PHYSICS

Unit 4 – Written examination 2

TSSM
Creating VCE Success

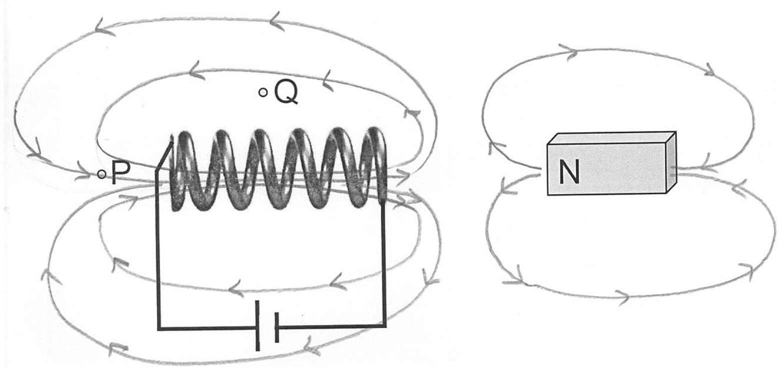
2012 Trial Examination

SOLUTIONS

SECTION A – Core
Electric Power

Question 1

Refer to pic below. Note lines should be continuous and not touch.



Question 2

Answer: **A**
Explanation: As per diagram, field lines around solenoid found through RH Grip rule. Field lines run from left to right inside the solenoid and right to left outside.

Question 3

Answer: **3.3 A, out of the page**
Explanation: Use RH Slap rule to determine direction of current at P.
$F = nBIL$

$$I = \frac{F}{nBL} = \frac{0.08}{1 \times 0.6 \times 0.04} = 3.33A$$

Question 4

Answer: **0.125 T, North**
Explanation: Use RH Slap rule to determine direction of magnetic field required for clockwise rotation. Note that L = 0.2m as the square area is 0.04 m^2.

$$F = nBIL$$

$$B = \frac{F}{nIL} = \frac{0.3}{20 \times 0.6 \times 0.2} = 0.125T$$

Question 5

F_{AB} – **stays constant**. All parameters, including the angle of wire relative to the field (constant 90^o)
F_{BC} – **increases**. The angle of the wire relative to the field increases from 0^o to ~ 30^o, thus F = BILsinθ increases.

Question 6

Answer: **Commutator should be sketched with split in vertical orientation.**
Explanation: For effective operation, the split should align with the brushes as the coil moves to a vertical position (ie. 90^o past current position). This allows the current to be reversed, force changes direction and continuous rotation ensues.

Question 7

Answer: **0 Wb**
Explanation: The angle vector of the coil is at 90^o to the magnetic field, so:
$\Phi = BA\cos\theta = BA\cos 90 = 0$. An alternate explanation is that no field lines will pass through the coil in its present position, so flux is zero.

Question 8

Answer: **0.3 s**

Explanation:

$$\xi = n\frac{\Delta\Phi}{\Delta t}$$

$$\Delta t = n\frac{\Delta\Phi}{\xi} = 10\frac{0.3 \times 0.4}{4} = 0.3s.$$

Note change in flux is equal to ***BA*** for a quarter turn as the coil moves from min to max in 90^o.

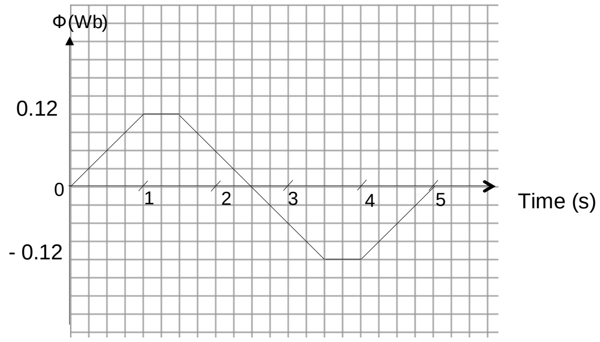
Question 9

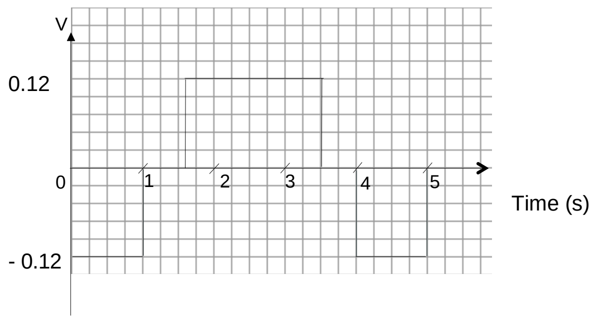
Answer: **Clockwise.**
Explanation: Increasing voltage in the solenoid leads to an increasing magnetic field to the left. As per Lenz' Law, the loop responds with an induced field to the right and corresponding clockwise current (as viewed from A using the RH grip rule).

