PHYSICS

Units 3 & 4 – Written examination

(TSSM's 2009 trial exam updated for the current study design)

SOLUTIONS

SECTION A - Multiple Choice (1 mark each)

Question 1

Answer: D

Explanation:

$$\frac{E_1}{E_2} = \left(\frac{r_2}{r_1}\right)^2$$

$$\frac{E_1}{8.0 \times 10^4} = \left(\frac{4}{2}\right)^2$$

$E_1 = 3.2 \times 10^5$ N C^{-1}

Question 2

Answer: B

Explanation:
Using the right hand grip rule, thumb in direction of current, fingers gripping wire out of the page at Point P.

Question 3

Answer: C

Explanation:

$$F = \frac{kqq}{r^2}$$

$$F = \frac{GMm}{r^2}$$

$$Ratio = \frac{kqq}{GMm} = \frac{9.0\times10^{9}\times1.6\times10^{-19}\times1.6\times10^{-19}}{6.67\times10^{-11}\times1.67\times10^{-27}\times1.67\times10^{-27}} = 1.24 \times 10^{36}$$

Question 4

Answer: C

Explanation:
Half the radius of Earth and a quarter of the mass using $\frac{GM}{r^2}$ will equate to the same as Earth hence 9.8 N kg^{-1}

Question 5

Answer: A

Explanation:
Using right hand slap rule – thumb velocity direction, fingers out of the page, force right.

Question 6

Answer: B

Explanation:
A south end is created at the end closest to the magnet to oppose the change, hence the field is up through the magnet. Using RH rule current would be anticlockwise as viewed from above.

Question 7

Answer: D

Explanation:
$s = ut$
$70 = 40\cos\theta \times 3.5$
$\theta = 60°$

Question 8

Answer: D

Explanation:
$a = \frac{v^2}{r} = \frac{30^2}{150} = 6 \text{ m s}^{-2}$

Question 9

Answer: C

Explanation:
Acceleration of the system
$T = ma$
$39.5 = 2.5(a + 9.8)$
$a = 6 \text{ m s}^{-2}$

Tension in Rope 1
$T = ma = (1 + 2 \times 0.25)(6 + 9.8) = 23.7$ N

Question 10

Answer: B

Explanation:
Length contraction applies for the moving muons, so they will have less time to decay and therefore more arrive at the end of the detection zone.

Question 11

Answer: B

Explanation:
$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{240}{6000} = 1:25$$

Question 12

Answer: C

Explanation:
Radiowaves have the longest wavelength

Question 13

Answer: A

Explanation:
Air from less dense to more dense slows down. As it slows down its wavelength increases but frequency remains same.

Question 14

Answer: D

Explanation:
All points are not in phase, there is an energy transfer, the distance between nodes in half a wavelength. D is correct

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Question 15

Answer: B

Explanation:
Closed Pipe

$$f_n = \frac{nv}{4L}$$

$$220 = \frac{340}{4L}$$

$L = 0.38$ m

Open Pipe

$$f_n = \frac{nv}{2L} = \frac{340}{2 \times 0.38} = 440 \text{ Hz}$$

Question 16

Answer: C

Explanation:
Less constructive and destructive interference as you move across the screen.

Question 17

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

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Question 18

Answer: B

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

Question 19

Answer: C

Explanation:
Heisenberg uncertainty principle states it is impossible to know exact location and momentum of a particle

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Question 20

Answer: B

Explanation:
Systematic errors in experimental observations usually come from the measuring instruments

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SECTION B – Short Answer

Question 1 (8 marks)

a. $E = \frac{F}{q} = \frac{20\times10^{-9}}{5\times10^{-9}} = 4$ N C^{-1}
As charge is negative and the force is down the field will be up

3 marks

b. $F = qE = 1.6 \times 10^{-19} \times 4 = 6.4 \times 10^{-19}$N
As electron is also negative its force will also be down

3 marks

c. $F = ma$
6.4×10^{-19}N = $9.1\times 10^{-31} \times a$
$a = 7.03 \times 10^{11}$m s^{-2}

2 marks

Question 2 (6 marks)

a. Using area under Graph 1 to determine increase in kinetic energy (that is, loss of potential energy).

$$KE_{surface} = KE_{400km} + area \times mass$$
$$KE_{surface} = 0.5 \times m \times v^2 + 4\times10^5 \times 0.5 \times [0.370 + 0.593] \times 650$$
$$KE_{surface} = 6.58\times10^7 + 12.52\times10^7$$
$$KE_{surface} = 1.91\times10^8 J$$
$$v = 767\, m\, s^{-1}$$

3 marks

b.

$$\frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$
$$R = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$$
$$R = \sqrt[3]{\frac{6.67\times10^{-11} \times 2\times10^{22} \times (2.1\times10^4)^2}{4\pi^2}}$$
$$R = 2.46\times10^6\, m$$

3 marks

Question 3 (5 marks)

a. Using the RH slap rule for current, force on Cable A

$$F = BIL$$
$$B = \frac{F}{IL}$$
$$B = \frac{0.12}{2.5 \times 0.1}$$
$$B = 0.48\,T$$

Direction is out of the page

3 marks

b. Attracted
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.

