PHYSICS

Units 3 & 4 – Written examination

TSSM™
Creating VCE Success

(TSSM's *2014 trial exam updated for the current study design*)

SOLUTIONS

Section A - Multiple Choice (1 mark each)

Question 1

Answer: D

Explanation:
Magnetic field lines come out of the north end of the magnet and loop into the south end.

Question 2

Answer: C

Explanation:
Using the Right Hand Rule, thumb representing current into the page magnetic field loops clockwise via fingers.

Question 3

Answer: B

Explanation: $V = 125\ kV = 125000\ V,\ d = 25\ cm = 0.25\ m$

$$E = \frac{V}{d}$$

$$E = \frac{125000}{0.25}$$

$$E = 5.0 \times 10^5\ V\ m^{-1}$$

Question 4

Answer: A

Explanation: $F = qE$

$$F = 1.6 \times 10^{-19} \times 5.0 \times 10^5$$

$$E = 8.0 \times 10^{14}\ N$$

Question 5

Answer: C

Explanation:
Using the left hand slap rule on an electron moving at right angles to a magnetic field gives the direction of the magnetic field as being into the page.

Question 6

Answer: B

Explanation:
$r = 20.7\ m, p = 2.05 \times 10^{-18}\ kg\ m\ s^{-1}$
$r = \frac{mv}{eB}$
$B = \frac{mv}{er}$
$B = \frac{2.05 \times 10^{-18}}{1.6 \times 10^{-19} \times 20.7}$
$B = 0.64\ T$

Question 7

Answer: D

Explanation:
$T = 40\ ms$
$F = \frac{1}{T} = \frac{1}{0.04} = 25$ Hz

Question 8

Answer: D

Explanation:
$V_{peak} = 4 \times 2 = 8\ V$
$V_{RMS} = \frac{V_{peak}}{\sqrt{2}} = \frac{8}{\sqrt{2}} = 5.7$ V

Question 9

Answer: C

Explanation:
$F = ma = 2 \times 10 = 20$ N
$20 = m \times 4$
$m = 5$ kg

Question 10

Answer: C

Explanation:
$force\ of\ incline = mg\sin\theta = 3 \times 9.8\sin 20 = 10.05$ N down the incline
$\sum F = force\ up - force\ down = 16 - 10.05 = 5.94$ N up the incline
$acceleration\ = \frac{F}{m} = \frac{5.94}{3} = 1.98$ m s^{-2} up the incline.

Question 11

Answer: C

Explanation:
For a stationary observer only the length of the spaceship will appear to have contracted.
C and **D** both show a UFO whose length has been contracted. But **D** also shows a contraction in height. Relative to the observer the UFO is not moving in this direction so there would be no observed contraction in its height. This leaves **C** as the answer.

Question 12

Answer: A

Explanation:
Doppler Effect – sound moving toward you has a perceived decrease in wavelength hence an increase in frequency but as the car passes you the wavelength now stretches hence there will be a decrease in pitch

---

Question 13

Answer: B

Explanation:
$\sin\theta_c = \frac{n_2}{n_1}$
$n_2 = 1.732\sin 60 = 1.5$

Question 14

Answer: B

Explanation:
Sound is a longitudinal wave, meaning compressions are moving away in line with the *X*-axis, in the same axis as the wave.

Question 15

Answer: D

Explanation:
Laser relies on both induced and simulated emission.

Question 16

Answer: C

Explanation:
Incandescent lights rely on light being emitted as they are heated.

Question 17

Answer: B

Explanation:
$$\lambda = \frac{v}{f} = \frac{340}{17000} = 0.02\ m$$
Testing for diffraction: $\frac{\lambda}{w} = \frac{0.02}{0.2} = 0.1$. This ratio indicates that there will be minimal diffraction (0.1 << 1), so the 17 kHz signal will be quite directional, leading to high intensity at P, but much reduced at Q.

