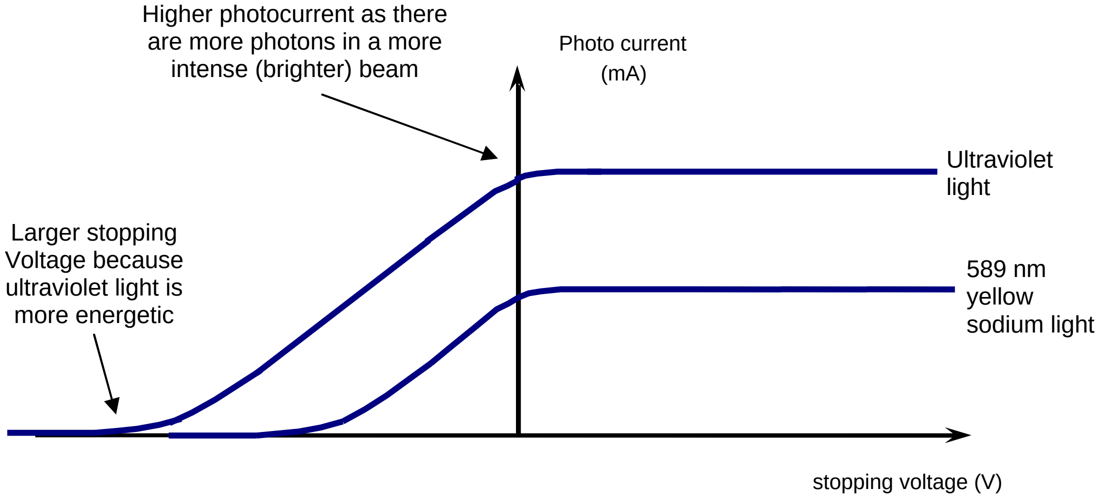
AREA 2 – INTERACTIONS OF LIGHT AND MATTER

<table>
<tr><th>Q</th><th>Marks</th><th>Answer</th><th>Solution</th></tr>
<tr><td>1</td><td>2</td><td>3.38 × 10^{–19} J</td><td>$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{589\times10^{-9}}$ = 3.3769 × 10^{-19} J</td></tr>
<tr><td>2</td><td>2</td><td colspan="2">



The new graph needs to have a higher photocurrent and a larger stopping voltage than the sodium graph.</td></tr>
<tr><td>3</td><td>2</td><td>2.6 × 10^{–19} J</td><td>$KE_{max} = E_{photons} - W = (5.7 \times 10^{-19}) - (3.1 \times 10^{-19}) = 2.6 \times 10^{-19}$ J</td></tr>
<tr><td>4</td><td>2</td><td>2.6 × 10^{–19} J</td><td>Intensity affects current, not maximum kinetic energy, hence the energy is unchanged.</td></tr>
<tr><td>5</td><td>2</td><td colspan="2">Method one: Use a metal cathode with a lower work function.
Method two: Use a light source of higher energy (or higher frequency or lower wavelength).</td></tr>
<tr><td>6</td><td>2</td><td>10.4 eV</td><td>$E = \frac{16.6\times10^{-19}}{1.6\times10^{-19}}$ = 10.375 eV</td></tr>
<tr><td>7</td><td>2</td><td>A, C, F</td><td>In order to be absorbed, photon energy must match the energy difference between states or it can be greater than the ionisation energy. The values that match the difference between levels are from the 3rd excited state to the 2nd excited state (answer A) or directly from the 2nd excited state to the ground state (answer C). Answer F is greater than the ionisation energy so the photon will be absorbed and a photo electron will be emitted with the excess energy. (3 correct = 2 marks, 2 or 1 correct = 1 mark).</td></tr>
<tr><td>8</td><td>2</td><td>n = 4</td><td>The circumference of the electron shell contains four full wavelengths, ∴ the principal quantum number, n = 4.</td></tr>
</table>

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Q	Marks	Answer	Solution
9	**2**	**883.5 nm**	The distance BD is equal to the path difference. For a nodal line, pd = (n – ½) λ where n = 2 for 2nd nodal line. pd = (2 – ½) × 589 nm = 1.5 × 589 = 883.5 nm
10	**2**	This experiment demonstrates interference and interference is a wave phenomenon. Where the waves from each slit undergo destructive interference, nodal lines (or minima or dark lines) are produced. Where the waves from each slit undergo constructive interference, antinodal lines (or maxima or bright lines) are produced.	
11	**1**	**1.65×10^{-10} m**	Since the diffraction patterns are almost identical, the de Broglie wavelength of the electrons must have been the same as the wavelength of the X-rays which was 1.65×10^{-10} m.
12	**2**	**4.0×10^{-24} kg m s^{-1}**	$p = \dfrac{h}{\lambda} = \dfrac{6.63\times10^{-34}}{1.65\times10^{-10}}$ = 4.018×10^{-24} kg m s^{-1}
13	**2**	Diffraction is a wave phenomenon. Since the electrons produced a diffraction pattern, it is possible for matter (electrons) to have wave characteristics.	