Question 10

Answer: **As per graphs below.**
Explanation: The flux graph is proportional to the increasing field in the solenoid. The emf graph is the negative derivative $\xi = -n\frac{\Delta\Phi}{\Delta t}$, so as flux increases, there will be constant negative voltage and vice versa. Note the positive and negative gradients in the flux graph are the same, so emf values are same in magnitude, positive and negative.

$\Phi_{\max} = BA = 0.4 \times 0.3 = 0.12\,Wb$ $\quad\quad$ $\xi = -n\frac{\Delta\Phi}{\Delta t} = -1\frac{0.12}{1} = -0.12\,V$





Question 11

Answer: **162 W**
Explanation: $P_{LOSS} = I^2R = 4.5^2 \times 8 = 162\,W$

Question 12

Answer: **4964 V**
Explanation: $V_A = V_{GEN} - V_{LINE} = 5000 - IR = 5000 - 36 = 4964V$

Question 13

Answer: **B - 20:1**
Explanation: The school would most likely require voltage ~ 240-250 V, so a step down transformer would be most suitable (A or D). D is effectively a 1000:1, which would reduce the voltage to a far lower level than desirable.

For the 20:1, $V_{SCHOOL} = \frac{4964}{20} = 248V$

Question 14

Answer: **As per table.**

Parameter	Effect of new equipment
Voltage at school	Decrease
Current in transmission line	Increase
Total power supplied to school	Increase
Total power at generator site	Increase

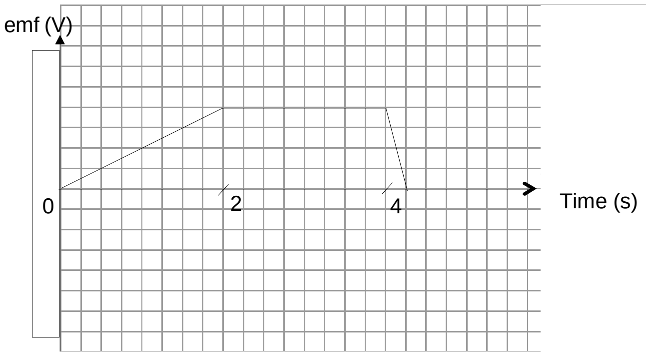
Explanation: The major effect to note here is that the voltage at the school would decrease due to the less efficient system. An increase in current in the transmission lines would lead to greater voltage losses and thus less voltage available at the end site. The power would increase (greater current demanded at both school and generator) throughout the system, although the losses would be more significant.

Question 15

Answer: **A**
Explanation: As the rod rotates, positive charge in the rod will be moving perpendicular to the magnetic field. Using the RH slap rule for a moving charge, this positive charge will be “pushed” along the rod towards Point A, thus giving a positive potential relative to Point B.

Question 16

Answer: **See graph.**
Explanation: When the mass accelerates, the speed of the rod's rotation increases and thus the voltage increases. Once the mass falls at a constant speed, a given section of the rod is moving at a constant speed (UCM from Unit 3), so the potential will be a constant DC value. A sharp negative gradient at t = 4 sec corresponds to the rapid stop in rotation.



SECTION A – Core
Interactions of Light and Matter

Question 1

Answer: **429 nm**
Explanation: With C as the centre of the pattern, X represents a point which has a path difference of 3.5 wavelengths.

$$PD = 3.5 \times \lambda = 1.5 \times 10^{-6} m$$

$$\lambda = 4.29 \times 10^{-7} m$$

Question 2

Answer: **A**
Explanation: Each of the adjustments would lead to an increase in the spacing (W) of the pattern:

$$W \alpha \frac{\lambda L}{d}$$

Question 3

Young's double slit experiment is clear evidence of the wavelike properties of light. Interaction between two sources of light that leads to a series of nodes (destructive interference) and antinodes (constructive interference) will only occur under wavelike conditions, not particle.

