Neap:

Trial Examination 2009

VCE Physics Unit 4

Written Examination

Suggested Solutions

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SECTION A – CORE

Area of study 1 – Electric power

Question 1

$V = IR$

$I = \frac{12}{10}$

$= 1.2$ A 1 mark

Question 2 **E** 2 marks

The direction of the magnetic field produced by the current carrying coil at the position Q is into the page. This is given by using the right hand grip rule and noting the direction of the current flow from the battery (conventional current from positive to negative of the battery via the circuit).

Question 3 **C** 2 marks

The strength of the magnetic field at point P will be less than the field strength at Q as the field is more concentrated at point Q.

Question 4 **C** 2 marks

The ratio of the strength of the magnetic field produced by the coil at point Q when $R = 6\ \Omega$ compared to when $R = 10\ \Omega$ is 5 : 3.

The strength of the magnetic field is proportional to the current and the current is inversely proportional to the resistance for a fixed voltage $\left(I = \frac{V}{R}\right)$.

Question 5

The peak-to-peak voltage for the iron is given by $2\sqrt{2} \times 240 = 678$ V. 1 mark

Question 6

$P = IV$

$I = \frac{2400}{440}$ 1 mark

$= 10$ A 1 mark

Question 7

$F = NIlB$

$= 50 \times 3 \times 0.05 \times 0.4$ 1 mark

$= 3.0$ N 1 mark

($V = IR$ is used to determine the current: ($12 = l \times 4$ which gives $l \times 3$)

Question 8 **E** 2 marks

The direction of the force acting on side A is into the page.

This is determined using either the left-hand FBI rule or the right-hand slap rule.

Question 9 **G** 2 marks

The direction of the force acting on side BC is zero as the current is parallel to the direction of the magnetic field.

Question 10

The purpose of the split-ring commutator in the DC motor is to reverse the current every half-cycle. 1 mark
This ensures that the coil will keep turning in the same direction. 1 mark

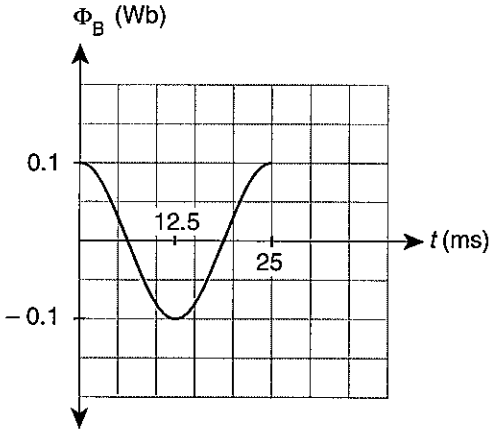
Question 11

$\Phi_B = BA$

$= 0.5 \times 0.2$ 1 mark

$= 0.1$ Wb 1 mark

Question 12



Correct graph shape 1 mark
Correct time scale 1 mark

Question 13

The purpose of the slip rings in an AC generator is to take the alternating current produced from the generator and transfer it to an external load. One slip ring is electrically connected to one side of the coil and the other slip ring to the other side of the coil. 2 marks

Question 14 **D** 2 marks

The voltage variation of the generator as seen at the CRO is AC (alternating current).

Question 15

15 (turns)

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$

$$\frac{240}{12} = \frac{300}{N_2}$$ 1 mark

$$N_2 = 15$$ 1 mark

Question 16

$$P = IV$$

$$I = \frac{30}{12}$$ 1 mark

$$= 2.5 \text{ A}$$ 1 mark

Question 17

The size downlights draw a current of 15 A (6×2.5 A).
power in = power out

$$V_1 I_1 = V_2 I_2$$

$$240 \times I_1 = 12 \times 15$$ 1 mark

$$I_1 = 0.75 \text{ A}$$ 1 mark

Question 18 **B** 2 marks

When one of the downlights malfunctions and burns out, the other five downlights keep working and the current going through the windings of transformer T_2 decreases. This is because there is less power being drawn.

