PHYSICS

Unit 4 – Written examination 2

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2010 Trial Examination

SOLUTIONS

SECTION A – Core

Area of Study 1- Electric Power

Question 1

Answer: **B**

Explanation: Using the RH grip rule for current in Cable A

Question 2

Answer: 0.48 T, directed out of the page

Explanation: Using the RH slap rule for current, force on Cable A

$$F = BIL$$

$$B = \frac{F}{IL}$$

$$B = \frac{0.12}{2.5 \times 0.1}$$

$$B = 0.48\,T$$

Question 3

Answer: Attracted

Explanation: Using the RH grip rule, the magnetic field out of the page at Cable A implies that the current through B must also be directed up. Using the RH slap rule for this current and the field due to Cable A (into the page) results in a force on B directed left. Thus cables are attracted to one another.

Question 4

Answer: 0.009 N EAST

Explanation: Current flows from C to B, within a field directed South. RH slap rule results in a force directed east.

$$F = BIL$$
$$F = 0.2 \times 0.03 \times 1.5$$
$$F = 0.009\, N$$

Question 5

Answer: **D**

Explanation: The loop is rotating, but the current, length and magnetic field remain constant for side CD, so the force will not change.

Question 6

Answer: Commutator. Only this device would be able to change the direction of the DC source so that the force on sides CD and AB reverses every 180^{o} and ensures continuous rotation.

Question 7

Answer: **C** See Q.8

Question 8

Answer:
With the switch disconnected, the flux through the secondary coil is zero.
When the switch is connected, the primary coil creates a magnetic field in the core directed to the left.
This left field means that the flux is now directed to the right in the secondary coil.
The secondary coil induces a current and an associated opposing magnetic field to the left.
This current must therefore be from A to B across the load.
Note that once the switch has been connected and there is no more change to the system, the current will not continue in the secondary coil (which is why AC is required for ordinary transformers).

Question 9

Answer: 10 A

Explanation: Use the voltage drop in the cables.

$$V = IR$$
$$I = \frac{V}{R}$$
$$I = \frac{50}{5}$$
$$I = 10\, A$$

Question 10

Answer: 300 turns

Explanation: Current at the generator is 10000/250 = 40 A. Current in the lines is 10 A. Thus the transformer is a step-up in the ratio of 1:4

$$\frac{1}{4} = \frac{n}{1200}$$
$$n = 300$$

Question 11

Answer: 237.5 V

Explanation:

$$V_{prim\,step-down} = 250 \times 4 - 50 = 950\,V$$
$$V_{\sec step-down} = \frac{950}{4} = 237.5\,V$$

Question 12

Answer: **D**

Explanation: A is incorrect as this would reduce voltage loss. B is incorrect as this would increase transmission voltage and reduce transmission current – reducing voltage loss and power loss. C is incorrect as this would reduce the current demand in the transmission lines, reducing voltage loss.

Question 13

Answer: 707 V

Explanation:

$$V_{p-p} = 2\sqrt{2} \times V_{RMS}$$
$$V_{p-p} = 2\sqrt{2} \times 250$$
$$V_{p-p} = 707\,V$$

Question 14

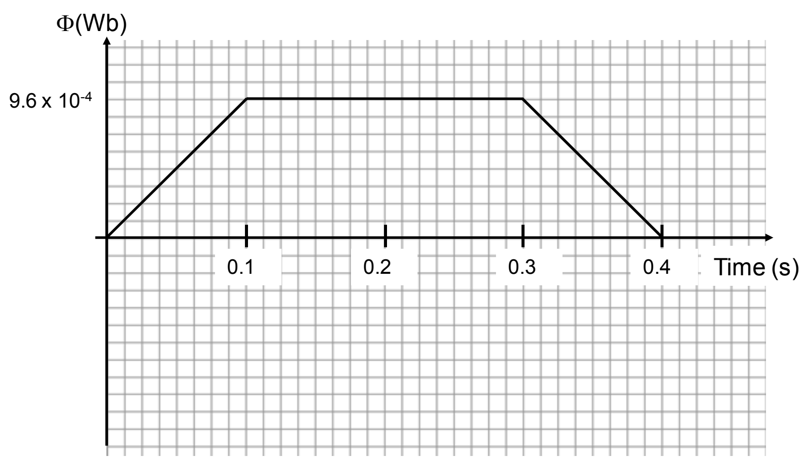
Answer: 113 A

Explanation:

$$I_{RMS} = \frac{P}{V_{RMS}}$$
$$I_{RMS} = 40\ A$$
$$I_{p-p} = 2\sqrt{2} \times I_{RMS}$$
$$I_{p-p} = 2\sqrt{2} \times 40$$
$$I_{p-p} = 113\ A$$