Question 4

Answer: **3.2 x 10^{-19} J**
Explanation: The stopping voltage V_o is shown as 2 V on the graph. This is the voltage required to stop the fastest moving electron.

$$KE = Vq = 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19} J$$

Question 5

Answer: **8.6 x 10^{-20} J**
Explanation: The work function is the energy required to liberate an electron from the metal – any excess energy from the incoming photon will be converted to KE of the electron.

$$KE = Vq = hf - W$$

$$W = hf - KE$$

$$W = 6.63 \times 10^{-34} \times \frac{3 \times 10^{8}}{490 \times 10^{-9}} - 3.2 \times 10^{-19}$$

$$W = 8.6 \times 10^{-20} J$$

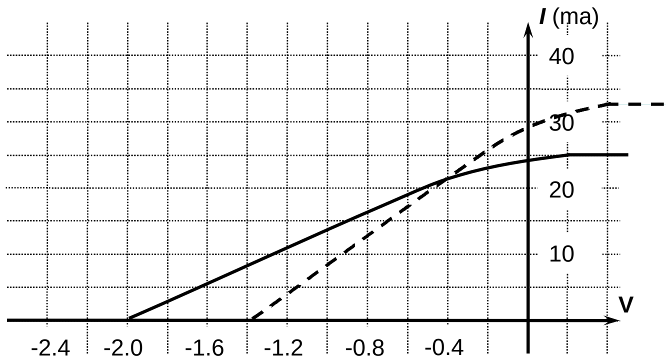
Question 6

Answer: **See diagram below**
Explanation: Reducing the frequency (*f*) of the light source will reduce the kinetic energy of the emitted electrons ($KE = hf - W$). Thus, the stopping voltage Vo will be smaller in magnitude. However, due to the same overall power requirement, there will need to be more photons per second

$E = nhf$

$n = \frac{E}{hf}$

Thus, the maximum photocurrent will increase.



Question 7

Answer: **6.14 x 10^{-11} m**
Explanation:

$\lambda = \frac{h}{\sqrt{2mKE}} = \frac{6.63\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times400\times1.6\times10^{-19}}}$

$\lambda = 6.14\times10^{-11} m$

Question 8

Answer: **2.02 x 10^{4} eV**
Explanation:

$E = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3\times10^{8}}{6.14\times10^{-11}}$

$E = 2.02\times10^{4}\, eV$

Question 9

Answer: **366 nm**
Explanation: The energy required is the difference between energy levels: 3.4 eV.

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

$\lambda = \frac{hc}{E} = \frac{4.14\times10^{-15}\times3\times10^{8}}{3.4} = 3.66\times10^{-7} m$

Question 10

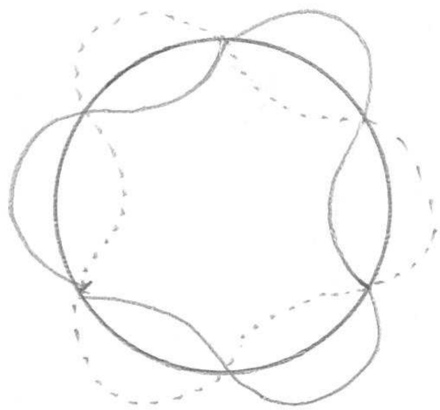
Answer: **A, C, D**
Explanation: Any transition from a higher to lower energy state below n = 4 is allowed.
A: n = 3 to n = 2
C: n = 3 to n = 1
D: n = 4 to n = 1

Question 11

The existence of discrete energy levels is evidence of the wavelike properties of electrons (matter) as they are modelled as standing waves which can only have certain wavelengths ($\lambda = n \times 2\pi r$). Discrete wavelengths leads to discrete momenta and energies for the electrons, hence discrete energy levels. The fact that electrons can transition between these levels, emitting and absorbing photons as particles supports the particle model for matter as well.

