Neap:

Trial Examination 2011

VCE Physics Unit 4

Written Examination

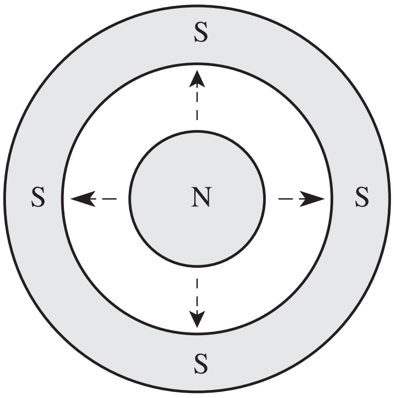
Suggested Solutions

SECTION A

Area of study 1 – Electric power

Question 1

The magnetic field lines between the poles of a bass loudspeaker magnet run from North to South as shown.



1 mark

Question 2 **F**

The direction of the magnetic force acting on the current carrying wire is out of the page (use right hand slap or left hand FBI rule). 2 marks

Question 3

$F = (N)(I)l(B)$

The length of one loop of wire $l = (2\pi)(3.0 \times 10^{-2}) = 0.188$ m 1 mark

$F = (200)(0.1)(2\pi)(3.0 \times 10^{-2}\text{ m})(1.0)$ 1 mark

$F = 3.8$ N 1 mark

Question 4 **A, B** and **C**

The designer of the bass loudspeaker requires a larger force to act on the speaker cone.

As $F = (N)(I)e(B)$, all three of the changes suggested would achieve this: Increase the current in the coil; Increase the number of turns of wire; Increase the strength of the magnetic field. 2 marks

Question 5

The RMS current being drawn by the electric kettle can be determined by using the Electric Power equation.

$$P = IV$$

$$2400\text{ W} = I \times 240\text{ V}$$

$$I = 10.0\text{ A}$$

2 marks

Question 6

The resistance of the electric kettle can be determined using Ohm's law, $V = IR$.

$240 \text{ V} = 10 \text{ A} \times R$

$R = 24 \ \Omega$ 2 marks

Note: No consequential marks from the wrong current determined in Question 5 as the resistance can also be determined from the primary data and the formula $P = \frac{V^2}{R}$.

Question 7

The magnitude of the force acting on side *PQ* is found using $F = (N)(I)l(B)$.

The first step is to determine the current using $V = IR$ which gives $I = 6.0 \text{ A}$. 1 mark

$F = (30)(6.0)(0.1)(1.0)$

$= 18 \text{ N}$ 1 mark

Question 8 **B**

The direction of the force acting on side *PQ* is: down (use right hand slap or left hand FBI rule). Note that the current needs to be determined from the battery terminals (the current runs from *P* to *Q*). 2 marks

Question 9

The function of the brushes in a DC motor is to provide a sliding electrical contact between the battery terminals and the split-ring commutator. (Carbon brushes are often used as they both conduct electricity and also minimise frictional contact between the slip-rings and the brush.) 2 marks

Question 10

The purpose of the curved magnets in the DC motor is to:

1. Provide a magnetic field for the current carrying coils of wire.
2. Create a magnetic field that is perpendicular to the current carrying coils of wire for a longer time period than a straight magnet. This improves the overall torque.

2 marks

Question 11

The magnetic flux Φ_B is given by

$\Phi_B = BA$

$= 1.8 \text{ Wb or Tm}^2$ 2 marks

Note: 1 mark for correct numerical answer and 1 mark for correct unit.

Question 12

The purpose of the slip-rings in an AC generator is to allow the alternating current produced by the generator to be connected to an external circuit. 2 marks

Question 13 **D**

The voltage variation of the AC generator as seen at V_{OUT} gives a sinusoidal graph. 2 marks

Question 14 B

The voltage variation of the generator with a single split-ring commutator as seen at V_{OUT} gives a rectified DC output. 2 marks

Question 15

The current through the carbon fibre wire when the electric blanket is set on maximum heat is

$$P = IV$$
$$60 \text{ W} = I \times 24 \text{ V}$$
$$I = 2.5 \text{ A}$$

2 marks

Question 16

0.25 A

The current drawn from the mains electricity when the electric blanket is set on maximum heat can be determined by transformer radio which in this case is 24 V : 240 V or 1:10. 2 marks

