Neap:

Trial Examination 2012

VCE Physics Unit 4

Written Examination

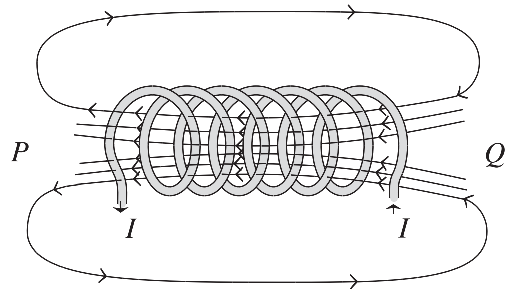
Suggested Solutions

SECTION A

Area of study 1 – Electric power

Question 1

a. The answer is *P*. The field lines point in the direction of North. Therefore *P* is North and *Q* is South.



1 mark

b. The answer is **A**. The two electromagnets attract each other as a South meets a North where they meet each other. 2 marks

Question 2

a. Each string of 6 globes in each of the parallel strings has 240 V across it. Therefore one globe has a 40 V potential difference (the 6 globes in the string being in series). 1 mark

Using $P = IV$

$10\text{ W} = I \times 40\text{ V}$

Therefore $I = 0.25\text{A}$ 1 mark

b. The resistance of globe *G* can be calculated using

$V = IR$

$40\text{ V} = 0.25 \times R$ 1 mark

Therefore $R = 160\ \Omega$. 1 mark

Note: a sensible consequential based on an incorrect answer to Question 2a, but correct working for Question 2b, can be awarded 2 marks.

c. Each string of six globes in each of the parallel strings draws 0.25 A. 1 mark

Therefore the current being drawn from the mains is $I = 3 \times 0.25 = 0.75\text{ A}$. 1 mark

d. The answer is **D**. When globe *G* fails and no longer works, the bottom row does not work (as this is a series circuit with the other five globes in series with globe *G*) but the other two rows are the same brightness as before (as they still are in parallel with the 240 V AC supply).

2 marks

Question 3

a. 0 N

Side *AD* of the coil is **parallel** to the magnetic field therefore no force. 2 marks

b. The magnitude of the force acting on side *AD* is given by

$F = NIlB$

To determine I use $V = IR$

$12 = I \times 4.0$

$I = 3.0 \text{ A}$ 1 mark

$F = (50)(3.0)(0.1)(2.0)$

$= 30 \text{ N}$ 1 mark

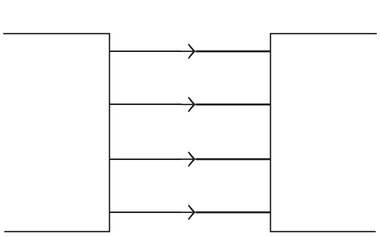
c. The answer is **B**. The direction of the force acting on side *AD* is down.

The direction of the force is given by the right-hand slap rule or the left-hand *FBI* rule. 2 marks

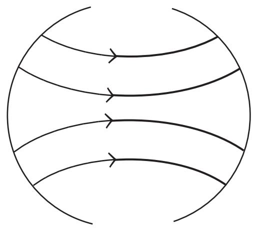
d. When the switch is closed the DC motor rotates a quarter of a cycle anticlockwise (as seen from the front) and then comes to a stop standing up vertically. 2 marks

e. The student-built DC motor could be made to work properly if a split-ring commutator was placed between the power supply and the motor. 2 marks

f. The purpose of the curved magnets in a DC motor is to provide a maximum torque for a longer period of time as the magnetic field is perpendicular to the current for a longer period of time than with a straight magnet (see diagram below).



straight pole pieces



curved pole pieces

2 marks

Question 4

a. The magnetic flux Φ_B for exactly one quarter of a rotation after the coil is parallel to the magnetic field will be the maximum magnetic flux given by

$\Phi = BA$

$= (2.0)(1.0)$ 2 marks

$= 2.0 \text{ Wb}$ 1 mark

Note: must have the correct unit Wb or T m^2 for the full 3 marks

b. The magnitude of the average emf generated by the generator in one quarter of a revolution is given by

$$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$$

$$= -\frac{(100)(2.0)}{\left(\frac{1}{40}\right)}$$

$$= -8000 \text{ V}$$

1 mark

$|\varepsilon| = 8.0$ kV 1 mark

c. The answer is **B**. The voltage variation of the DC generator with a split-ring commutator is rectified AC. 2 marks

d. The answer is **D**. The voltage variation of the generator with two slip rings will be alternating current (AC). 2 marks