Question 12

For n = 3, there must be 3 complete wavelengths around the circumference of the atom. In the diagram below, the dotted path represents the other half of the standing wave envelope (as per standing wave convention).



SECTION B – Detailed Studies

1. Synchrotron

Question 1

Answer: **D**
Explanation: The booster ring takes fast electrons from the linac and accelerates them further before injecting them into the storage ring.

Question 2

Answer: **B**
Explanation: The beam line runs from the storage ring to the experimental stations

Question 3

Answer: **B**

Explanation:
$$W = E_k = eV$$
$$\Rightarrow V = \frac{0.5mv^2}{e} = \frac{0.5\times 9.1\times 10^{-31}\times (1.2\times 10^{7})^2}{1.6\times 10^{-19}} = 409.5V$$

Question 4

Answer: **D**
Explanation: $v = \frac{RBq}{m} = \frac{0.1\times 4.2\times 10^{-3}\times 1.6\times 10^{-19}}{9.1\times 10^{-31}} = 7.38\times 10^{7}\ ms^{-1}$

Question 5

Answer: **D**
Explanation: Use the RH slap rule for moving charge, ensuring that the "current" is moving in the opposite direction to the negatively charged electron.

Question 6

Answer: **B**
Explanation: Synchrotron, then laser are significantly more intense sources than the tube.

Question 7

Answer: **A**
Explanation: Synchrotron radiation is emitted as the electrons change direction, not speed. The magnetic force effect on the moving charges is achieved by the undulators and wigglers.

Question 8

Answer: **A**

Explanation: $\lambda = \frac{hc}{E} = \frac{4.14\times10^{-15}\times3\times10^{8}}{3.6\times10^{3}} = 3.45\times10^{-10}\,m = 0.345nm$

Question 9

Answer: **D**

Explanation: $\lambda = \frac{2d\sin\theta}{n} = \frac{2\times4\times10^{-9}\sin(21^{o})}{1} = 2.8\times10^{-9}\,m$

Question 10

Answer: **A**

Explanation: $\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right) = \frac{2\times2.8\times10^{-9}}{2\times4\times10^{-9}} = 45^{o}$

Question 11

Answer: **B**

Explanation:

$$hf_{in} = hf_{out} + 0.5mv^2$$

$$f_{out} = \frac{hf_{in} - 0.5mv^2}{h}$$

$$f_{out} = \frac{6.63\times10^{-34}\times1.5\times10^{18} - 0.5\times9.1\times10^{-31}\times\left(1.1\times10^{7}\right)^2}{6.63\times10^{-34}}$$

$$f_{out} = 1.42\times10^{18}\,Hz$$

Question 12

Answer: **B**
Explanation: Thomson scattering, by defintion, occurs when a photon interacts without loss of energy or change in frequency. An example is Bragg Diffraction.

SECTION B – Detailed Studies
2. Photonics

Question 1

Answer: **B**
Explanation: LED sources are relatively narrow (30 – 70 nm) and incoherent (laser is coherent).

Question 2

Answer: **A**
Explanation: Mercury gas discharge tubes are similar to common fluorescent tubes used at home.

Question 3

Answer: **C**
Explanation: $\lambda = \frac{hc}{E} = \frac{4.14\times10^{-15}\times3\times10^{8}}{2.4} = 5.18\times10^{-7}\,m$

Question 4

Answer: **C**
Explanation: Higher frequency means higher band gap, so blue has the greatest.

Question 5

Answer: **C**
Explanation: The LED has a voltage drop of 2.1 V, whilst the resistor used in the ohmic calculation has 3.9 V.

$$I = \frac{V}{R} = \frac{3.9}{200} = 0.0195\,A$$

Question 6

Answer: **A**
Explanation: $P = VI = 2.1\times0.0195 = 0.041\,W$

Question 7

Answer: **C**
Explanation: The addition of the second LED in parallel will decrease the brightness of the original LED as the current will now be shared by both LEDs without any increase in voltage. Thus power (brightness) will be less than in the original scenario.