Question 19

4.0×10^6 W

$$P = IV$$

$$I = \frac{5.0 \times 10^8}{5.0 \times 10^5}$$

$$= 1.0 \times 10^3$$ 1 mark

$$P_{\text{lost}} = I^2 R$$

$$= (1.0 \times 10^3)^2 \times 4$$

$$= 4.0 \times 10^6 \text{ W}$$ 1 mark

Question 20

The power is transmitted from Yallourn to Melbourne at 500 kV instead of 10 kV because there is much less power loss (0.8% power is lost). The current would go up by a factor of 50 at 10 kV transmission and the power loss by $50^2 = 2500$ ($\times$ 4 MW = 10 000 MW, which is clearly impossible as it is much more than the 500 MW that we want to transmit). 2 marks

Area of study 2 – Light and matter

Question 1

If light is modelled as a photon, it has a discrete amount of energy ($E = hf$) that can be absorbed by the electron in the metal. 1 mark

If this energy is greater than the work function, then the electron is able to escape from the metal surface as a photoelectron. 1 mark

If the wave model is applied, then an electron can continuously accumulate energy so that it eventually has enough to escape from the metal surface irrespective of the frequency of the light, but this does not happen in reality. 1 mark

Question 2

$E_{k\,(max)}$ in eV = stopping voltage in V

From graph, stopping voltage = 0.6 V

Hence $E_{k\,(max)}$ = 0.6 eV 2 marks

1 mark for value
1 mark for correct unit

Question 3

h = gradient of graph = $\dfrac{0.6}{1.4 \times 10^{14}}$ 1 mark

$h = 4.3 \times 10^{-15}$ eV s 1 mark

Question 4

The work function of the unknown metal = $hf_0 = 4.14 \times 10^{-15} \times 5.6 \times 10^{14}$ 1 mark

$W = 2.3$ eV 1 mark

hence the metal is potassium. 1 mark

Question 5

For destructive interference, $PD = \left(n - \frac{1}{2}\right)\lambda$

$765 \times 10^{-9} = \left(2 - \frac{1}{2}\right)\lambda$ 1 mark

$\lambda = 5.1 \times 10^{-7}$ m 1 mark

Question 6

$p = \dfrac{h}{\lambda} = \dfrac{6.63 \times 10^{-34}}{5.1 \times 10^{-7}}$ 1 mark

$p = 1.3 \times 10^{-27}$ kg m s^{-1} 1 mark

$Consequential\ mark = \dfrac{6.63 \times 10^{-34}}{Q5}$

Question 7 **B** 2 marks

Since $\Delta x = \frac{\lambda l}{d}$

A – lower frequency so longer wavelength would increase spacing

B – increasing d will decrease spacing

C – increasing l will increase spacing

D – reducing the intensity will reduce the brightness of the pattern but not change the spacing.

Question 8

For the same pattern to occur the de Broglie wavelength of the electron must be the same as the de Broglie wavelength of the X-ray.

$\lambda_{\text{X-ray}} = \frac{c}{f} = \frac{3 \times 10^8}{2.1 \times 10^{18}} = 1.43 \times 10^{-10}$ m 1 mark

$\lambda_{\text{X-ray}} = 1.43 \times 10^{-10} = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times v}$ 1 mark

$v = 5.1 \times 10^6$ m s^{-1} 1 mark

Question 9

The wavelength of the proton must be similar to the atomic spacing for diffraction to occur (this is the distance calculated in Question 8 of approximately 1.4×10^{-10} m). 1 mark

Since the mass of the proton is much greater than that of the electron, the de Broglie wavelength will be much smaller. 1 mark

This means that no diffraction will occur. 1 mark

Question 10 **B** and **D** 2 marks

A – this is the difference between level 2 and 3; electron is in $n = 1$ so this cannot be absorbed.

B – this is the difference between 1 and 2 so can be absorbed.

C – this is not any of the energy levels so cannot be absorbed.

D – this is greater than the ionisation energy so can be absorbed.

Question 11

highest frequency = highest energy (since $E = hf$) = 3.61 eV 1 mark

$3.61 = 6.63 \times 10^{-34} \times f$ so $f = 8.7 \times 10^{14}$ Hz 1 mark

Detailed study 1 – Synchrotron (26 marks)

Question 1 **B**

The synchrotron produces electromagnetic radiation by using magnets to bend the paths of electrons. As their path changes, they accelerate, producing a changing electric field, which in turn produces a changing magnetic field, *ad infinitum*. This electromagnetic radiation self propagates at the speed of light.