Question 17

The total resistance of the carbon fibre wire when the electric blanket is set on maximum heat can be determined by using $P = \frac{V^2}{R}$.

$$R = \frac{V^2}{P}$$
$$= \frac{(24)^2}{60} = 9.6 \ \Omega$$

2 marks

Question 18 D

For Yao to turn his electric blanket down from the maximum heat setting (HIGH) 60 W to the lowest heat setting (LOW) 15 W, the total resistance of the carbon fibre wire has to be increased by a factor of four using $P = \frac{V^2}{R}$. 2 marks

Question 19

The current in the transmission wires for a 500 MW system transmitting at 500 kV is calculated using $P = IV$.

$$5.0 \times 10^8 = I \times 5.0 \times 10^5$$
$$I = 1.0 \times 10^3 \text{ A} = 1.0 \text{ kA}$$

2 marks

Question 20

4:1

The power-loss ratio for the 500 MW electrical power being transmitted at 250 kV rather than 500 kV is calculated using $P_{LOSS} = I^2R$. The resistance of the transmission network remains constant.

As the voltage is halved, the current doubles for the same amount of power to be transmitted and therefore the P_{LOSS} increases by a factor of 4. 2 marks

Area of study 2 – Interactions of light and matter

Question 1

$p = \frac{h}{\lambda} = h\frac{f}{c}$

$= (6.63 \times 10^{-34}) \times \frac{(7.8 \times 10^{14})}{(3.0 \times 10^{8})}$ 1 mark

$= 1.7 \times 10^{-27}$ kg m s^{-1} 1 mark

Question 2

$\lambda = \frac{v}{f}$

$= \frac{3.0 \times 10^{8}}{7.8 \times 10^{14}} = 3.9 \times 10^{-7}$ m 1 mark

$\frac{\text{Path difference}}{\lambda} = \frac{5.8 \times 10^{-7}}{3.9 \times 10^{-7}} = 1.5$ so path difference $= 1.5\,\lambda$ 1 mark

Thus the point on the graph is the 2nd nodal line which is point *A*. 1 mark

Question 3

The correct answer is **A**. (See Question 4 below for explanation.) 1 mark

Question 4

Interference can only be described using a wave model. 1 mark

When the wave passes the slits, it diffracts and the two resultant circular waves interfere, causing constructive interference if they meet in phase, or destructive interference when they meet out of phase. 1 mark

Even with only one photon in the apparatus at a time, the wave-like nature of light will enable the interference pattern to be produced. 1 mark

Question 5

$E_{k(\text{max})} = qV_0 = 1.6 \times 10^{-19}$

$= 1.6 \times 10^{-19}$ J 1 mark

$E_{k(\text{max})} = hf - hf_0$ so $1.6 \times 10^{-19} = (6.63 \times 10^{-34})((7.8 \times 10^{14}) - f_0)$ 1 mark

$f_0 = 5.4 \times 10^{14}$ Hz 1 mark

Question 6

The stopping voltage will **remain the same**. 1 mark

Increasing the intensity of the light increases the number of photons and hence the number of photoelectrons emitted. 1 mark

But the energy of individual photoelectrons remains unchanged so the stopping voltage will be the same.

1 mark

Question 7

$$E_k = qV = \frac{1}{2}\text{ m } v^2$$

$(1.6 \times 10^{-19})(1.2 \times 10^3) = \frac{1}{2}(9.1 \times 10^{-31})(v^2)$ 1 mark

$v = 2.1 \times 10^7\text{ m s}^{-1}$ 1 mark

Question 8

For the X-ray photons and the electrons to produce the same diffraction pattern, they must have the same wavelength. For the electrons (and hence the photons):

$\lambda = \frac{h}{mv} = \frac{(6.63 \times 10^{-34})}{(9.1 \times 10^{-31})(2.1 \times 10^7)}$ 1 mark

$\lambda = 3.6 \times 10^{-11}$ m (Note: consequential on Question 7) 1 mark

Question 9 A

If the energy of the electrons decreases, since $E = hf = \frac{hc}{\lambda}$, then their wavelength would increase.