Question 18

Answer: D

Explanation:
A, B and C are all correct.

Question 19

Answer: B

Explanation:
$5.4 \times 1.6 \times 10^{-19} = {}^{1}/_{2} \times 9.1 \times 10^{-31} v^2$
$v = 1378006.20$ m s^{-1}
$\rho = mv = 9.1 \times 10^{-31} \times\ 1378006.20 = 1.25 \times 10^{-24}$ kg m s^{-1}
$E = pc =\ 1.25 \times 10^{-24} \times 3 \times 10^{8} = 3.76 \times 10^{-16} J = 2351.22\ eV = 2.2\ keV$

Question 20

Answer: A

Explanation:
The variable being tested against a control is an independent variable.

SECTION B – Short Answer

Question 1 (4 marks)

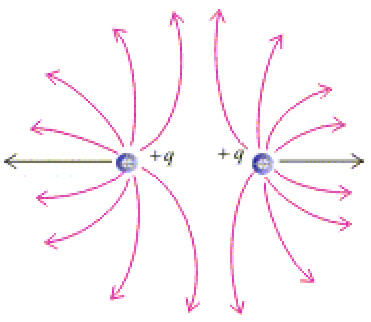
a. $E = \frac{kq}{r^2} = \frac{9 \times 10^9 \times 0.32}{2^2} = 7.2 \times 10^8$ V m^{-1}

2 marks

b. $F = \frac{kqq}{r^2} = \frac{9 \times 10^9 \times 0.32 \times 1.6 \times 10^{-19}}{2^2} = 1.15 \times 10^{-10}$ N away from the charge.

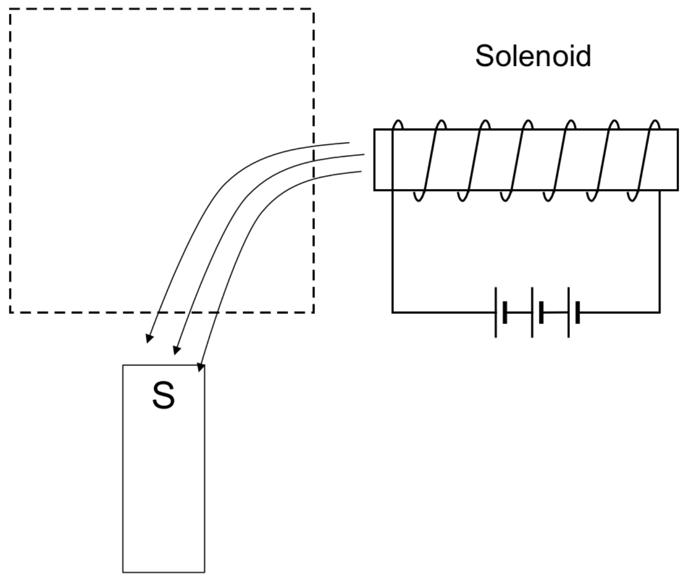
2 marks

Question 2 (2 marks)



2 marks

Question 3 (2 marks)



2 marks

Question 4 (5 marks)

a. $R_{satellite} = 6.37 \times 10^6 + 700 \times 1000\ m$
$R_{satellite} = 7.07 \times 10^6\ m$

$$T = \sqrt{\frac{4\pi^2 R^3}{GM_{earth}}}$$
$$T = \sqrt{\frac{4\pi^2(7.07\times10^6)^3}{6.67\times10^{-11}\times5.97\times10^{24}}}$$
$$T = 5919\ s$$

3 marks

b.
$$v = \frac{2\pi R}{T}$$
$$v = \frac{2\pi\times7.07\times10^6}{5146}$$
$$v = 7505\ m\ s^{-1}$$
$$v = 7505\ \times 3.6 = 2.70 \times 10^4\ km\ h^{-1}$$

2 marks

Question 5 (6 marks)

a.

