PHYSICS

Units 3 & 4 – Written examination

TSSM
Creating VCE Success

(TSSM's *2016 trial exam updated for the current study design*)

<u>SOLUTIONS</u>

SECTION A - Multiple Choice (1 mark each)

Question 1

Answer: B

Explanation:
$$E = \frac{F}{q} = \frac{5.76 \times 10^{-14}}{1.6 \times 10^{-19}} = 3.6 \times 10^{5}\ \text{V m}^{-1}$$

Question 2

Answer: A

Explanation: Use the RH slap rule for moving electrons. Field into the page, current down (electrons moving up). Force is to the right.

Question 3

Answer: A

Explanation:
$$r = \frac{mv}{Bq}$$
$$r = \frac{9.1 \times 10^{-31} \times 1.9 \times 10^{8}}{0.4 \times 1.6 \times 10^{-19}}$$
$$r = 0.0027\ \text{m}$$
$$r = 2.7\ \text{mm}$$

Question 4

Answer: B

Explanation:
$$\text{Turns} = 4500 \times \frac{12}{240} = 225$$

Question 5

Answer: D

Explanation:
$I_{peak} = 10 \times 20 = 200$ A RMS, $I = 200 \times \sqrt{2} = 283$ A.

Question 6

Answer: D

Explanation:
$v = u + at$
$v = 15 + -9.8 \times 2$
$v = -4.6 \text{ m s}^{-1}$ (i.e. down)

Question 7

Answer: D

Explanation:
$Terry\ F = ma = 25 \times 12 = 300\text{N}$
$\text{action} = \text{reaction Force on Chris} = 300 \text{ N}$
$300 = 75a$
$a = 4 \text{ m s}^{-2}$

Question 8

Answer: D

Explanation: By definition, it is impossible to detect motion as the laws of physics are the same.

Question 9

Answer: B

Explanation: Time dilation effects mean that the pulse will appear slower as the observer moves away.

Question 10

Answer: C

Explanation: Option C is an LED.

Question 11

Answer: A

Explanation: Option A is a laser.

Question 12

Answer: C

Explanation:
$f = \frac{v}{\lambda} = \frac{330}{1.2} = 275 \text{ Hz}$

Question 13

Answer: A

Explanation: Sound is a longitudinal wave, so particles will oscillate parallel to the direction of the wave.

Question 14

Answer: B

Explanation: electromagnetic waves are transverse waves made up of fluctuating electric and magnetic fields. As an EM wave is propagating in the forward, the electric field oscillates in the parallel, and the magnetic field oscillates perpendicular to it.

Question 15

Answer: D

Explanation:
$\sin\theta_C = \frac{n_r}{n_1} = \frac{1.33}{1.52}$
$\theta_c = 61°$

Question 16

Answer: B

Explanation: The amplitude is measured from the centre to the peak – hence twice the amplitude.

Question 17

Answer: B

Explanation:
$f = \frac{v}{4L} = \frac{330}{4 \times 0.4} = 206$ Hz

Question 18

Answer: A

Explanation: The next resonant frequency is f_3, which has a wavelength of 4L/3. The first antinode is L/3 from the open end, a distance of 0.133 m.

Question 19

Answer: A

Explanation: With two open ends, the fundamental frequency is $f = \frac{v}{2L}$, which is higher than the open-closed scenario.

Question 20

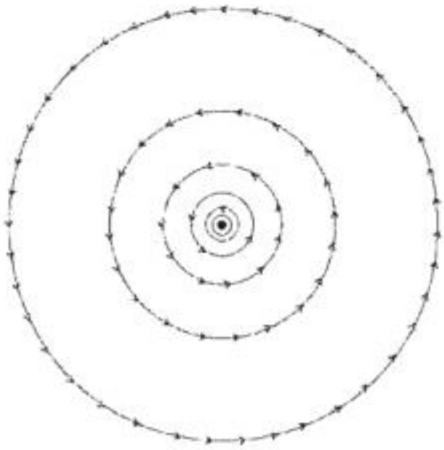
Answer: C

Explanation: Low frequency sound means a longer wavelength and given diffraction is proportional to λ/w, the sound intensity at X will increase.