An increase in wavelength will lead to an increase in the amount of diffraction. 2 marks

Question 10

Photon energy:

$E = hf = \frac{hc}{\lambda}$

$= \frac{(4.14 \times 10^{-15})(3.0 \times 10^8)}{(3.5 \times 10^{-7})} = 3.54\text{ eV}$ 1 mark

For the photon to be absorbed by the sodium ion in its ground state, there must be an excited energy level in the sodium ion which is 3.54 eV higher than the ground state. 1 mark

As there is not an energy state at this level (–1.59 eV), then the photon cannot be absorbed. 1 mark

Question 11

The energy difference between the two energy levels that the photon moves between must be equal to 1.08 eV. 1 mark

From the diagram, this corresponds to $n = 3$, to $n = 2$, (3.02 – 1.94 = 1.08), so the ion was originally in the $n = 3$ state. 1 mark

SECTION B – Detailed Studies

Detailed study 1 – Synchrotron (24 marks)

Question 1 **C**

When an electron changes direction, the change in the electric field produces a changing magnetic field, which in turn induces a changing electric field, and so on. This self-propagates as electromagnetic radiation at a speed of 3.0×10^{8} m s^{-1}.

Question 2 **C**

$$F = ma = \frac{qV}{d}$$

$$(9.1 \times 10^{-31}) \times a = \frac{(1.6 \times 10^{-19})(2000)}{(0.2)}$$

$$a = 1.8 \times 10^{15} \text{ m s}^{-2}$$

Question 3 **D**

$$E = \frac{V}{d} = \frac{2000}{0.2}$$

$$= 10000 \text{ V m}^{-1} = 10000 \text{ N C}^{-1}$$

Question 4 **C**

The electrons emitted by the electron gun pass in to the linac to undergo further acceleration before moving into the booster ring and then the storage ring.

Question 5 **A**

The beamline carries the synchrotron radiation produced in the storage ring to the experimental work stations.

Question 6 **A**

Since the direction of the electron motion and the magnetic field are parallel, there is no force exerted on the electron.

Question 7 **C**

$$r = \frac{mv}{Bq}$$

$$0.15 = \frac{(9.1 \times 10^{-31})(2.0 \times 10^{6})}{B \times (1.6 \times 10^{-19})}$$

$$B = 7.6 \times 10^{-5} \text{ T}$$

Question 8 **D**

Using the right hand push rule, point thumb (current) to the right and fingers (field) upwards. This results in the palm (force) pushing out of the page.

Question 9 **B**

The undulator produces the brightest light for selected wavelengths – up to 1 million times that produced by a bending magnet, because of the constructive interference that occurs.

Question 10 **B**

For Bragg diffraction to occur, constructive interference must occur between the waves that have been reflected from subsequent layers of atoms in the crystal.

Question 11 **D**

$$2d\sin\theta = n\lambda$$

Assume $n = 1$ to start with,

$$2(1.2 \times 10^{-10})\sin(28) = 1\lambda$$

$\lambda = 6.5 \times 10^{-11}$ m – which is not one of the options.

For $n = 2$, $\lambda = 5.6 \times 10^{-11}$ (which is option **C**)

For $n = 3$, $\lambda = 3.8 \times 10^{-11}$ (which is option **B**)

For $n = 4$, $\lambda = 2.8 \times 10^{-11}$ (which is option **A**)

Hence all three options (**A**, **B** and **C**) could produce Bragg diffraction in this sample.

Question 12 **C**

When Thomson scattering occurs, the collision between the photon and a particle is elastic. As a result, the wavelength of the scattered photon is the same as the wavelength of the incident photon.

Detailed study 2 – Photonics (24 marks)

Question 1 **C**

The particular light source spectrum shown in Figure 1 is monochromatic (one specific wavelength) and therefore most likely to be produced by a laser.

Question 2 **A**

The predominant colour produced by the particular light source spectrum shown in Figure 1 is at 632.8 nm, which is in the red part of the visible spectrum.

Question 3 **C**

An LED produces its light via the spontaneous emission of photons.

Question 4 **B**

The energy gap for this tail light LED is given by $E = hf$.

$$E = (4.14 \times 10^{-15})(4.62 \times 10^{14})$$
$$= 1.91 \text{ eV}$$

Note: Make sure you use the correct value for Planck's constant.

Question 5 A

The physics principle of how an optic fibre works is total internal reflection.