$F = nBIL$
$F = 3 \times 0.15 \times 0.6 \times 0.06$
$F = 0.0162\ N$

Direction found by right-hand slap rule (field to the left, current out of the page).

3 marks

b. The commutator reverses the direction of the current every half turn (1 mark). This reverses the direction of the force on the side within the field (1 mark). The reversal occurs when the coil is vertical, thus ensuring the rotation is continuous (1 mark)

Question 6 (4 marks)

a. Clockwise, as the arrival of the south pole of the solenoid increases the flux to the left. The copper loop responds by increasing the flux to the right, with an associated clockwise current.

2 marks

b. Current would cease to flow. Once stationary, the solenoid would impose a constant flux inside the loop. According to Faraday's law, a constant flux would yield zero emf, so no current would be induced.

2 marks

Question 7 (8 marks)

a.

$$emf = n\frac{\Delta\phi}{\Delta t}$$
$$emf = 30\frac{100 \times 10^{-6}}{0.5}$$
$$emf = 0.006\ V$$

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

$$R = \frac{0.006}{0.015}$$
$$R = 0.4\ \Omega$$

3 marks

b. **Table shown below.** Note that emf corresponds to the negative gradient function (i.e when flux is increasing, emf is positive etc.)

emf	Time(s)
Maximum positive	1.25, 2.25 (1 mark)
Zero	1.0, 1.5, 2.0, 2.5, 3.0 (1 mark)
Maximum negative	0.75, 1.75, 2.75 (1 mark)

c. emf will double in magnitude and double in frequency
$emf = -n\frac{\Delta\phi}{\Delta t}$, so if the rate of change of flux doubles, the emf will also increase. The change in time also affects the period of the emf.

2 marks

Question 8 (11 marks)

a. $R = \frac{V}{I}$

$R = \frac{6}{4}$

$R = 1.5\ \Omega$

2 marks

b. $\%\ loss = \frac{P_{LOSS}}{P_{IN}}$

$\%\ loss = \frac{I^2R}{VI}$

$\%\ loss = \frac{4^2 \times 1.5}{30 \times 4} = 20\%\ \text{loss}$

2 marks

c. New current in lines due to transformer:

$I = \frac{4}{10} = 0.4\ A$

$\%\ loss = \frac{P_{LOSS}}{P_{IN}}$

$\%\ loss = \frac{I^2R}{VI}$

$\%\ loss = \frac{0.4^2 \times 1.5}{30 \times 4} = 0.002 = 0.25\%$

3 marks

d. Voltage loss in lines:

$V = IR = 0.4 \times 1.5 = 0.6\ \text{V}$

Voltage at lights is equal to the supply, less losses, then stepped down by transformer.

$$V_{lights} = \frac{240 - 0.6}{10} = 23.94 \text{ V}$$

2 marks

e. Voltage at the lights is reduced. The increase in current at the lights leads to an increase in current in the cables (0.4 A to 0.8 A)
The increase in current leads to a larger voltage drop across the cables. Thus there is less voltage at the primary side of the transformer and thus marginally less voltage at the lights.

3 marks

Question 9 (9 marks)

a.

$F_{driving} = 1800 + 1200$
$F_{driving} = 3000\ N$

2 marks

b. $u = 90\ km\ h^{-1} = 90 \div 3.6 = 25\ m\ s^{-1}$
$v = 108\ km\ h^{-1} = 108 \div 3.6 = 30\ m\ s^{-1}$
Both speeds correctly converted to m s^{-1}.

$v^2 = u^2 + 2ax$
$30^2 = 25^2 + 2 \times 0.80 \times x$
$900 = 625 + 1.6x$
$275 = 1.6x$
$x = 172\ m$

2 marks

c. $\Sigma F = T - F_r$
$1400 \times 0.80 = T - 1200$
$1120 = T - 1200$
$T = 2320$ N

2 marks

d. The car and caravan are travelling up the hill at a constant speed of 90 km h^{-1}. So the resultant force acting on the system is zero. This means that the driving force must be equal in size to the sum of the resistive forces acting on the car and caravan plus the component of the systems weight force pulling it down the hill.