SECTION B – Short Answer

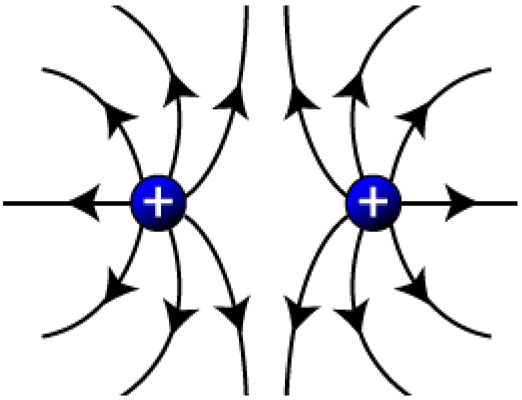
Question 1 (3 marks)

a.



1 mark

b.



2 marks

Question 2 (4 marks)

a. $F = Eq = 5 \times 10^5 \times 5 \times 10^{-6} = 2.5\text{N}$

2 marks

b. $F = ma$
$2.5 = 0.1 \times a$
$a = 25$ ms^{-2}

2 marks

Question 3 (4 marks)

a.
$\frac{GM}{4\pi^2} = \frac{R^3}{T^2}$

$R = \sqrt[3]{\frac{6.67\times10^{-11}\times4\times10^{30}\times(398\times60\times60\times24)^2}{4\pi^2}}$

$R = 2.00 \times 10^{11}$ m
$R = 2.00 \times 10^{8}$ km

2 marks

b. $v = \sqrt{\frac{GM}{R}}$

$v = \sqrt{\frac{6.67\times10^{-11}\times4\times10^{30}}{2\times10^{11}}}$

$v = 36531$ m s^{-1}
$v = 3.65 \times 10^{4}$ m s^{-1}

2 marks

Question 4 (4 marks)

a. RIGHT - Using the Right Hand Grip rule, based on the direction of current in the solenoid.

1 mark

b. $F = BIL$
$0.02 = B \times 1.3 \times 0.06$
$B = 0.256$ T
Current*:* INTO THE PAGE

3 marks

Question 5 (8 marks)

a. $L = \sqrt{0.4} = 0.632\ m$

$F = nBIL$
$F = 10 \times 0.3 \times 0.2 \times 0.632$
$F = 0.38$ N

2 marks

b. With current flowing from B to A, the RH slap rule dictates that the force on this side will be down. Thus, the coil rotates anticlockwise.

2 marks

c. C -
Although the coil has rotated, the direction of the current relative to the field is still perpendicular and the size of n, B, I & L remain constant. So the force will remain unchanged.

2 marks

d. The split-ring commutator is designed to reverse the direction of the current every half-turn. This causes the force on the sides (eg. AB) to reverse in direction and thus ensures continues rotation of the coil.

2 marks

Question 6 (6 marks)

a. $emf = -n\frac{\Delta\phi}{\Delta t}$

$0.085 = 10 \times \frac{0.15A}{0.2}$

$A = 0.0113 \text{ m}^2$

Then,

$A = 0.0113$

$\pi r^2 = 0.0113$

$r = 0.06 \text{ m}$

$r = 6 \text{ cm}$

3 marks

b. Clockwise (1 mark) - As the loop enters the magnetic field, flux increases to the right. As per Lenz' Law, this leads to an induced magnetic field to the left (1 mark) and corresponding clockwise current in the loop (1 mark)

3 marks

Question 7 (7 marks)

a. Apply a quarter turn time interval of 0.05 s (Period = 1/freq = 1/5 = 0.2 sec).

$emf = -n\frac{\Delta\phi}{\Delta t}$

$V = 25 \times \frac{0.15 \times 0.2}{0.05}$

$V = 15 \text{ V}$

2 marks

b. As the coil rotates from horizontal to vertical, the flux increases to the right. Due to Lenz's Law, there is an induced magnetic field to the left, with a corresponding current directed from X to Y (use RH grip rule).

3 marks

c. If the frequency of rotation is increased, the output voltage will increase in frequency and also in magnitude due to the reduced time interval in Faraday's equation.