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Detailed study 1 – SYNCHROTRON AND ITS APPLICATIONS

Q	Marks	Answer	Solution
1	**2**	**5000 eV**	$KE = e\,V = 1 \times 5000$ (in eV) = 5000 eV
2	**4**	$KE = 5000\text{ eV} = 5000 \times 1.6 \times 10^{-19}\text{ J} = 8 \times 10^{-16}\text{ J}$ $KE = \frac{1}{2} m v^2 \rightarrow v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2 \times 8 \times 10^{-16}}{9.1 \times 10^{-31}}}$ $= \sqrt{1.758 \times 10^{15}}$ $= 4.19 \times 10^{7}\text{ ms}^{-1}$ $\therefore$ it is proven	
3	**2**	**Change one:** reverse the polarity of the accelerating potential. **Change two:** increase the voltage of the accelerating potential. (needs to be ~ 9000 kV)	
4	**2**	$\mathbf{4.0 \times 10^{-3}}$ **T**	$r = \frac{mv}{eB} \rightarrow B = \frac{mv}{er}$ $= \frac{9.1 \times 10^{-31} \times 4.2 \times 10^{7}}{1.6 \times 10^{-19} \times 0.06} = 3.981 \times 10^{-3}\text{ T}$
5	**5**	**E D** **A B** **C**	
6	**2**	The electric fields in the booster ring accelerate the electrons to close to the speed of light.	
7	**2**	The magnetic fields in the booster ring force the electrons to travel in circular motion.	
8	**2**	$\mathbf{3 \times 10^{16}}$ **Hz**	From the graph, the peak power occurs at a wavelength of 10^{1} nm $= 10 \times 10^{-9}$ m. $c = f\lambda \rightarrow f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{10 \times 10^{-9}} = 3 \times 10^{16}\text{ Hz}$
9	**2**	**A**	Compton scattering is inelastic $\therefore$ the scattered X-ray photons will have less energy and since $E = \frac{hc}{\lambda}$, λ will increase. Speed is unchanged as all photons travel at *c*.
10	**2**	**C**	Thomson scattering is elastic $\therefore$ the scattered X-ray photons will have no change in energy and hence no change in wavelength. Speed is unchanged as all photons travel at *c*.

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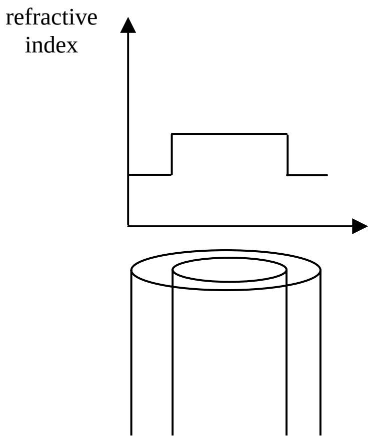
Detailed study 2 – PHOTONICS

Q	Marks	Answer	Solution
1	3	**1.38 eV** **2.21 × 10^{-19} J**	$E_{gap} = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3\times10^{8}}{900\times10^{-9}} = 1.38$ eV $E_{gap} = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{900\times10^{-9}} = 2.21\times10^{-19}$ J OR calculate one of the above and convert to the other unit using 1.6×10^{-19}.
2	2	**A**	Fixed band gap energies correspond to very unique wavelengths of light. Since a nanometre (nm) is a much smaller unit than a micrometre (μm), the range of wavelengths must be in nm and have the smallest range $\therefore$ answer A.
3	2	**helium-neon** **ruby** **or** **Nd-YAG**	The most common gas laser is the helium-neon gas mixture laser. Helium on its own is another acceptable answer. Ruby lasers used to be the most common solid-state lasers. Currently, neodymium – yttrium aluminium garnate lasers are the most common solid-state lasers.
4	2	Step-index optical fibres have a sudden difference in the refractive index at the core-cladding boundary.	
5	2	 Must be a distinct difference in refractive index from the cladding to the core (core being higher than the cladding → $n_{core} > n_{cladding}$).	