$\Sigma F = 0 \text{ N}$

$F_{driving} - 3000 - (2600 + 1400) \times 9.8 \times sin8^o = 0 \text{ N}$
$F_{driving} - 3000 - 5456 = 0 \text{ N}$
$F_{driving} = 8456 \text{ N}$

3 marks

Question 10 (6 marks)

a.

$u_v = 28.0 \times sin50^0$
$u_v = 21.45\, m\, s^{-1}$

$v = u + at$
$0 = 21.45 + (-9.8)t$
$t = 2.18 \times 2 = 4.38 \text{ s}$

3 marks

b. $R = u_{horizontal} \times t$

$u_h = 28.0 \times cos50^0$
$u_h = 18.0\, m\, s^{-1}$
$R = 18.0 \times 4.38$
$R = 78.84\, m$
Note that this answer consequentially relies upon the answer to part a).

2 marks

c. Answer: **E**
When air resistance is taken into account the resultant force acting on Lou Zeland will be equal to the vector sum of his weight force, arrow **F**, and air resistance which will act in the opposite direction to that in which he is travelling at that instant, arrow **D**. Arrow **E** best represents this vector sum.

1 mark

Question 11 (5 marks)

a.

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
$(m_1 + m_2)u = m_1v_1 + m_2v_2$
$(720 + 3.6) \times 0 = 720v_1 + 3.6 \times 500$
$0 = 720v_1 + 1800$
$v_1 = \frac{^-1800}{720}$
$v_1 = {}^-2.5\, m\, s^{-1}$
$v_{cannon} = 2.5\, m\, s^{-1}$ to the left

3 marks

b.

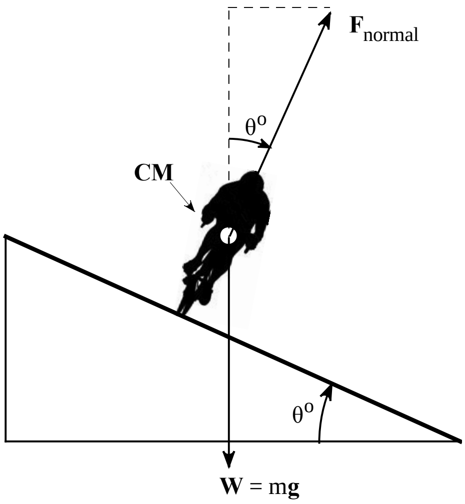
$F_{cannon} = \frac{m\Delta v}{\Delta t} = \frac{3.6 \times 500}{0.0088}$

$F_{cannon} = 2.05 \times 10^5\ N$

2 marks

Question 12 (4 marks)

a. 1 mark for each force correctly drawn and labelled. Total: 2 marks



b. $F_{centripetal} = F_{normal} + W$

$F_c = F_n sin\theta$

$mg = F_n cos\theta$

$F_n = \frac{mg}{cos\theta}$

$F_c = \frac{mv^2}{r} = \frac{mgsin\theta}{cos\theta} = mgtan\theta$

$\frac{mv^2}{r} = mgtan\theta$

$tan\theta = \frac{v^2}{rg}$

$tan\theta = \frac{14.5^2}{25 \times 9.8}$

$\theta = tan^{-1}\left(\frac{14.5^2}{25 \times 9.8}\right)$

$\theta = 40.63^o$

2 marks

Question 13 (4 marks)

a. At point **R**,

$$F_c = F_n + mg = \frac{mv^2}{r}$$
$$\frac{mv^2}{r} = mg \quad as\ F_n = 0$$
$$v = \sqrt{rg}$$
$$v = \sqrt{6 \times 10}$$
$$v = 7.75\ m\ s^{-1}$$

$$Ek_{\boldsymbol{P}} = Ep_{\boldsymbol{R}} + Ek_{\boldsymbol{R}}$$
$$Ek_{\boldsymbol{P}} = 250 \times 10 \times 12 + \frac{1}{2} \times 250 \times 7.75^2$$
$$Ek_{\boldsymbol{P}} = 37507.8$$
$$Ek_{\boldsymbol{P}} = 37507.8 = \frac{1}{2} \times 250 \times v^2$$
$$v^2 = 300$$
$$v = 17.3\ m\ s^{-1}$$