2 marks

Question 8 (9 marks)

a. $I = 30 \times \frac{1}{5}$
$I = 6\ A$

1 mark

b. $V_{drop} = IR$
$V = 6 \times 3$
$V = 18$ V

2 marks

c. $\%P_{LOSS} = \frac{I^2R}{VI}$
$\%P_{LOSS} = \frac{6^2 3}{400 \times (6 \times 5)}$
$\%P_{LOSS} = 0.009 = 0.9\%$

3 marks

d. $V = 400 \times 5 - 18$
$V = 1982$ V
$V_S = \frac{1982}{5} = 396$

3 marks

Question 9 (11 marks)

a. $\Sigma F = ma$
$60 - 5 \times 9.8 \times \sin(10) - 2 \times 9.8 \times \sin(10) - 15 - 3 = (5 + 2)a$
$a = 4.30$ m s^{-2}

2 marks

b. $\Sigma F = ma$
$T - 2 \times 9.8 \times \sin(10) - 3 = 2 \times 4.30$
$T = 15.0$ N

2 marks

c. $\Sigma F = ma$
$2 \times 9.8 \times \sin(10) - 3 = 2 \times a$
$a = 0.22$ m s^{-2}

$v^2 = u^2 + 2\text{as}$
$v = \sqrt{2 \times 0.236 \times 4}$
$v = 1.32$ m s^{-1}
$v \sim 1.3$ m s^{-1} as required

3 marks

d. $m_1v_1 + m_1v_1 = (m_1 + m_2)v_2$
$2 \times 1.32 + 0 = (2 + 3.5)v$
$v = 0.48$ m s^{-1}

2 marks

e. Inelastic (1 mark), as kinetic energy is not conserved.
$KE_i = 0.5mv^2$
$KE_i = 0.5 \times 2 \times 1.32^2$
$KE_i = 1.74$ J

$KE_f = 0.5mv^2$
$KE_f = 0.5 \times 5.5 \times 0.48^2$
$KE_f = 0.64$ J

2 marks

Question 10 (8 marks)

a. $mg \times 10 = mgh + 0.5k\Delta x^2$
$2.4 \times 9.8 \times 10 = mgh + 0.5 \times 30 \times (10 - 4 - h)^2$
$h = 2.59 \; or \; 7.84$ m (solving quadratic)

We can ignore the 7.84 m answer as this is above the natural length of the spring. A height of 2.59 m means that the spring has extended (10 – 4 – 2.59 = 3.41 m)

3 marks

b. $mg = k\Delta x$
$2.4 \times 9.8 = 30\Delta x$
$\Delta x = 0.784$ m

Thus the height is equal to (10 – 4 – 0.784 = 5.22 m)

2 marks

c. $mg \times 10 = mg \times 5.2 + 0.5k\Delta x^2 + 0.5mv^2$
$2.4 \times 9.8 \times 10 = 2.4 \times 9.8 \times 5.2 + 0.5 \times 30 \times 0.8^2 + 0.5 \times 2.4 \times v^2$
$v = 9.3$ m s^{-1}

3 marks

Question 11 (5 marks)

a. $t = \frac{x}{u_x}$

$t = \frac{z}{vcos(\theta)}$

$t = \frac{75}{35\cos(25)} = 2.36$ s

2 marks

b. $s = u_y t + 0.5at^2$

$s = u \times sin(\theta)t + 0.5at^2$

$s = 35\sin(25) \times 2.36 + 0.5 \times (-9.8) \times 2.36^2$

$s = 7.62$ m

3 marks

Question 12 (5 marks)

a. $a = \frac{v^2}{r} = \frac{15^2}{100}$

2 marks

b. $F_{net} = \frac{mv^2}{r} = N - mg$

$\frac{75 \times v^2}{100} = 1500 - 75 \times 9.8$

$v = 31.9 \text{ m s}^{-1}$

3 marks

Question 13 (6 marks)

a. $E = mc^2 = 1.3 \times 10^{-28} \times (3 \times 10^8)^2 = 1.17 \times 10^{-11}$ J

2 marks

b. $W = (\gamma - 1)m_o c^2 = (4 - 1) \times 1.17 \times 10^{-11} = 3.51 \times 10^{-11}$ J

2 marks

c. Given γ = 4.0 and Solving for *v* from $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ gives *v* = 0.97*c*