2 marks

Question 4 (6 marks)

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

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

2 marks

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

2 marks

c. 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.

2 marks

Question 5 (4 marks)

a.

$F_{NET} = ma$

$F_{NET} = 85 \times 4$

$F_{NET} = 340\ N$

2 marks

b. The net force on the stuntman is 340 N up. So the overall result of Tension and Weight must give 340 N

$F_{NET} = T - W$

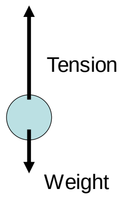
$340 = T - 850$

$T = 1190\ N$

2 marks

Question 6 (7 marks)

a. As per diagram. Note tension force should be greater than weight as the net force must be up (towards the centre of the circular path)



2 marks

b. For uniform circular motion, the centripetal force (net force) must be towards the centre of the circle. In this case, this means up.

2 marks

c. $v = \frac{2\pi r}{T} = \frac{2\pi \times 0.85}{0.8} = 6.67$ m s^{-1}

At the bottom

$F = W + T$

$$\frac{0.1 \times 6.67^2}{0.8} \uparrow = 0.1 \times 9.8 \downarrow\ + T$$

$T = 6.54$ N

3 marks

Question 7 (7 marks)

a. $v^2 = u^2 + 2as$
$v^2 = 0 + 2 \times 9.8 \times 2.7$
$v = 7.27$ m s^{-1}

2 marks

b. $s = ut + {}^1/_2\, at^2$
$4 = 0 \times t + {}^1/_2 \times 9.8 \times t^2$
$t = 0.74s$

Horizontal
$s = ut + {}^1/_2\, at^2$
$4 = u \times 0.74$
$u = 5.39$ m s^{-1}

2 marks

c. $\tan\theta = \frac{7.27}{5.39}$
$\theta = 53.45°$
$v = \sqrt{7.27^2 + 5.39^2} = 9.05$ m s^{-1}

3 marks

Question 8 (7 marks)

a. Taking east as positive
$\Delta p = m\Delta v$
$\Delta p = 1500 \times (3 - -12)$
$\Delta p = 22500\, kg\, m\, s^{-1}$
East

2 marks

b.
$\Delta p = F\Delta t$
$F = \frac{\Delta p}{t}$
$F = \frac{22500}{0.24}$
$F = 93750\, N$
East

2 marks

c. The collision is not isolated, because external forces (that is, the wall) transfer momentum to the Earth.

2 marks

Question 9 (7 marks)

a.

$$v^2 = u^2 + 2as$$

$$s = \frac{v^2 - u^2}{2a}$$

$$s = \frac{-7^2}{2 \times -9.8}$$

$$s = 2.5\,m$$

2 marks

b. Use conservation of energy principles

$$E_{TOP} = mgh$$

$$E_{TOP} = 5 \times 9.8 \times 2.5$$

$$E_{TOP} = 122.5\,J$$

$$E_{0.5} = 122.5J$$

$$122.5 = mgh + 0.5mv^2$$

$$v = \sqrt{\frac{122.5 - 5 \times 9.8 \times 0.5}{0.5 \times 5}}$$

$$v = 6.26\,m\,s^{-1}$$

2 marks

c. Use conservation of energy principles – with elastic potential energy included (a compression of x = 0.3 m

$$E_{0.2} = 122.5J$$

$$122.5 = mgh + 0.5kx^2$$

$$k = \frac{122.5 - 5 \times 9.8 \times 0.2}{0.5 \times (0.3)^2}$$

$$k = 2504N\,m^{-1}$$

3 marks

Question 10 (7 marks)

a. $\gamma = \frac{1}{\sqrt{1-v^2}} = \frac{1}{\sqrt{1-0.85^2}} = 1.9$

$L = \frac{L_o}{\gamma}$

$L = \frac{250}{1.9}$

$L = 132\,m$

3 marks

b.

$T = T_o\gamma$

$T = 4 \times 1.9$

$T = 7.6\,hrs$

2 marks

c.

$E_k = (\gamma - 1)m_o c^2$

$E_k = (1.9 - 1) \times 15000 \times (3 \times 10^8)^2$

$E_k = 1.215 \times 10^{21}\ J$

2 marks

Question 11 (5 marks)

a. C

2 marks

b. 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).

3 marks

Question 12 (9 marks)

a. Use the voltage drop in the cables.

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

2 marks

b. *:* 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

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

3 marks

c.

