Neap:

Trial Examination 2007

VCE Physics Unit 4

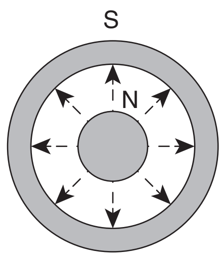
Written Examination

Suggested Solutions

SECTION A – CORE

Area of study 1 – Electric power

Question 1



2 marks

1 mark for showing north (N) in or near the inner circular magnet
1 mark for showing south (S) in or near the outer circular magnet

Question 2 **F** 2 marks

The direction of the force can be determined with the left-hand FBI rule or the right-hand slap rule.

Question 3

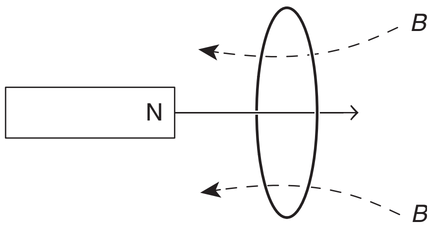
$$V_{\text{peak-to-peak}} = 2\sqrt{2}V_{\text{RMS}}$$
$$= 2\sqrt{2} \times 240$$
$$= 679 \text{ V}$$

1 mark

Question 4

$$I_{\text{RMS}} = \frac{P}{V_{\text{RMS}}}$$
$$= \frac{1800}{240}$$ 1 mark
$$= 7.5 \text{ A}$$ 1 mark

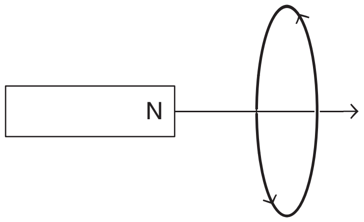
Question 5



2 marks

Note that, by Lenz's law, the induced field opposes the field producing it.

Question 6



1 mark

Consequential mark: if Q5 shows the magnetic field right to left, accept opposite current direction

Question 7

$V = IR$

$I = \frac{V}{R}$ 1 mark

$= \frac{12}{2}$

$= 6.0$ A 1 mark

Question 8

$F = NIlB$

$= 6.0 \times 0.1 \times 0.6 \times 20$ 1 mark

$= 4.3$ N 1 mark

Accept 0.4 N

Question 9 **F** 1 mark

The direction of the force on a current-carrying wire in a magnetic field can be determined with the left-hand FBI rule or the right-hand slap rule.

Question 10

There is no force acting on side *BC* as the direction of the current is the same as the direction of the magnetic field.

0 N 2 marks

Question 11 **G** 1 mark

There is no force acting on side *BC* as the direction of the current is the same as the direction of the magnetic field.

Question 12

The split-ring commutator in the DC motor reverses the current every half a cycle. 1 mark
The means that the magnetic forces acting on each side also swap over every half a cycle so that the DC motor continually keeps rotating in one direction. 2 marks
Without the split-ring commutator, the coil would turn and eventually stop at 90°. 1 mark

Accept any combination of the above to a maximum of 3 marks

Question 13

$\Phi = BA$

$= 0.1$ Wb, as the coil is parallel to the field. 1 mark

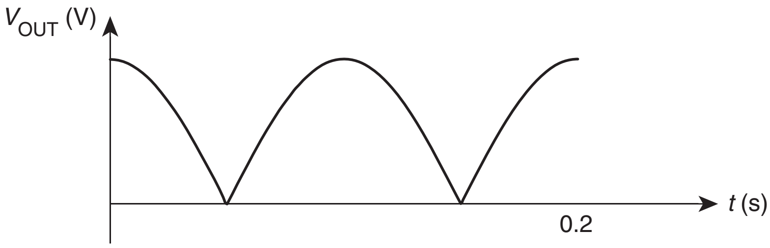
Question 14

$\varepsilon = -\dfrac{\Delta\Phi}{\Delta t}$

$= -\dfrac{0.1}{5 \times 10^{-2}}$ 1 mark

$= -2.0$ V 1 mark

Question 15



3 marks

2 marks for correct shape of graph

1 mark for correct period

Question 16

$I_{RMS} = \dfrac{P}{V_{RMS}}$

$= \dfrac{1.0 \times 10^9}{1.0 \times 10^4}$

$= 1.0 \times 10^5$ A 1 mark

$= 100$ kA 1 mark

Question 17

$n_P : n_S = V_P : V_S$

$= 10 \text{ kV} : 500 \text{ kV}$ 1 mark

$= 1 : 50$ 1 mark

Question 18

$P_{LOSS} = I^2R$

$= 2000^2 \times 4.0$ 1 mark

$= 16$ MW 1 mark

Consequential marks: $P_{LOSS} = \left(\dfrac{Q15}{50}\right)^2 \times 4.0$

Question 19

$P_{LOSS} = I^2R$

$= (1.0 \times 10^5)^2 \times 4.0$

$= 4.0 \times 10^{10}$ W

$= 40000$ MW 1 mark

The power loss is greater than the power supplied by the generator. 1 mark

All the electrical energy will be lost as Ohmic heating of the wires, and no electrical power will be available to the consumer. 1 mark