2 marks

Question 14 (4 marks)

a. $v = f\lambda$
$42.0 = 8.25 \times \lambda$
$\lambda = 5.09$ cm

$v = f\lambda$
$31.5 = 8.25 \times \lambda$
$\lambda = 3.81$ cm

2 marks

b. $\frac{v_1}{v_2} = \frac{\sin\theta_1}{\sin\theta_2}$
$\frac{42}{31.5} = \frac{\sin 30}{\sin\theta_2}$
$\theta_2 = 22.0°$

2 marks

Question 15 (4 marks)

a. $PD = 1.5\lambda$
$825 = 1.5\lambda$
$\lambda = 550$ nm
$\lambda = 5.5 \times 10^{-7}$ m

2 marks

b. The dark bands on the pattern are points of destructive interference. They arise because waves arrive out of phase due to the different distances from each source to the point. At D and other nodal points, the two waves are half a wavelength out of phase, resulting in destructive interference.

2 marks

Question 16 (10 marks)

a. Light of known frequency is the independent variable.

1 mark

b. 1.5×10^{14} Hz
The threshold frequency is significant as it indicates the limit of the photon frequency required to liberate electrons under the photoelectric effect. Below the threshold frequency, incoming photons do not have sufficient energy ($E = hf$) to overcome the work function of the metal surface.

2 marks

c. Use the photoelectric effect equation, ensuring that the student's value for *h* is used.

Student's value for Planck's constant:

$$h = \frac{4.2 \times 10^{-19}}{(7.86 - 1.5) \times 10^{14}}$$
$$h = 6.6 \times 10^{-34} \text{ J s}$$

Incoming photon:

$$f = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{400 \times 10^{-9}} = 7.5 \times 10^{14} \text{ Hz}$$

Stopping voltage:

$$V_o q = hf - hf_0$$
$$V = \frac{6.6 \times 10^{-34}(7.5 - 1.5) \times 10^{14}}{1.6 \times 10^{-19}}$$

$$V = 2.48 \text{ V}$$

3 marks

d. No effect. The increase in intensity will lead to more electrons being liberated, but the overall energy will not be affected as this is driven by the frequency (wavelength) of the incoming light. Thus the stopping voltage required to stop the electrons will not be affected

2 marks

e. Systematic - Since measurements are affected by the voltmeter, the voltage reading attained could be less than the actual stopping potential.
Random – variation in human response time.

2 marks

Question 17 (5 marks)

a. $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mKE}}$
$$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 250 \times 1.6 \times 10^{-19}}}$$
$$\lambda = 7.77 \times 10^{-11} \text{ m}$$

2 marks

b. $p = \sqrt{2mKE}$
$$p = \sqrt{2 \times 9.1 \times 10^{-31} \times 250 \times 1.6 \times 10^{-19}}$$
$$p = 8.53 \times 10^{-24} \text{ N s}$$

1 mark

c. The pattern would become narrower (ie. reduced radius of concentric circles). This is because an increase in voltage of the electrons would lead to higher energy and higher momentum. Due to $\lambda = \frac{h}{p}$, the wavelength of the electrons would be less and as diffraction (spreading) is proportional to $\frac{\lambda}{w}$, the pattern would become narrower.

2 marks

Question 18 (7 marks)

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

$\lambda = \frac{4.14\times10^{-15}\times3\times10^{8}}{8.9}$

$\lambda = 1.3955 \times 10^{-7}$ m

$\lambda = 140$ nm

2 marks

b. Discrete energy levels in an atom support a wave model for electrons as they can be modelled as standing waves. As such, the electrons can only have discrete wavelengths such that they "fit" within the circumference of the atom. Discrete wavelengths correspond to discrete momenta and energy levels, which means that the electrons can only transition in discrete steps rather than over a continuous range.

c. An absorption spectrum is generated when an atom absorbs photons specific incoming wavelengths (corresponding to energy transitions from the diagram). These wavelengths appear as black lines on an otherwise continuous spectrum of colour. An emission spectrum is comprised of all of the wavelengths of photons emitted as electrons transition from higher to lower energy states. It consists of a series of narrow coloured bands on an otherwise black background.
