PHYSICS

Unit 4 – Written examination 2

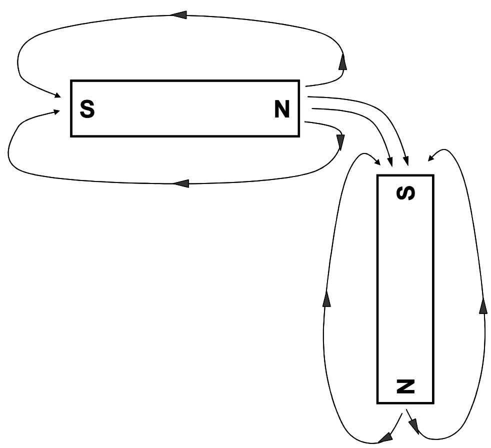
2008 Trial Examination

SOLUTIONS

SECTION A – Core

Area of Study 1- Electric Power

Question 1



Field lines must be continuous, starting from a North pole and finishing at a South pole.

Question 2

Answer: D

Explanation: Use RH Grip rule for the wire

Question 3

Answer: 90 turns.

Explanation: Use

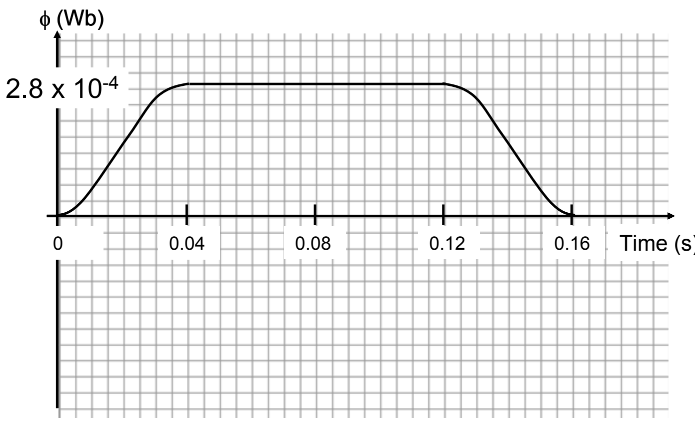
$$F = nBIL$$
$$8.1\times10^{-2} = n\times0.3\times0.03\times0.1$$
$$n = 90\,turns$$

Question 4

FORCE on SIDE AB	FORCE on SIDE BC	CURRENT in SIDE AB
No change	Decreased (zero at vertical)	Increased (zero at horizontal)

Question 5

Answer:

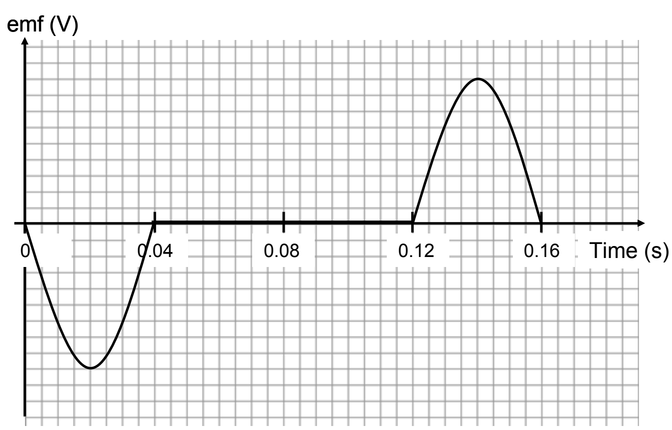


Explanation:

$\Phi_{\max} = BA = 0.4 \times \pi \times 0.015^2 = 2.8 \times 10^{-4}\,Wb$

Question 6

Answer :



Explanation:

The emf is the negative gradient function of the flux curve, due to $emf = -n\dfrac{\Delta\phi}{\Delta t}$

Question 7

Answer: C

Explanation:

Use $emf = -n\dfrac{\Delta\phi}{\Delta t}$

$$0.353 = -n\frac{2.8\times10^{-4}}{0.04}$$

$$n = 50$$

Question 8

- The **flux** curve would have the same maximum, but the timescale would be reduced.
- The **emf** curve would have a larger maximum voltage and a reduced timescale.

Question 9

Answer: Clockwise.