Question 20 **B, C, A** 2 marks

It is important that students first turn off the electrical equipment at the switch on the power outlet (**B**), so as not to leave a possibly dangerous piece of equipment to be touched by other students. Students should then pull out the electric cord from the power outlet (**C**), in case the electrical fault is due to faulty wiring (e.g. a single-pole switch with active–neutral incorrectly wired), in which case the equipment will be live even though turned off at the switch. Finally, students should get up, leave the equipment and walk over to tell the teacher that there may be an electrical fault (**A**).

Question 21

Outdoor use or wet location use of the transformer may involve getting it wet and hence the possibility of shorting, severe electrical shock or even electrocution if humans come into contact with the transformer. 1 mark

Opening the case will most likely expose the human user to 240 V AC mains electricity, again with the possibility of severe shock or electrocution. 1 mark

Area of study 2 – Interactions of light and matter

Question 1

Light from the sun is produced by vibration of electrons due to thermal energy (temperature). 1 mark
This light is incoherent because all the electrons vibrate independently, so the resulting light waves are not in phase with one another. 1 mark

Question 2

$E = hf$

$= 4.14 \times 10^{-15} \times 7.0 \times 10^{14}$ 1 mark

$= 2.9$ eV 1 mark

Question 3

In eV, $V_0 = E_{k_{max}} = hf - W$

$V_0 = 0.7$ V

$0.7 = 2.9 - W$ 1 mark

$W = 2.2$ eV 1 mark

Consequential mark for (Q2 – 0.7)

Question 4 C 2 marks

Halving the intensity will reduce the number of photoelectrons ejected (so the photocurrent will decrease) but the photoelectrons will still have the same amount of energy $(E_{k_{max}} = hf - W)$, so will require the same stopping voltage.

Question 5

The particle model explains this observation because if the energy of the photon $(E = hf)$ is less than the work function of the metal, each electrons will not gain enough energy from a photon to escape from the metal, so no electrons will be ejected. 1 mark
If light behaved as a wave, then electrons would be able to accumulate energy until they have enough to escape from the metal, regardless of the energy of the light. 1 mark
This does not occur, so the particle model gives a better explanation of this effect. 1 mark

Question 6

Waves from slit *P* and slit *Q* travel distances that differ by $\left(n - \frac{1}{2}\right)\lambda$ to points on the screen and hence arrive out of phase with one another. 1 mark

If the waves are out of phase, then destructive interference occurs and this produces the dark bands. 1 mark

Question 7 **B** and **C** 2 marks

*1 mark for answer **B***
*1 mark for answer **C***

The spacing between bands is $\frac{\lambda l}{d}$, with λ the wavelength, *l* the distance from the slits to the screen, and *d* the distance between the slits.
Hence the spacing can be increased by increasing the wavelength, increasing the distance from the slits to the screen or by decreasing the distance between the slits. Changing the intensity will have no effect on the spacing of the bands.

Question 8

photon momentum $= \dfrac{h}{\lambda}$

$= \dfrac{6.63 \times 10^{-34}}{2.0 \times 10^{-10}}$ 1 mark

$= 3.3 \times 10^{-24}$ kg m s^{-1} 1 mark

Question 9

If the electrons produce a similar diffraction pattern to that produced by the X-rays, then the de Broglie wavelength of the electrons is similar to the wavelength of the X-rays.

Hence, for the electrons, $\lambda = 2.0 \times 10^{-10}$. 1 mark

For electrons, $\lambda = \dfrac{h}{mv}$

$2.0 \times 10^{-10} = \dfrac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times v}$

$v = 3.6 \times 10^{6}$ m s^{-1} 1 mark

$E_k = \dfrac{1}{2}mv^2$

$= \dfrac{1}{2} \times 9.1 \times 10^{-31} \times (3.6 \times 10^{6})^2$

$= 6.0 \times 10^{-18}$ J 1 mark

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

*1 mark for answer **B***

*1 mark for answer **D***

The electrons can only jump between energy levels or ionise, so possible transitions are $n = 0$ to $n = 1$ (4.9 eV), $n = 0$ to $n = 2$ (6.7 eV), $n = 0$ to $n = 3$ (8.8 eV), or any energy greater than the ionisation energy (10.4 eV).