Question 15

Answer: See graph below:



Question 16

Answer: 9.6×10^{-3} V

Explanation:

$$emf = n\left|\frac{\Delta\varphi}{\Delta t}\right|$$
$$emf = 1 \times \frac{9.6 \times 10^{-4}}{0.1}$$
$$emf = 9.6 \times 10^{-3}\ V$$

Area of Study 2 – Light and Matter

Question 1

Answer: 4

Explanation: A path difference of 2.5 μm represents 4λ, based on the wavelength of the source. So, 4 dark bands (nodes) would be crossed, corresponding to path differences of: 0.5λ, 1.5λ, 2.5λ & 3.5λ

Question 2

Answer: When the path difference between Slit 1 and Slit 2 is a half integer multiple of the wavelength (e.g. 1.5λ), the sources will arrive at the screen out of phase and complete destructive interference will result, leading to a dark band.

Question 3

Answer: **A and C**

Explanation: B is incorrect as this would lead to a widening of the pattern. D is incorrect as the spacing of the pattern is independent of the intensity of the source.

Question 4

Answer: **A**

Explanation: 0.38 eV is the only energy that cannot be derived from a drop from a given excited state to a lower energy state.

Question 5

Answer: **B**

Explanation:
Use $E = \frac{hc}{\lambda}$
A represents a jump from ground to 1st excited state (1.63 eV). **C** represents a jump from ground to 3rd excited state (2.85 eV). **D** represents a photon with enough energy to ionize the atom (3.82 eV)

Question 6

Answer: Electrons can be considered as particles in terms of the way they make transitions between energy levels in an atom. However, they must also be considered to have wavelike properties as they can only exist as standing waves with only discrete wavelengths feasible to form an excited state. Discrete wavelengths correspond to discrete momenta, which implies discrete energy levels around the nucleus.

Question 7

Answer: Both electrons and x-rays will diffract in similar ways, as long as the de Broglie wavelength of the electron is comparable to that of the x-rays. For the electrons: $\lambda = \frac{h}{p} = \frac{h}{mv}$. Assuming both are directed towards a similar sized gap or obstacle, the ratio: $\frac{\lambda}{w}$ will dictate the extent of the diffraction.

Question 8

Answer: **5.02 x 10^{-2} nm**

Explanation:

$$KE = Vq$$
$$KE = 600 \times 1.6 \times 10^{-19}$$
$$KE = 9.6 \times 10^{-17}\ J$$

$$p = \sqrt{2mKE}$$
$$p = \sqrt{2 \times 9.1 \times 10^{-31} \times 9.6 \times 10^{-17}}$$
$$p = 1.32 \times 10^{-23}\ kg\ m\ s^{-1}$$

$$\lambda = \frac{h}{p}$$
$$\lambda = \frac{6.63 \times 10^{-34}}{1.32 \times 10^{-23}}$$
$$\lambda = 5.02 \times 10^{-11}\ m$$

Question 9

Answer: **3.96 x 10^{-15} J**

Explanation:

$$\lambda = 5.01 \times 10^{-11}\ m$$
$$E = \frac{hc}{\lambda}$$
$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{5.02 \times 10^{-11}}$$
$$E = 3.96 \times 10^{-15}\ J$$

Question 10

Answer: **7.7 x 10^5 m s^{-1}**

Explanation:

$$KE = Vq$$
$$KE = 1.7 \times 1.6 \times 10^{-19}$$
$$v = \sqrt{\frac{2 \times 1.7 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}}$$
$$v = 7.7 \times 10^{5}\ m\,s^{-1}$$

Question 11

Answer: **1.90 x 10^{14}** Hz

Explanation: Photoelectric effect states:

$$Vq = hf - hf_0$$
$$f_0 = \frac{hf - Vq}{h}$$
$$f_0 = \frac{6.63 \times 10^{-34} \times 6 \times 10^{14} - 1.7 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}$$
$$f_0 = 1.90 \times 10^{14}\ Hz$$

Question 12

Answer: **C and D**

Explanation: **A** is incorrect as, according to the photon model, the intensity of the source is proportional to the number of photons. Hence the photocurrent is proportional to the intensity, not the energy that the photons can impart to the electrons.
B is incorrect as the photoelectric effect clearly demonstrates that there is no time delay for ejection of electrons, once the threshold frequency has been passed.