Explanation:

Consider a positive charge at A. If the turbine spins clockwise, at the instant shown, the positive charge will be rising. The RH slap rule shows that the charge will be pushed (by an induced force) from A to B as required. (Note: The pushing of the charge is the induced current)

Question 10

The slip rings are permanently connected to opposite sides of the coil, so as the induced current alternates in direction, the slip rings carry this alternating current to the external circuit.

Question 11

This setup is a **generator**, as the coil is rotating within a magnetic field. An **alternator** is similar, but the magnet rotates inside stationary coils, where current is induced.

Question 12

A transformer requires alternating current because it relies on the transfer of constantly changing flux (which is created in the primary coil by the alternating input current). This flux is carried by a central iron core and induces voltage and current in the secondary circuit. DC current will not work because it will only lead to a constant magnetic field and thus no change in flux.

Question 13

Answer: 566 V

Explanation:

$$V_{peak} = 400 \times \sqrt{2}$$
$$V_{peak} = 566V$$

Question 14

Answer: 17.7 A

Explanation:

$$I_{RMS} = \frac{P}{V_{RMS}}$$
$$I_{RMS} = \frac{2500}{400}$$
$$I_{RMS} = 6.25\,A$$
$$I_{peak-peak} = I_{RMS} \times 2\sqrt{2}$$
$$I_{peak-peak} = 17.7\,A$$

Question 15

Answer: 25 V

Explanation:

$$V_{drop} = IR$$
$$V_{drop} = 6.25 \times 4$$
$$V_{drop} = 25V$$

Question 16

Answer: D

Explanation:

V_{prim} = 400 – 25 = 375 V
V_{sec} = 110 V

Ratio: 375 : 110
= 75 : 22

Question 17

An increase in current in the shack will lead to an increase in the current in the cables. This will lead to a larger voltage drop in the cables and thus a smaller V_{PRIM}. When stepped down, this will make V_{SEC} less than 110 V.

Area of Study 2 – Light and Matter

Question 1

Source of Light	Spectrum (Continuous / Discrete)	Nature of Phase (Coherent / Incoherent)	Electron behaviour (Thermal motion / Quantised energy level)
LASER	Discrete	Coherent	Quantised energy level
Candle	Continuous	Incoherent	Thermal motion
Metal Vapour Lamp	Discrete	Incoherent	Quantised energy level
Incandescent Globe	Continuous	Incoherent	Thermal motion

Question 2

The bright band at **X** is the 2nd anti-nodal line from the centre. It is formed due to interference between the two point sources created by the slits. The 2nd anti-nodal line corresponds to a path difference of 2λ between the two sources. Fundamentally, it is a wavelike phenomenon.

Question 3

Answer: A

Explanation:

Both the decrease of gap size and increase in wavelength (blue to red) lead to a wider pattern, so X (the 2nd antinode) will be further from the centre – a shift left.

Question 4

Answer: C

Explanation:

To solve this, we need to compare the wavelengths of both sources:

$$\lambda_{electron} = \frac{h}{\sqrt{2mKE}} = 2.7\times10^{-12}$$

$$\lambda_{x-ray} = 110\,pm = 1.1\times10^{-10}$$

A gap of 2 x 10^{-12} will lead to λ/w ratios:

$$\frac{\lambda_{electron}}{w} = 1.35 \text{ (moderate diffraction)}$$

$$\frac{\lambda_{x-ray}}{w} = 55 \text{ (extensive diffraction)}$$

Question 5

- According to the wave model, electrons will be ejected from the surface of a metal surface for **[all]** of the frequencies used, with **[shorter]** delay for high frequencies.
- The wave model predicts an increase in the light intensity to be associated with an increase in **[electron energy]** and an **[increased]** stopping voltage magnitude. This is because the energy of the wave is most related to its **[amplitude]**.
- According to the preferred particle model, an increase in the maximum photocurrent is associated with an increase in **[intensity]**.
- The particle model also accurately predicts the existence of a threshold frequency, below which the energy of the incoming photons is **[less]** than the work function of the metal. The interaction of photons and electrons is a **[one-to-one]** event.