Question 11

Electrons exhibit both particle-like and wavelike properties, and have a de Broglie wavelength. 1 mark

Electrons can only occupy those energy levels around the nucleus where a standing wave can exist. 1 mark

The circumference of the orbit associated with the energy level must be a whole-number multiple of the electron's de Broglie wavelength, and so only particular energy levels are possible. 1 mark

SECTION B – DETAILED STUDIES

Detailed study 1 – Synchrotron and its applications

Question 1

light 1 mark
experimental station 1 mark

Question 2

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

$1.6 \times 10^{-19} \times V = \frac{1}{2} \times (9.1 \times 10^{-31}) \times (7.5 \times 10^6)^2$ 1 mark

$V = \dfrac{\frac{1}{2} \times (9.1 \times 10^{-31}) \times (7.5 \times 10^6)^2}{1.6 \times 10^{-19}}$ 1 mark

$= 160$ V 1 mark

Question 3 **B** 2 marks

After being ejected by the electron gun, electrons enter the linac (linear accelerator) for further acceleration.

Question 4 **C** 2 marks

The synchrotron radiation is produced when electrons move in a curved path, and hence are accelerating. This curved path is due to magnets and their effect on the electrons.

Question 5

$r = \frac{p}{Be}$

$= \dfrac{6.4 \times 10^{-23}}{0.7 \times 1.6 \times 10^{-19}}$ 1 mark

$= 5.7 \times 10^{-4}$ m 1 mark

Question 6

$p = mv$

$6.4 \times 10^{-23} = 9.1 \times 10^{-31} \times v$

$v = 7.0 \times 10^7$ m s^{-1} 1 mark

$F = Bev$

$= 0.7 \times 1.6 \times 10^{-19} \times 7.0 \times 10^7$ 1 mark

$= 7.9 \times 10^{-12}$ N 1 mark

To find the direction, we apply the right-hand push rule: the fingers (the magnetic field) point from left to right, the thumb (the direction of conventional current) points down, and the palm (the direction of the magnetic force) points out of the page.
The direction of the force is out of the page. 1 mark

Question 7

'Collimated' means that the beam of light does not diverge (spread out) as it travels. 1 mark

This is an advantage because it means that the intensity of the beam does not diminish as it travels along a path. 1 mark

Question 8

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

For the smallest angle, $n = 1$. 1 mark

$2 \times 2.9 \times 10^{-10} \times \sin\theta = 1 \times 2.4 \times 10^{-10}$ 1 mark

$\theta = 24.4°$ 1 mark

Question 9

For significant diffraction to occur, the wavelength of the incident light must be close to the spacing between the atoms in the crystal. 1 mark

The wavelength of the X-rays and the atom spacing are quite close to one another, so diffraction will occur. The wavelength of visible light is much larger than the atom spacing, so no diffraction will occur. 1 mark

Question 10

Description	Type of scattering
The collision between electrons and photons is elastic	**T**
The scattered photons have larger wavelengths than the incident photons.	**C**
Momentum is conserved in the collision between the electrons and the photons.	**T, C**

3 marks

1 mark for each correct answer

Thomson scattering is elastic, so the photon does not lose any energy. The wavelengths of the incident and scattered photons are the same.

Compton scattering is inelastic, so the photon loses energy in the collision. The wavelengths of the scattered photons will be larger than the wavelengths of the incident photons.

Momentum is conserved in all collisions.

Detailed study 2 – Photonics

Question 1

Forward-biased LEDs produce light by the process of spontaneous emission. 1 mark

An electron at the bottom of the conduction band (the n-type region) of a semiconductor falls into a hole at the top of the valence band (the p-type region). 1 mark

The band-gap energy, E_g, is equivalent to the energy of the electromagnetic radiation produced. 1 mark

Accept any combination of the above to a maximum of 2 marks

Question 2

Green light is of a higher frequency than red light and therefore a photon of green light has more energy than a photon of red light. 1 mark

Therefore, the band-gap energy, E_g, of a green LED must be greater than the band-gap energy of a red LED. 1 mark

Question 3

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

$$= \frac{hc}{E_g}$$

$$E_g = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{6.6 \times 10^{-7}}$$ 1 mark

$$= 1.9 \text{ eV}$$ 1 mark

Question 4

monochromatic 1 mark

coherent 1 mark

in phase 1 mark

Question 5

Laser light is particularly dangerous to our eyes. 1 mark

This is because the laser produces a highly concentrated and intense narrow-focused beam that can cause considerable damage if shone into the eyes (e.g. burning holes in the retina). 1 marks

Question 6 **D** 2 marks

The term 'total internal reflection' best describes how a light beam is transmitted through an optical fibre.