Question 8

Answer: **A**

Explanation:
$$n_1 \sin\theta_c = n_2 \sin 90^o$$
$$n_2 = 1.45 \times \sin(80.5^o) = 1.43$$

Question 9

Answer: **B**

Explanation:
$$\sin\alpha = \sqrt{n_1^2 - n_2^2}$$
$$\alpha = \sin^{-1}(\sqrt{1.45^2 - 1.43^2}$$
$$\alpha = 14^o$$

Question 10

Answer: **A**
Explanation: Rayleigh scattering is most significant for lower wavelengths (ie. higher frequencies) such as blue light.

Question 11

Answer: **A**
Explanation: Step index, multimode fibres are very vulnerable to modal dispersion over longer distances, making them better suited to short range computer networks.

Question 12

Answer: **A**
Explanation:
$$P = P_o \times (1-a)^n$$
$$1-a = \sqrt[n]{\frac{P}{P_o}}$$
$$1-a = \sqrt[4]{\frac{6}{10}}$$
$$1-a = 0.88$$
$$a = 0.12$$
Where n = number of km, a = loss rate. This implies that there are losses of 1 – 0.88 = 12% acting on each km of fibre.

SECTION B – Detailed Studies
3. Sound

Question 1

Answer: **B**

Explanation: Period = 4 x 10^{-3} s (from graph). $f = \frac{1}{T} = \frac{1}{0.004} = 250\,Hz$

$\lambda = \frac{v}{f} = \frac{240}{250} = 0.96\,m$

Question 2

Answer: **A**
Explanation: 0.48 m represents half a wavelength in distance. After, t = 2 ms the initial pulse would have moved forward so that the displacement is at 0.0 m.

Question 3

Answer: **D**

Explanation: t = 2.5 ms represents slightly less than 1 period ($T = \frac{1}{f} = \frac{1}{340} = 2.9\,ms$). As a result, the pressure would increase, but not completely to the maximum compression initially shown at P.

Question 4

Answer: **C**
Explanation: 300 Hz at 65 dB is on the 60 phon.
A: 50 Hz at 70 dB is on the 50 phon – less loud
B: 100 Hz at 70 dB is on the 60 phon – equally loud
D: 20 Hz at 80 dB is on the 50 phon – less loud

Question 5

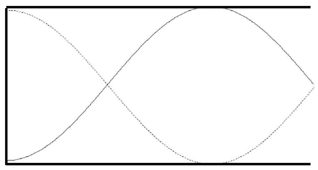
Answer: **B**

Explanation: First quiet point corresponds to the first node, which implies a wavelength of $\lambda = \frac{4L}{3}$

So the resonant frequency is $f = \frac{3v}{4L} = \frac{3 \times 340}{4 \times 2.4} = 106\,Hz$

Question 6

Answer: **C**
Explanation: With a node at one-third along the tube closed at one end, this is the third harmonic.



Question 7

Answer: **A**
Explanation: When dealing with resonance in a tube, frequency is proportional to the speed of sound in a medium: $f_o = \frac{v}{4L}$

Question 8

Answer: **A**
Explanation: The baffle increases the path length from the front to the back of the speaker, so there is less destructive interference between postive and negative pressure regions.

Question 9

Answer: **D**
Explanation: A 20 dB decrease in sound intensity level implies a 100 fold decrease in intensity. Using inverse square law, this would require an increase in distance of 10^2, so d_2 = 5 x 10 = 50 m.
Alternatively:

$$I_1 = 10^{\frac{L_1}{10}-12} = 3.16\times10^{-3}$$

$$I_2 = 10^{\frac{L_2}{10}-12} = 3.16\times10^{-5}$$

$$d_2 = \sqrt{d_1^2 \times \frac{I_1}{I_2}} = \sqrt{5^2 \times 100} = 50\,m$$

Question 10

Answer: **B**
Explanation: Assume sound from the elevated point source spreads in three dimensions (ie. spherically).

$$P = IA = 3.16\times10^{-3}\times\left(4\pi\times5^2\right) = 0.993W$$

Question 11

Answer: **A**
Explanation: Reducing the width of the gap in the curtain will increase the level of diffraction and thus the intensity for an observer positioned off the centre line will increase. $Diffraction\ \alpha\ \frac{\lambda}{w}$

Question 12

Answer: **B**
Explanation: Both velocity (aka ribbon) and the dynamic microphone use principles of electromagnetic induction in their operation. Crystal microphones use the polarity of crystals and electret relies on capacitive effects.