Question 5

a. The current in the transmission wires can be calculated using

$P = IV$

$$I = \frac{(1.0 \times 10^4)}{250}$$

1 mark

$$= 40 \text{ A}$$

1 mark

b. The power lost in the transmission lines can be calculated using

$$p = I^2R$$

$$= (40)^2(2.0)$$

$$= 3200 \ W$$

1 mark

1 mark

c. There is a voltage drop given by $V = IR = (40)(2.0) = 80$ V across the transmission lines. 1 mark

Therefore the voltage available at the lighting system is $250 \text{ V} - 80 \text{ V} = 170 \text{ V}$. 1 mark

d. The scientists can use the 2.4 km of the same type of wire to create 4 parallel strands of wire in each direction (three new ones plus the one already there) with an equivalent total resistance of $0.5\ \Omega$. Use the parallel resistance formula for four $2.0\ \Omega$ resistors). 1 mark

This then means the power loss will be only 800 W instead of the 3200 W with the original wiring, therefore making more power available for the penguin lighting system. 1 mark

Area of study 2 – Interactions of light and matter

Question 1

a. $W = hf_0 = 4.14 \times 10^{-15} \times 4.0 \times 10^{14}$ — 1 mark

$W = 1.7$ eV — 1 mark

b. $\Delta E_k = hf - W = (4.14 \times 10^{-15} \times 6.0 \times 10^{14}) - 1.7$ — 1 mark

$\Delta E_k = 0.828 \text{ eV} = 0.828 \times 1.6 \times 10^{-19} \text{ J} = 1.3 \times 10^{-19} \text{ J}$ — 1 mark

$\Delta E_k = \frac{1}{2}m\ v^2$ so $1.3 \times 10^{-19} = \frac{1}{2} \times (9.1 \times 10^{-31}) \times v^2$ — 1 mark

$v = 5.4 \times 10^5 \text{ m s}^{-1}$ — 1 mark

c. The correct answer is **C**. — 2 marks

When the intensity of light is reduced but the frequency remains the same, there will be less photons to absorb and hence less photoelectrons ejected each second. As the frequency has not changed, the energy provided by each photon, and hence the maximum kinetic energy of the photons, will not change.

d. Each photon of light has a discrete amount of energy, $E = hf$. — 1 mark

If the photon energy is less than the minimum energy required for an electron to escape from the surface of the metal (the work function) no photoelectron will be emitted. — 1 mark

If light were a continual wave the electron could collect energy from light of any frequency until it had sufficient energy to escape, hence a wave model cannot explain this phenomena. — 1 mark

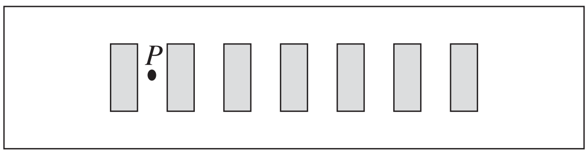
Question 2

a. $\frac{\text{path difference}}{\text{wavelength}} = \frac{1.75 \times 10^{-6}}{700 \times 10^{-9}} = 2.5$ therefore destructive interference occurs.

1 mark

$\left(n - \frac{1}{2}\right) = 2.5$ so $n = 3$, P is on the third dark band on the left side (close to S_1). — 1 mark

P drawn correctly on diagram as shown below. — 1 mark



Note: subtract 1 mark if P *is on the right of the central band rather than the left.*

b. The correct answer is **B.** — 2 marks

$\Delta x = \frac{\lambda L}{d}$ so if the wavelength is increased, the spacing of the bands will increase. This means that both light and dark bands will get wider.

c. $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{700 \times 10^{-9}}$ 1 mark

$p = 9.5 \times 10^{-28}$ kg m s^{-1} 1 mark

d. An individual photon/particle cannot cancel itself out or destructively interfere with itself, so a particle model cannot be used to explain the destructive interference. 1 mark

Interference can only be explained by a wave model so this is evidence for the wavelike nature of light. 1 mark

Question 3

The correct answers are **A** and **C.** 2 marks

For X-rays and particles to produce the same diffraction pattern, the de Broglie wavelength of the particle must be the same as the wavelength of the X-rays. Since for both particles and photons, $\lambda = \frac{h}{p}$, if the wavelength is the same then they must have the same momentum also.