Question 6

Answer: $1.74\times10^{-27}\,Jsm^{-1}$

Explanation:

$$p=\frac{h}{\lambda}=\frac{6.63\times10^{-34}}{380\times10^{-9}}$$

Question 7

Answer: $6.15\times10^{-25}\,kgms^{-1}$

Explanation:

$$p=\sqrt{2mKE}=\sqrt{2\times9.1\times10^{-31}\times1.3\times1.6\times10^{-19}}=6.15\times10^{-25}\,kgms^{-1}$$

Question 8

Answer: $4.75\times10^{14}\,Hz$

Explanation:

$$V=hf-hf_o$$

$$1.3=4.14\times10^{-15}\times\frac{3\times10^{8}}{380\times10^{-9}}-4.14\times10^{-15}\times f_o$$

$$f_o=4.75\times10^{14}\,Hz$$

Question 9

Answer: B & C

Explanation:

Check each wavelength to determine its Energy value: $E = \frac{hc}{\lambda}$

776 nm = 1.6 eV (No corresponding energy gap)
591 nm = 2.1 eV (drop from 4 to 3)
185 nm = 6.7 eV (drop from 3 to 1)
226 nm = 5.5 eV (No corresponding energy gap)

Question 10

Electrons will only exist at energy levels which correspond to standing waves (the wavelength for this is derived from their de Broglie wavelength). From the energy level diagram, it appears that the 4.5 eV (276 nm) level is not viable for this particular atom.

SECTION B – Detailed Studies

Detailed Study 1 – Synchrotron and applications

Question 1

C

Question 2

Answer: A

Explanation:

$$Vq = \frac{1}{2}mv^2$$
$$V = \frac{9.1\times10^{-31}\times\left(0.06\times3\times10^8\right)^2}{2\times1.6\times10^{-19}}$$
$$V = 921V$$

Question 3

D

Question 4

Answer: B

Explanation:

$$r = \frac{mv}{Bq}$$
$$B = \frac{mv}{rq}$$
$$B = \frac{9.1\times10^{-31}\times\left(0.01\times3\times10^8\right)}{2.1\times10^{-3}\times1.6\times10^{-19}}$$
$$B = 8.1\times10^{-3}\,T$$

Question 5

Answer: A

Explanation:

$$F = qvB$$
$$F = 1.6\times10^{-19}\times\left(0.01\times3\times10^8\right)\times8.125\times10^{-3}$$
$$F = 3.9\times10^{-15}\,N$$

Question 6

Answer: D

Question 7

Answer: C

Explanation:

First: $\lambda_{x-ray} = \frac{hc}{E} = \frac{4.14\times10^{-15}\times3\times10^{8}}{1.5\times10^{3}} = 8.28\times10^{-10}\ m$

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

$\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right)$

$\theta = \sin^{-1}\left(\frac{1\times8.28\times10^{-11}}{2\times543.09\times10^{-9}}\right)$

$\theta = 4.37 \text{ x } 10^{-20}$

Question 8

Answer: A

Explanation:

Item 1: Very Bright: Allows shorter exposure time or allows selection of a monochromatic beam (which is bright enough alone) for clearer images.

Question 9

Answer: B

Explanation:

Item 2: Coherent: Eliminates interference effects associated with multiple photons out of phase.

Note: Item 3: Low divergence: Remains very accurate – a sharp spot on the target.

Question 10

Answer: D

Question 11

*Answer***:** A

Question 12

*Answer***:** A

Question 13

Answer: C

Explanation:

$$hf_{in} = hf_{out} + \frac{1}{2}mv^2$$
$$v = \sqrt{\frac{2h(f_{in} - f_{out})}{m}}$$
$$v = \sqrt{\frac{2 \times 6.63 \times 10^{-34}(2.5 \times 10^{18} - 2.34 \times 10^{18})}{9.1 \times 10^{-31}}}$$
$$v = 1.53 \times 10^7 \ ms^{-1}$$

Detailed Study 2 – Photonics

Question 1

Answer: D

Question 2

Answer: A

Explanation:

$$\lambda = \frac{hc}{E_g}$$
$$\lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{1.34}$$
$$\lambda = 9.27 \times 10^{-7} \ m$$

Question 3

Answer: D

Explanation:

Smaller diameter fibre reduces the number of possible modes. Graded-index fibre reduces modal dispersion by allowing rays in the outside layers to travel faster. Single-mode fibre eliminates modal dispersion by having only one-mode.