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Q	Marks	Answer	Solution
6	**2**	**lowest = 2** **highest = 3**	Higher order modes take longer to reach the far end of the optical fibre. They often have more zig-zags in their path through the fibre, $\therefore$ lowest order = pulse 2 and highest order = pulse 3.
7	**2**	**A**	The diagram in question 6 shows modal dispersion. The three pulses reach the far end of the optical fibre at different times due to the different paths they travel along the fibre. This spreads the three pulses out in time. $\therefore$ answer A.
8	**2**	**B**	Material dispersion occurs in single mode fibres ($\therefore$ not answers A or D). The small range of wavelengths all travel at slightly different speeds along the optical fibre. $\therefore$ answer B.
9	**3**	**596 nm**	$E = \frac{hc}{\lambda} \rightarrow \lambda = \frac{hc}{E} = \frac{6.63\times10^{-34}\times3\times10^{8}}{3.34\times10^{-19}}$ $= 5.955 \times 10^{-7}$ m $= 5.955 \times 10^{-7} \div 10^{-9}$ nm = 595.5 nm
10	**1**	**72**	count the circles OR 9 rows × 8 in each row = 72 pixels
11	**2**	This image was not formed by a coherent optical fibre bundle! The 72 optical fibres that produced the first image have not maintained their positions relative to each other, causing the image to be jumbled or "incoherent".	
12	**2**	**D**	Rayleigh scattering is caused by tiny particles that are smaller than the wavelength of the light. These particles take the form of small imperfections in the core of the optical fibre, $\therefore$ answer D.

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Detailed study 3 – SOUND

Q	Marks	Answer	Solution
1	2	**53 dB**	$L = 10\log_{10}\left(\frac{I}{I_0}\right)$ $= 10\log\left(\frac{2.0\times10^{-7}}{10^{-12}}\right) = 10 \times 5.3 = 53$ dB
2	3	**200 m**	Since the intensity has increased by a factor of 4 and $I \propto \frac{1}{d^2}$ → d must have halved ∴ $d = 200$ m instead of 400 m OR Since sound intensity $I \propto \frac{1}{d^2}$ → $I \times d^2 = \text{constant}$ at 400 m, constant $= 2 \times 10^{-7} \times 400^2 = 0.032$ at the new distance d, the constant will also have this value, so $0.032 = 8.0 \times 10^{-7} \times d^2$ → $d = \sqrt{\frac{0.032}{(8.0\times10^{-7})}} = 200$ m
3	2	**D**	The loud sounds occur when certain frequencies form a standing wave that resonates in the ear canal ∴ answer D.
4	3	**2.46 cm**	for a closed pipe, $f_n = \frac{nv}{4L}$ → $L = \frac{nv}{4f}$ $= \frac{1\times344}{4\times3500} = 0.02457$ m $= 0.02457 \times 100$ cm $= 2.46$ cm
5	1	**approx 50 dB**	Go up at 100 Hz to the 20 phon line, then left to the x-axis. The sound intensity level is approximately 50 dB.
6	2	**Hz dB** **~59** **~400 or ~5500**	Go up at 10,000 Hz and across at 70 dB. These two lines should intersect on the 60 phon line. The missing coordinates must also intersect on the 60 phon line in order to have the same loudness. 2000 Hz intersects the 60 phon line at approximately 59 dB. 62 dB intersects the 60 phon line at approximately 400 Hz or 5500 Hz.
7	2	**C**	The lowest pitch or frequency standing wave has the longest wavelength since $v = f\lambda$ and v is constant.
8	2	**D**	Answer C is the fundamental. Answer D is the first overtone, which for a closed pipe, is three times the fundamental frequency.

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Q	Marks	Answer	Solution
9	2	E	Answer C is the fundamental. The second resonant frequency above the fundamental is pipe E. This is the fifth harmonic. Closed tubes only resonate at odd harmonics.
10	2	D I	Four loops on a string is the fourth harmonic which is also the third overtone $\therefore$ answers I and D.
11	2	Fidelity refers to the accuracy of the microphone to reproduce the original sound. Newer microphones can reproduce human speech more accurately than older microphones.	
12	2	A	The diagram shows the positive and negative plates of a condenser (or capacitor) $\therefore$ answer A.

END OF SUGGESTED SOLUTIONS

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