3 marks

b. Answer: **D** 1 mark

The net force acting on the motorcycle at point **Q** will be the vector sum of the normal reaction force acting on the motorcycle and its weight. At **Q** the normal reaction force will be acting towards the centre of the circle, represented by arrow **E**. Arrow **C** represents the direction of the weight force. Arrow **D** best represents this vector sum.

Question 14 (5 marks)

a. $U_{spring} = \frac{1}{2}kx^2 = area\ under\ the\ graph$

$$U_{spring} = \frac{1}{2} \times 0.060 \times 5.00$$
$$U_{spring} = 0.15\ J$$

2 marks

b. $Ek = 0.70 \times 0.15$

$$Ek = 0.105$$
$$0.105 = \frac{1}{2} \times \frac{8}{100} \times v^2$$
$$v^2 = 2.625$$
$$v = 1.62\ m\ s^{-1}$$

3 marks

Question 15 (6 marks)

a. The speed of light will always be the same no matter what the motion of the light source or observer, therefore 3.0×10^8 m s^{-1}

2 marks

b. $t = \frac{x}{v_{constant}}$

$t = 10.5/0.65$

$t = 16.2$ years

2 marks

c. $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$$\gamma = \frac{1}{\sqrt{1 - \frac{(0.65c)^2}{c^2}}}$$

$\gamma = 1.3159$

$t_o = {}^{t}/_{\gamma}$

$t_o = {}^{16.2}/_{1.3159}$

$t_o = 12.3$ years

2 marks

Question 16 (9 marks)

a. To verify Snell's Law by showing that the ratio of the sin value of incident angle to the sine of refracted angle is a constant and is equal to the refractive index of the perspex, by measuring the respective angle made by the bent light ray to the normal at the point of bending when a light ray is projected trough a perspex block at different angle.