Question 4

a. $\Delta E = \frac{hc}{\lambda}$

So $10.4 = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{\lambda}$ 1 mark

$\lambda = 1.2 \times 10^{-7}$ m 1 mark

b. $\Delta E = hf = (4.14 \times 10^{-15}) \times (5.0 \times 10^{7}) = 2.1$ eV 1 mark

This corresponds to the energy difference between $n = 4$ and $n = 3$ so the energy transition is from $n = 4$ to $n = 3$. 1 mark

SECTION B – Detailed Studies

Detailed study 1 – Synchrotron (24 marks)

Question 1 C

Component 1 is the linac, component 2 is the booster ring, component 3 is the storage ring and component 4 is the beamline.

Question 2 B

The storage ring is the part of the synchrotron which contains the insertion devices, causing the electrons to change direction and emit synchrotron radiation as they do so.

Question 3 B

$\Sigma F = ma = (9.1 \times 10^{-31}) \times (1.32 \times 10^{15}) = 1.2 \times 10^{-15}$ N

Question 4 B

$$E = \frac{\Delta V}{d} = \frac{F}{q} = \frac{ma}{q}$$

$$\text{so } \Delta V = \frac{mad}{q} = \frac{(9.1 \times 10^{-31}) \times (1.32 \times 10^{15}) \times (0.2)}{1.6 \times 10^{-19}}$$

$$= 1.5 \times 10^{3} \text{ V}$$

Question 5 C

$u = 0$, $v = ?$, $a = 1.32 \times 10^{15}$, $x = 0.2$ m

$v^2 = u^2 + 2ax = 0 + (2 \times 1.32 \times 10^{15}) \times 0.2$

$v = 2.3 \times 10^{7}$ m s^{-1}

Question 6 B

This can be determined using the right hand push (slap) rule. The thumb should point to the left (current direction), the palm should point up the page (force direction), results in fingers pointing out of the page (indicating the field direction).

Question 7 B

$$r = \frac{mv}{Bq} = \frac{9.1 \times 10^{-31} \times 5.0 \times 10^{7}}{2.0 \times 10^{-3} \times 1.6 \times 10^{-19}} = 0.14 \text{ m}$$

Question 8 D

If the electron beam is undeflected the field direction must be parallel to the current direction, hence it must either be to the right or the left of the page.

Question 9 D

The undulator rapidly changes the direction of electrons so that they emit energy in the form of electromagnetic radiation.

Question 10 C

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

$2 \times d \times \sin(17) = 2 \times 1.5 \times 10^{-10}$

$d = 5.1 \times 10^{-10}$ m

Question 11 B

Other maxima will be detected for angles where $n = 1, 2, 3$ etc. in the equation $2d\sin\vartheta = n\lambda$

When $n = 1$, $\vartheta = 8.5°$, when $n = 3$, $\vartheta = 26.2°$, when $n = 4$, $\vartheta = 36°$ so the only option with two of these angles is option **B**, $8.5°$ and $26.2°$.

Question 12 D

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

For the incident photons, $1.5 = \frac{4.14 \times 10^{-15} \times 3.0 \times 10^{8}}{\lambda}$

$\lambda = 8.3 \times 10^{-10}$ m

Since Compton scattering occurs, the collision is inelastic and energy is lost, so the scattered photons will have less energy and a longer wavelength than the incident photons. Thus the wavelength must be greater than 8.3×10^{-10} m, i.e. option **D**.

Detailed study 2 – Photonics (24 marks)

Question 1 B

On the list given only the laser produces coherent light.

Question 2 C

On the list given only the laser produces monochromatic light.

Question 3 B

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

Question 4 D

The energy gap for blue LED is given by $E = \frac{hc}{\lambda}$

$$E = \frac{(4.14 \times 10^{-15})(3.0 \times 10^{8})}{4.35 \times 10^{-7}} = 2.86 \text{ eV}$$

Note: Make sure the correct value for Planck's constant is used.

Question 5 C

When the current in the LED is 20 mA this means that the voltage drop across the LED is 2.0 V. Therefore there is a 4.0 V voltage drop across the resistor. Use $V = IR$ to get $R = 200\ \Omega$.

Question 6 A

Both LEDs will work but each one will shine less than *L* mW.