Question 7

A multimode fibre is one that can carry more than one mode of electromagnetic radiation. 2 marks

Question 8

$$n_1 \sin\theta_c = n_2 \sin 90°$$

$$\theta_c = \sin^{-1}\frac{n_2}{n_1}$$ 1 mark

$$= \sin^{-1}\frac{1.48}{1.51}$$

$$= 78.6°$$ 1 mark

Question 9

The acceptance angle is the maximum angle at which light can enter an optical fibre and still be totally internally reflected and propagate along the fibre. 2 marks

Question 10

Rayleigh scattering is the scattering of light from internal imperfections within the glass. 1 mark
The amount of Rayleigh scattering increases with increasing frequency. 1 mark
Signals of different frequencies will undergo different amounts of attenuation. 1 mark

Question 11

A coherent optical-fibre bundle is one in which the individual fibres are in the same position relative to one another at both ends of the bundle. 2 marks
This is important for medical imaging purposes so that the image transmitted through the bundle is identical to the object being examined. 1 mark

Detailed study 3 – Sound

Question 1

longitudinal 1 mark
parallel 1 mark

Question 2

$v = f\lambda$

$340 = f \times 1.2$ 1 mark

$f = 283$ Hz 1 mark

Question 3

For the fundamental in a pipe closed at one end, $\lambda = 4l$. 1 mark

Hence $l = \frac{\lambda}{4}$

$= \frac{1.2}{4}$

$= 0.3$ m 1 mark

Question 4 **D** 2 marks

Only odd harmonics are produced in a pipe that is closed at one end.

For the third harmonic $l = \frac{3\lambda}{4} = 0.9$ m and for the fifth harmonic $l = \frac{5\lambda}{4} = 1.5$ m.

The other lengths are not possible in a pipe closed at one end.

Question 5

sound intensity level $= 10\log_{10}\left(\frac{I}{I_0}\right)$

$= 10\log_{10}\left(\frac{1.8 \times 10^{-7}}{1.0 \times 10^{-12}}\right)$ 1 mark

$= 52.6$ dB 1 mark

Question 6

inverse square relationship: $\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$ 1 mark

$\frac{1.8 \times 10^{-7}}{2.0 \times 10^{-8}} = \left(\frac{r_2}{2}\right)^2$ 1 mark

$r_2 = 6.0$ m 1 mark

Question 7

$\lambda_{\text{flute}} = \frac{340}{880} = 0.4 \text{ m}$

$\lambda_{\text{clarinet}} = 1.2 \text{ m}$ 1 mark

For maximum diffraction to occur, the ratio of wavelength to gap size must be greater than or equal to one. 1 mark

$\frac{\lambda_{\text{clarinet}}}{\text{gap size}} = \frac{1.2}{1.1} > 1$

$\frac{\lambda_{\text{flute}}}{\text{gap size}} = \frac{0.4}{1.1} < 1$

At *B*, the clarinet will be louder than the flute as the sound has been diffracted by the doorway. 1 mark

At *A*, the flute will be louder than the clarinet as the sound has **not** been diffracted by the doorway. 1 mark

Question 8

Doubling the sound intensity (W m^{-2}) means that the sound intensity level (dB) will increase by about 3 dB, so the dB reading at *A* will be 33 dB. 1 mark

From the graph, the minimum sound intensity at which Merryn can hear a 50 Hz sound is approximately 50 dB. 1 mark

Hence Merryn will **not** hear the sound. 1 mark

Question 9 **C** 2 marks

The purpose of the baffle is to increase the distance between the front and the back of the speaker cone, so that the sound produced by one face of the cone does not destructively interfere with the sound produced by the other face.

Question 10

Both the dynamic loudspeaker and dynamic microphone operate using electromagnetic principles. 1 mark

In the dynamic loudspeaker, a changing current in the coil around the magnet produces a force on the magnet, causing the cone to move backwards and forwards to produce sound waves. 1 mark

In the dynamic microphone, sound waves cause the cone to vibrate, resulting in movement of the magnet with respect to the coil. The changing flux through the coil induces a changing current. 1 mark