Question 2 **D**

$$E = \frac{V}{d} = \frac{40 \times 10^3}{0.5} = 8.0 \times 10^4 \text{ V m}^{-1}$$

Question 3 **C**

$$qV = \frac{1}{2}mv^2$$

$$(1.6 \times 10^{-19}) \times (40 \times 10^3) = \frac{1}{2}(9.1 \times 10^{-31}) \times v^2$$

$$v = 1.2 \times 10^8 \text{ m s}^{-1}$$

Question 4 **C**

Component	Purpose
Linac	accelerates electrons to close to the speed of light
Storage ring	uses insertion devices to bend electron path to produce synchrotron light
Beamline	acts as a path that directs radiation to its target and allows it to be tuned

Question 5 **B**

Using the right hand push rule, if the thumb points in the direction of current (upwards – opposite to electron flow) and the palm points in the direction of the force (right – towards the centre of the circle) then the fingers represent the direction of the field, and will point **out** of the page.

Question 6 **D**

$$r = \frac{mv}{Bq} = \frac{(9.1 \times 10^{-31}) \times (4 \times 10^6)}{(0.5 \times 10^{-3}) \times (1.6 \times 10^{-19})}$$

$$r = 0.046 \text{ m}$$

Question 7 **B**

$$F = qvB = (1.6 \times 10^{-19}) \times (4 \times 10^6) \times (0.5 \times 10^{-}\ ) = 3.2 \times 10^{-16} \text{ N}$$

Question 8 **D**

1.	electron gun
2.	linac
3.	booster ring
4.	storage ring

Question 9 **A**

The undulator consists of less powerful magnets than the wiggler, and this produces smaller deflections of the beam. This results in radiation that overlaps for specific wavelengths, and so is brighter for specific wavelengths. The multipole wiggler uses stronger magnets and produces a continuous spectrum of radiation that is less bright than that of the undulator.

Question 10 **B**

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

$$\sin\theta = \frac{n\lambda}{2d}$$

$$\theta = \sin^{-1}\frac{n\lambda}{2d}$$

$$= \sin^{-1}\frac{1\times(1.3\times10^{-10})}{2\times(1.6\times10^{-10})}$$

$$= 24°$$

Question 11 **A**

The main advantage of using X-rays produced by a synchrotron rather than X-rays produced in a conventional X-ray tube is that the synchrotron radiation is more intense, so it will produce a clear diffraction pattern. **B**, **C** and **D** are incorrect.

Question 12 **B**

The main difference between Thomson scattering and Compton scattering is that in Compton scattering the collisions are inelastic but in Thomson scattering they are elastic. Momentum is conserved in both types of scattering.

Question 13 **C**

When Compton scattering occurs the photon loses energy, as the collision is inelastic. This means that the scattered photon will have a lower frequency ($E = hf$) and hence a longer wavelength.

Detailed study 2 – Photonics (26 marks)

Question 1 **D**

An incandescent light source produces incoherent light because of the thermal motion of electrons.

Question 2 **D**

The term incoherent when applied to an incandescent light source means that the light emitted is out of phase.

Question 3 **C**

An LED produces light by the spontaneous emission of photons.

Question 4 **A**

The band energy gap is greater for an orange LED compared to a red LED as orange light is of a higher frequency.

Question 5 **B**

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

$$= \frac{(4.14 \times 10^{-15})(3.0 \times 10^{8})}{5.05 \times 10^{-7}}$$

$$= 2.46 \text{ eV}$$

Question 6 **B**

An optic fibre works on the principle of total internal reflection.

Question 7 **C**

$$n_1 \sin\theta_c = n_2 \sin(90°)$$

$$\theta_c = \sin^{-1}\left(\frac{1.46}{1.48}\right)$$

$$= 80.6°$$

Question 8 **C**

$$\theta_a = \sin^{-1}(\sqrt{n_1^{\,2} - n_2^{\,2}})$$

$$= \sin^{-1}(0.243)$$

$$= 14°$$

Question 9 **A**

The term multimode, as it applies to any optic fibre, is best explained as the ability to propagate more than one mode of electromagnetic radiation.

Question 10 **D**

Rayleigh scattering in relationship to an optic fibre is best explained as scattering of light due to variations in impurities in the fibre.