Detailed Study 1 – Synchrotron and applications

Question 1

Answer: **C**

Explanation: **A** is incorrect as x-rays have higher divergence than synchrotron radiation. **B** is incorrect as x-rays are less intense. **D** is incorrect as x-rays are less easily tuneable.

Question 2

Answer: **D**

Explanation:

$$KE = Vq$$
$$KE = \frac{1}{2}mv^2$$
$$KE = \frac{1}{2} \times 9.1 \times 10^{-31} \times \left(2.2 \times 10^7\right)^2$$
$$KE = 2.2 \times 10^{-16}\,J$$
$$Vq = 2.2 \times 10^{-16}$$
$$V = 1.38\,kV$$

Question 3

Answer: **B**

Explanation: Using the RH slap rule, with current from right to left due to the motion of the electron.

Question 4

Answer: **B**

Explanation:

$$F = qvB$$
$$v = \frac{1.9 \times 10^{-13}}{1.6 \times 10^{-19} \times 0.15}$$
$$v = 7.9 \times 10^6\,m\,s^{-1}$$

Question 5

Answer: **D**

Explanation:

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

$$r = \frac{9.1\times10^{-31}\times7.9\times10^{6}}{1.6\times10^{-19}\times0.15}$$

$$r = 3.0\times10^{-4}\ m$$

Question 6

Answer: **D**

Explanation: D is the best answer, with values most closely approximating operational characteristics.

Question 7

Answer: **B**

Explanation: The booster ring's purpose is to increase the energy of the electrons (hence, booster). However, relativistic effects mean that at speeds approaching light speed, much of the energy effectively increases the mass of the electrons, rather than their speed.

Question 8

Answer: **B**

Explanation: B is the only valid choice.

Question 9

Answer: **A**

Explanation: Radiation is definitely emitted progressively, rather than in discrete bursts. The direction is likened to that of water being flung from a wet tennis ball – that is, tangentially to the path of the electrons.

Question 10

Answer: **A**

Explanation: Wigglers produce a wide, powerful beam of radiation. Alternating the polarity of the magnets (that is, N to S) is key to their operation.

Question 11

Answer: **B**

Explanation: Compton scattering is elastic, with the scattered photon increasing in wavelength. By contrast, Thomson scattering is also elastic, but with no change in wavelength (as in Bragg diffraction)

Question 12

Answer: **B**

Explanation: Path difference is the key to this question as the x-rays travel different distances depending on their entry and exit from the lattice. The path difference will lead to constructive interference (bright antinodes) or destructive interference (dark nodes), which can be detected.

Question 13

Answer: **A**

Explanation: Using Bragg diffraction

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

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

$$d = \frac{3\times 0.2\times 10^{-9}}{2\sin 51^o}$$

$$d = 3.86\times 10^{-10}\ m$$

Detailed Study 2 – Photonics

Question 1

Answer: **C**

Explanation: All are correct but C, because the energy of the photons is proportional to its wavelength, not the intensity of the source.

Question 2

Answer: **C**

Explanation:

$$E = \frac{hc}{\lambda}$$
$$E = \frac{4.14\times10^{-15}\times3\times10^{8}}{600\times10^{-9}}$$
$$E = 2.1eV$$

Question 3

Answer: **C**

Explanation: Incoherent refers to the out of phase nature of the emitted photons. C is the best explanation for this.

Question 4

Answer: **B**

Explanation: Apply Snell's law at the critical angle

$$n_{core}\sin i = n_{clad}\sin r$$
$$n_{core} = \frac{n_{clad}\sin r}{\sin i}$$
$$n_{core} = \frac{1.47\sin 90}{\sin 82}$$
$$n_{core} = 1.484$$

Question 5

Answer: **B**

Explanation: If the medium outside the fibre was to increase in optical density, we would expect a reduction in the amount of refraction as the source enters the fibre. Thus, β would decrease.