Question 4

Answer: C

Question 5

Answer: C

Explanation:

$$i_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$
$$i_c = \sin^{-1}\left(\frac{1.46}{1.48}\right)$$
$$i_c = 80.57^{o}$$

Question 6

Answer: B

Explanation:

$$NA = \sin\alpha$$
$$NA = 0.242$$

Question 7

Answer: B

Explanation:

$$NA = \sqrt{{n_1}^2 - {n_2}^2}$$
$$0.242 = \sqrt{1.46^2 - {n_2}^2}$$
$$n_2 = 1.44$$

Question 8

Answer:.C

Question 9

Answer: A

Explanation:

In the case of a collapsed building, the incoherent bundle could provide the light source for a coherent bundle to be used to survey or identify objects that may be hard to reach by rescuers.

Question 10

Answer: C

Question 11

Answer: B

Explanation:

- **Rayleigh scattering** is the attenuation effect caused by the scattering of light from small core imperfections. It is more pronounced for shorter wavelengths.
- **Absorption** is the attenuation due to the absorption of optical energy by impurities in the fibre (e.g. metal ions and hydroxyl ions). This is most significant at longer wavelengths, where the resonance of silicon dioxide molecules is particularly evident.
- At Point X, Rayleigh scattering dominates the losses.

Question 12

Answer: C

Explanation:

Photons of 1.04 eV have a wavelength of $\lambda = \dfrac{hc}{E} = 1.2 \times 10^{-6}\ \mu m$

At this wavelength, the losses are 0.4 dB/km, so total loss = 4 dB

Question 13

Answer: A

Detailed Study 3 – Sound

Question 1

Answer: D

Explanation:

Sound waves are longitudinal in nature, and the speaker would move backwards and forwards at 40 Hz, causing the flame of the candle to oscillate in a similar way.

Question 2

Answer: A

Explanation:

$$f = \frac{1}{T} = \frac{1}{800 \times 10^{-6}} = 1250\,Hz$$

Question 3

Answer: C

Explanation:

$$\lambda = \frac{v}{f} = \frac{340}{1250} = 0.272\,m$$

Question 4

Answer: B

Explanation:

Refer to **Question 5**.

Question 5

Answer: B

Explanation:

The observation of reduced loudness at B is due to a lack of diffraction through the gap. The test ratio of $\frac{\lambda}{w} = \frac{0.087}{0.15} = 0.6$ is clearly less than 1, so there would only be moderate diffraction of the sound wave through the gap and thus less intense sound at B.

Question 6

Answer: D

Explanation:

Sound waves from the string enter the bottle and reflect off the water surface. As they return, they interact (superimpose) with further incoming pulses. If the wavelength (top of bottle to water) is suitable, a standing wave will result. The amplitude of this standing wave is double that of the original waves and thus a louder *resonant frequency* is heard.

Question 7

Answer: D

Explanation:

The fundamental frequency occurs where $\lambda = 4L$ (air tube closed at one end).
$v = f\lambda = 560 \times 4 \times 0.15 = 336\,ms^{-1}$

Question 8

Answer: C & D

Explanation:

For an open-closed system, resonant frequencies occur at odd harmonics *only*.
C: $1680 = 3f_o$
D: $2800 = 5f_o$.

Question 9

Answer: D

Explanation:

A: Carbon microphone
B: Dynamic microphone
C: Ribbon must be flexible and thin

Question 10

Answer: C

Explanation:

$$I = 10^{\frac{L}{10} - 12}$$

$$I = 10^{\frac{127}{10} - 12}$$

$$I = 5\ Wm^{-2}$$

Question 11

Answer: A

Explanation:

$$I = 10^{\frac{L}{10}-12}$$

$$I = 10^{\frac{105}{10}-12}$$

$$I = 3.16\times10^{-2}\ Wm^{-2}$$

Now apply inverse square law:

$$I_1 {d_1}^2 = I_2 {d_2}^2$$

$$d_2 = \sqrt{\frac{I_1}{I_2}{d_1}^2}$$

$$d_2 = \sqrt{\frac{5}{0.0316}1.5^2}$$

$$d_2 = 18.9\,m$$

Question 12

Answer: B

Question 13

Answer: D

Explanation:

The points (80,80) and (70, 900) are the only pair which lie on the same phon.