These two LEDs in series will have a combined voltage drop of 4.0 V across them. Therefore the resistor *R* will now only have a 2.0 V voltage drop across it. Using $V = IR$ the current will now be half of what it was originally (that is it will go from 20 mA to 10 mA) and hence the LEDs will shine less brightly than before.

Question 7 D

The optic fibre shown is a stepped-index fibre.

Question 8 B

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

$$\sin\theta_c = \frac{1.37}{1.41}$$
$$\theta_c = 76.3°$$

Question 9 D

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

$$\sin\alpha = \sqrt{1.41^2 - 1.37^2}$$
$$\alpha = 19.5°$$

Question 10 A

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

Question 11 B

The optical fibre loses half of its signal strength for every 2.0 km travelled along the optical pipe.

At a 5.0 km distance it will be $40\ \text{mW}\ (0.5)^{2.5} = 7.07\ \text{mW}$.

Question 12 **D**

Light travelling down a graded-index fibre bends as it travels through the different layers of the core. It does not reflect sharply at an intersection between the core and cladding as happens with step-index fibres, therefore *P* is a step index multimode fibre and *Q* is a graded-index multimode fibre.

Detailed study 3 – Sound (24 marks)

Question 1 **B**

The sound produced is a longitudinal wave, which means that the particle at point *P* will oscillate parallel to the direction of wave motion (left to right) at the same frequency as the wave.

Question 2 **A**

$$\lambda = \frac{v}{f} = \frac{330}{550} = 0.6 \text{ m}$$

Question 3 **B**

$$\text{dB} = 10\log_{10}\left(\frac{I}{I_0}\right) = 10\log_{10}\left(\frac{2.5 \times 10^{-7}}{10^{-12}}\right) = 54 \text{ dB}$$

Question 4 **D**

If the intensity is halved, the dB level is decreased by 3 dB. If it is halved again (so quartered in total) the dB level will decrease by another 3 dB, resulting in a total decrease of 6 dB.

Question 5 **D**

The dynamic loudspeaker operates due to electromagnetic principles. A changing current in the coil produces a changing magnetic field. This coil is wrapped around a magnet attached to the speaker cone, and the interaction of the two magnetic fields causes the speaker cone to move in and out.

Question 6 **A**

The baffle eliminates destructive interference between the waves produced by the front and back of the speaker cone, as they are out of phase. The ports produce a path difference so that for low frequencies the waves produced by the front and back of the cone meet in phase and so interfere constructively. This improves the frequency response of the speaker for low frequencies.

Question 7 **B**

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

$$360 = \frac{n \times 336}{4 \times 0.7}$$

$n = 3$ so this is f_3 or the first overtone for a closed end pipe (it can only produce the odd harmonics).

Question 8 B

For a closed end pipe, harmonics produced are for n = 1, 3, 5, 7 etc.

$$f_1 = \frac{1 \times 336}{4 \times 0.7} = 120 \text{ Hz}$$

$$f_3 = \frac{3 \times 336}{4 \times 0.7} = 360 \text{ Hz}$$

$$f_5 = \frac{5 \times 336}{4 \times 0.7} = 600 \text{ Hz}$$

$$f_7 = \frac{7 \times 336}{4 \times 0.7} = 800 \text{ Hz}$$

The only one of these that is given as an option is 120 Hz, hence option **B**.

Question 9 D

The second overtone is f_5 for a closed end pipe, and this pressure variation is shown in option **D**.

Question 10 D

The electret-condenser microphone operates on the principle of capacitance, the crystal microphone operates using the piezo-electric effect and the dynamic microphone operates using electromagnetic induction.

Question 11 A

Maximum diffraction will occur if the ratio $\frac{\lambda}{d}$ is bigger than 1, and if this occurs the sound will appear loudest to Erin.

For the 300 Hz sound, $\lambda = 1.03 \text{ m}$.

For the 1000 Hz sound, $\lambda = 0.34 \text{ m}$.

	Frequency of piano note	**Width of open doorway**	**Ratio $\frac{\lambda}{d}$**
A.	300 Hz	0.5 m	2.1
B.	1000 Hz	0.5 m	0.68
C.	300 Hz	1.5 m	0.69
D.	1000 Hz	1.5 m	0.23

Hence maximum diffraction will occur for the combination given in option **A**.

Question 12 C

Each of the curves represents sounds which are perceived equally as loud. Therefore as the 100 Hz sound at 40 dB is on the same curve as the 10 000 Hz sound at 60 dB, they will appear to have equal loudness to a person with average hearing.