Question 6 C

A high-order mode makes many internal reflections compared to a low-order mode.

Question 7 C

The critical angle for this one step-index multimode optic fibre is given by:

$$\sin\theta_C = \frac{1.48}{1.51}$$

$$\theta_C = 78.6°$$

Question 8 A

The acceptance angle for this one step-index multimode optic fibre is given by:

$$\sin\alpha = \sqrt{(1.51)^2 - (1.48)^2}$$

$$\alpha = 17.4°$$

Question 9 D

Attenuation in an optic fibre communication system is the loss of optical power of the signal along the optical fibre.

Question 10 B

The purpose of a coherent optic fibre bundle as used for medical imaging is the ability to create a precise image of the site under medical examination.

Question 11 C

The most likely reason for a significant loss of signal when an optical fibre sensor is placed under such excessive unintentional stress is that, although it does not break, it has excessive bending. The optical fibre cannot totally internally reflect all of the light as some of the incoming light has exceeded the critical angle.

Question 12 C

$$P = \frac{N\frac{hc}{\lambda}}{t}$$

$$N = \frac{P\lambda t}{hc}$$

$$= 1.28 \times 10^{16} \text{ photons per second}$$

Detailed study 3 – Sound (24 marks)

Question 1 **B**

$v = f\lambda$

$330 = 2500\ \lambda$

$\lambda = 0.13\ \text{m}$

Question 2 **D**

$\text{dB} = 10\log_{10}\left(\frac{\text{I}}{\text{I}_0}\right)$

$= 10\log_{10}\frac{(7.5 \times 10^{-4})}{(10^{-12})}$

$= 89\ \text{dB}$

Question 3 **D**

If the distance is $\frac{1}{3}$ of the original, then the intensity will be 9 times the original

(inverse square law, $\frac{\text{I}_1}{\text{I}_2} = \frac{r_2^2}{r_1^2}\Big)$.

Intensity $= 9 \times (7.5 \times 10^{-4}) = 6.8 \times 10^{-3}\ \text{W m}^{-2}$

Question 4 **C**

The loudspeaker operated because the changing current in the coil produces a magnetic field around the coil. This interacts with the magnetic field of the magnet and a force is exerted on the coil, causing it, and the cone attached to it, to move and produce the sound.

Question 5 **A**

The purpose of a port is to reduce the effects of resonance of the speaker box (baffle) by allowing waves of the resonant frequency to destructively interfere.

Question 6 **C**

The ribbon microphone has a thin strip of metal suspended between the poles of a permanent magnet. When sound waves cause the ribbon to vibrate, an EMF is induced in the ribbon.

Question 7 **B**

For a closed end pipe, $f_n = \frac{nv}{4L}$.

For the fundamental frequency:

$130 = \frac{(1 \times 330)}{4L}$

$L = 0.63\ \text{m}$

Question 8 **D**

Other frequencies that can be produced by a closed end pipe are odd multiples of the fundamental frequency. Hence the next highest frequency that can be produced is $3 \times 130\ \text{Hz} = 390\ \text{Hz}$.

Question 9 **A**

For each doubling in intensity, the sound level will increase by 3 dB. Since with four Vuvuzelas playing the intensity has doubled twice, the resultant sound level will be $120 + (2 \times 3) = 126$ dB.

Question 10 **D**

The second overtone will be the 5th harmonic $(n = 5)$. A node will be produced at the open end of the pipe and an antinode at the closed end. This corresponds to the diagram in **D** (diagram **C** is the 1st overtone or 3rd harmonic).

Question 11 **D**

The width of the coach's box (2.5 m) is approximately the same as the wavelength of the Vuvuzela sound $\left(\lambda = \frac{v}{f} = \frac{330}{130} = 2.5\ \text{m}\right)$. This means the frequency will diffract around the box and the coach will be able to hear this frequency loudly. The wavelength of the siren is much shorter than this so the sound will not diffract and the coach will not hear this as loudly. As there is a direct path to the scorer from both of the sound sources, they will appear to be approximately the same loudness for this listener.

Question 12 **A**

Anton is most sensitive to the sounds that he can detect and the lowest audible frequencies. Hence he is most sensitive to the sounds between 250 and 1000 Hz.