Question 11 **D**

The best combination of light source and optic fibre for long distance transmission of information is a single-mode optic fibre with a laser diode as the light source.

Question 12 **C**

A coherent optic fibre bundle as used for medical imaging purposes requires the individual fibres at both ends of the bundle to be in the same position relative to each other.

Question 13 **A**

An incoherent optic fibre bundle is used in medical imaging to provide the light for the area under medical investigation.

Detailed study 3 – Sound (26 marks)

Question 1 **A**

$$\lambda = \frac{v}{f} = \frac{340}{450} = 0.76 \text{ m}$$

Question 2 **C**

$$\text{dB} = 10\log_{10}\left(\frac{I}{I_0}\right) = 10\log_{10}\left(\frac{3.0 \times 10^{-2}}{10^{-12}}\right) = 105 \text{ dB}$$

Question 3 **B**

Distance has been increased by a factor 10. Since $\frac{I_1}{I_2} = \frac{r_2^2}{r_1^2}$, the intensity will decrease by a factor of 10^2 so

$$I = \frac{1}{10^2}(3.0 \times 10^{-2}) = 3.0 \times 10^{-4} \text{ W m}^{-2}$$

Or from the formula:

$$\frac{I_1}{3.0 \times 10^{-2}} = \frac{2^2}{20^2}$$

$$I_1 = 3.0 \times 10^{-4} \text{ W m}^{-2}$$

Question 4 **B**

If the intensity is doubled then the intensity level will increase by approximately 3 dB.

$$\text{dB} = 10\log_{10}\frac{2I}{I} = 10\log_{10}2 = 3 \text{ dB}$$

Question 5 **D**

Each of the curves shows equivalent perceived loudness for different frequencies compared to a reference 1000 Hz sound. From the graph 50 Hz at 80 dB has the same perceived loudness as 5000 Hz at 60 dB.

Question 6 **B**

A, C and **D** are all correct for standing waves. **B** is incorrect, as the frequency of the standing wave is the same as the frequency of the travelling wave that produced it.

Question 7 **C**

$$f_n = \frac{nv}{2l}$$

$$f_3 = \frac{3 \times 340}{2 \times 0.3} = 1700 \text{ Hz}$$

Question 8 **A**

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

If the pipe and the violin have the same frequency third harmonic,

$$\frac{nv}{2l_{\text{violin}}} = \frac{nv}{4l_{\text{pipe}}}$$

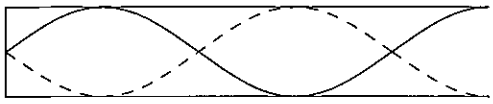
$$\frac{3 \times 340}{2 \times 0.3} = \frac{3 \times 340}{4 \times l}$$

$$0.6 = 4l$$

$$l = 0.15 \text{ m} = 15 \text{ cm}$$

Question 9 **A**

The correct diagram for the third harmonic in a closed end pipe is as follows.



Question 10 **D**

The electret condenser microphone operates using capacitance while the crystal microphone operates using the piezo-electric effect. Both the velocity and dynamic microphones utilise electromagnetic induction.

Question 11 **B**

Both the dynamic microphone and the moving coil loudspeaker consist of a cone attached to a wire coiled around a magnet. In the dynamic microphone, movements of the coil and wire relative to the magnet induce an electric current in the coil, while in the loudspeaker a changing current in the coil produces a changing magnetic field. The field interacts with the field produced by the magnet, resulting in a changing force on the wire and cone. This causes the cone to move in and out.

Question 12 **D**

The purpose of the baffle is to reduce or eliminate interference between the sound waves produced by the front and back of the speaker cone, as these will destructively interfere as they are 180° out of phase.

Question 13 D

Diffraction occurs when $\frac{\lambda}{d} \geq 1$. As the wavelength of the sound produced by the oboe is approximately equal to the width of the door ($\lambda = \frac{v}{f} = \frac{330}{320} \approx 1$), the sound waves from the oboe will diffract into the corridor. The wavelength of the sound produced by the flute is much shorter so $\frac{\lambda}{d} \leq 1$ and diffraction will not occur. This means that Max will hear the oboe more loudly than the flute. Helen is inside the classroom so neither sound will have diffracted, so they should have equal loudness as she is equidistant from each of the instruments.