Question 6

Answer: **A**

Explanation: Rayleigh scattering is most significant for shorter wavelengths

Question 7

Answer: **A**

Explanation: Increased attenuation would increase the costs of the long distance network and reduce its effectiveness, so 0.9 μm would be least suitable.

Question 8

Answer: **C**

Explanation: Rayleigh scattering is most significant for shorter wavelengths

Question 9

Answer: **D**

Explanation: By definition, a LASER source is coherent and monochromatic. This also leads to very low divergence, which is ideal for practical use.

Question 10

Answer: **D**

Explanation: Given that the system is multimodal, the best way to reduce modal dispersion is to use graded-index fibre, thus improving the smoothness of the paths through the fibre.

Question 11

Answer: **C**

Explanation: Material dispersion is due to the behaviour of different wavelengths. A laser operates with a narrower spectrum of wavelengths, so is less prone to material dispersion.

Question 12

Answer: **D**

Explanation: Reducing the diameter and using graded-index fibres are two options for reducing modal dispersion. Of course, using a single mode fibre would be even better!

Question 13

Answer: **C**

Explanation: Coherent illuminating bundles are not required as it does not matter if the fibre bundle is mixed and crosses over as it carries a light source to the patient. Images returning from the patient must be carried by a coherent bundle, however, to ensure accurate pictures are transmitted.

Detailed Study 3 - Sound

Question 1

Answer: **C**

Explanation:

$$f = \frac{1}{T}$$
$$f = \frac{1}{0.002}$$
$$f = 500\,Hz$$

Question 2

Answer: **A**

Explanation:

$$v = f\lambda$$
$$\lambda = \frac{v}{f}$$
$$\lambda = \frac{340}{500}$$
$$\lambda = 0.68m$$

Question 3

Answer: **A**

Explanation: Sound is transmitted as a longitudinal wave, so the candle will oscillate along the x-axis.

Question 4

Answer: **B**

Explanation: The extent of diffraction is determined by the ratio of λ/w. In this case $\lambda_{2\ ms}$ = 0.68 m, $\lambda_{1\ ms}$ = 0.34 m. So the 1 ms signal would diffract less, but both signals would still diffract significantly as the width is only 0.2 m.

Question 5

Answer: **D**

Explanation: For two sounds to be perceived equally loudly it must be located on the same phon, regardless of the dB or frequency. Only D satisfies this condition. C is incorrect as 52 dB at 4000 Hz is actually on a higher phon than 70 dB at 40 Hz.

Question 6

Answer: **D**

Explanation: Using the surface area of a sphere, radius 12 m.

$$P = I \times A$$
$$P = 1.2 \times 10^{-2} \times 4\pi \times 12^2$$
$$P = 21.7\,W$$

Question 7

Answer: **C**

Explanation: A decrease of 6 dB results from a decrease in intensity by a factor of 4 (each 3 dB increase is half I). Employing the inverse square law for distance and intensity, this must mean that the distance has doubled.

Question 8

Answer: **C**

Explanation: For a fundamental frequency of 134 Hz, the only valid option is 268 Hz (2nd harmonic). None of the others are whole number multiples of f_0

Question 9

Answer: **C**

Explanation: For a tube open at both ends

$$f_0 = \frac{v}{2L}$$
$$v = 2Lf_o$$
$$v = 2 \times 1.27 \times 134$$
$$v = 340\,m\,s^{-1}$$

Question 10

Answer: **A**

Explanation: The second resonant frequency above the fundamental is the fifth harmonic for an open-closed system. 0.8 m along the tube would correspond to an antinode, so the pressure variation would be maximized. At one point, the pressure would be well above atmospheric (compression), while half a period later, it would be well below (rarefaction).

Question 11

Answer: **C**

Explanation: The second resonant frequency above the fundamental is the fifth harmonic for an open-closed system. This corresponds to a wavelength of 1.6 m, and a frequency of 212.5 Hz
(closest to 213 Hz)

$$f_5 = \frac{5v}{4L}$$
$$f_5 = \frac{5 \times 340}{4 \times 2}$$
$$f_5 = 212.5\,Hz$$

Question 12

Answer: **B**

Explanation: A baffle reduces the interaction between out of phase waves in front and behind the speaker.

Question 13

Answer: **A**

Explanation: High fidelity requires a flat response curve. Human speech would be acceptable between 400 – 4000 Hz