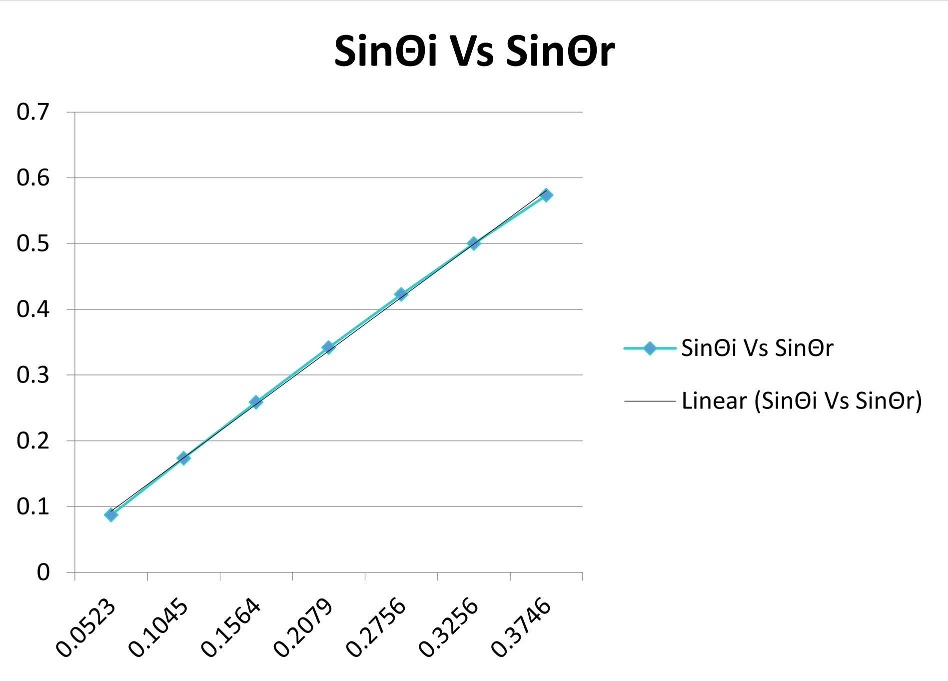
2 marks

b.

$\boldsymbol{\theta_i}$	$\boldsymbol{\theta_r}$	$\boldsymbol{sin\ \theta_i}$	$\boldsymbol{sin\ \theta_r}$
5°	3°	0.0872	0.0523
10°	6°	0.1736	0.1045
15°	9°	0.2588	0.1564
20°	12°	0.3420	0.2079
25°	16°	0.4226	0.2756
30°	19°	0.5000	0.3256
35°	22°	0.5735	0.3746

2 marks

c.



Finding the gradient using the first and last points

$$n = \frac{0.57350 - 0.08715}{0.3746 - 0.0523} = 1.51$$

3 marks

d. Random error – thickness of the light and the pencil used in marking the angles could lead to random errors. Another random error, the Perspex prism was moved to measure the angle.
Systematic – Perspex may have slightly different refractive index than theoretical value. Protractor may have been incorrectly calibrated.

2 marks

Question 17 (7 marks)

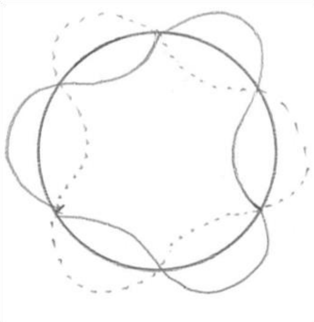
a. First determine the energy of the emitted photon:

$$E = \frac{hc}{\lambda} = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{2070 \times 10^{-9}}$$
$$E = 0.6\ eV$$

This corresponds to a drop from n = 3 to n = 2, as required.

2 marks

b. See diagram below. Three full wavelengths fit around the circumference of the 2D model of the atom.



2 marks

c. If electrons are able to exhibit wavelike properties, it stands to reason that they could form standing waves around the atom (as per 2b)
These standing waves are restricted to discrete wavelengths (n = 1, 2, 3 …)
Discrete wavelengths correspond to discrete momenta and energies for the electrons, which are thus shown as existing at discrete energy levels

3 marks

Question 18 (5 marks)

a.

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{470 \times 10^{-9}}$$

$$E = 4.23 \times 10^{-19}\ J$$

$E = \frac{4.23 \times 10^{-19}}{1.6 \times 10^{-19}} = 2.645\ eV$

Then, apply photoelectric effect equation:
$Vq = hf - W$
$Vq = 2.645 - 2.1$
$V = 0.545\ V$

3 marks

b.

$$f_o = \frac{W}{h} = \frac{2.1}{4.14 \times 10^{-15}}$$
$$f_o = 5.07 \times 10^{14}\ Hz$$

The existence of a threshold frequency supports the particle (photon) model for light as it validates the idea that photons require a minimum energy to liberate an electron
Light below the threshold frequency will not have sufficient energy to liberate an electron, regardless of its intensity.

2 marks

Question 19 (5 marks)

a. Two sources, directed from Slit 1 & 2, will arrive at Y in phase as the path difference between the two is three whole wavelengths of the laser source. Arriving in phase, they interfere constructively, leading to a bright spot.

3 marks

b. The path difference to Y is 3λ, so: $\lambda = \frac{1530}{3} = 510$ nm (1 mark)

Path difference to first node is 0.5λ

$P.D = 0.5\lambda = 0.5 \times 510 = 255$ nm

2 marks