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

2 marks

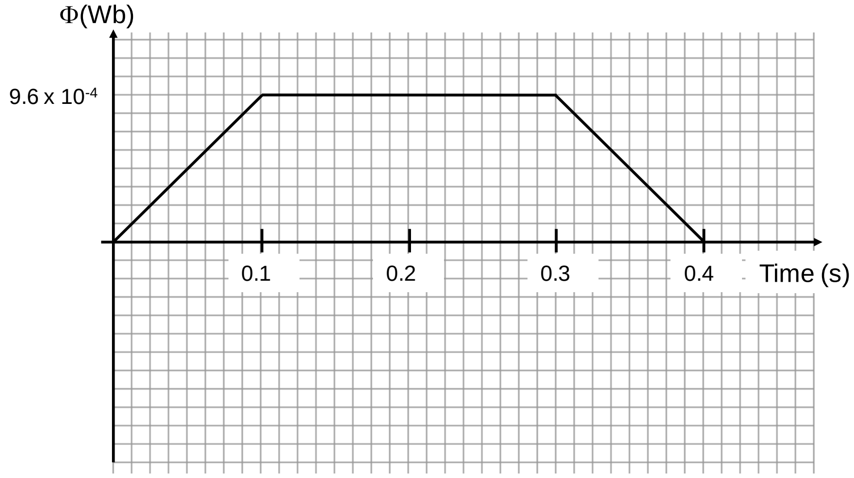
d.

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

2 marks

Question 13 (5 marks)

a.



3 marks

b. $emf = n\frac{\Delta \emptyset}{t} = = 9.6 \times 10^{-3}\text{V}$

2 marks

Question 14 (13 marks)

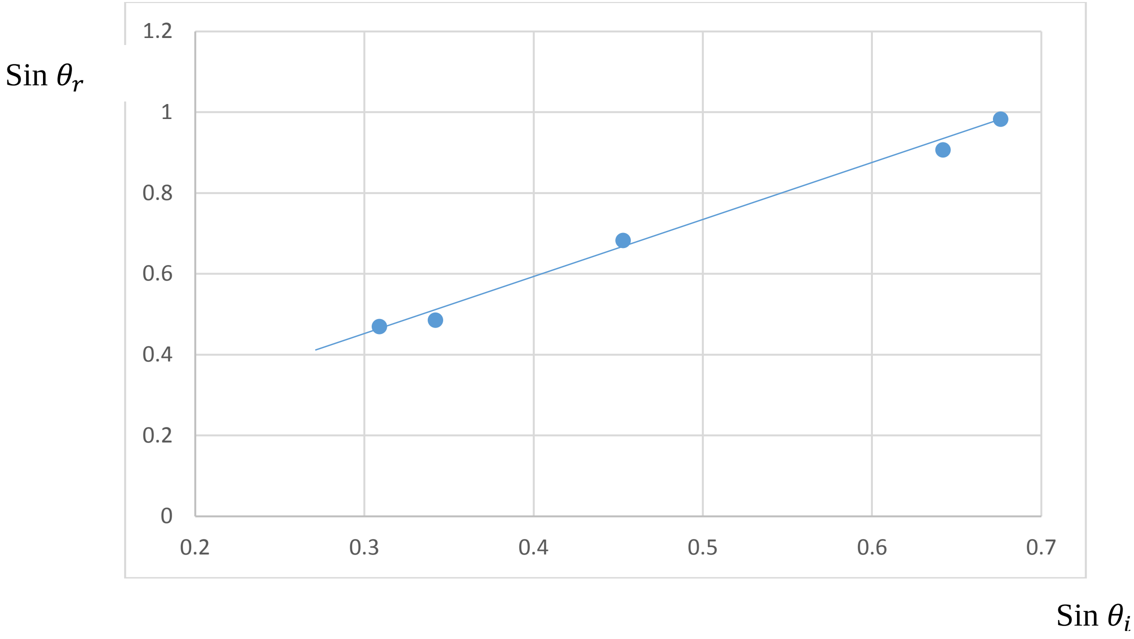
a. Within this experiment, by using a Perspex block and light source, by using known angles of incidence the associated angle of refraction will be found. This will prove that Snell's Law, $n_i \sin\theta_i = n_r \sin\theta_r$ and n_r for the Perspex will equal 1.5

2 marks

b. Independent variable = angle of incidence
Dependent variable = angle of refraction
Controlled variable = material type = Perspex

3 marks

c.



Gradient equals refractive index

3 marks

d. $\frac{0.982-0.469}{0.676-0.309} = 1.4$

2 marks

e. $\frac{1.5-1.4}{1.5} \times 100\% = 6.67\%\ error$

Systematic error – light not being 100% clear and making it hard to get true indication of angle.

Random error – errors in measurement of angle of incidence and angle of refraction by eye

3 marks

Question 15 (4 marks)

a. 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

2 marks

b. 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.

2 marks

Question 16 (6 marks)

a. 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.

2 marks

b.

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

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

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

2 marks

c. $E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{5.02 \times 10^{-11}}$

$$E = 3.96 \times 10^{-15}\text{J}$$

2 marks

Question 17 (4 marks)

a.

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

2 marks

b. Photoelectric effect states:

$$Vq = hf - hf_0$$

$$f_0 = \frac{hf - Vq}{h}$$

$$f_0 = \frac{6.63\times10^{-34}\times6\times10^{14} - 1.7\times1.6\times10^{-19}}{6.63\times10^{-34}}$$

$$f_0 = 1.90\times10^{14}\ Hz$$

2 marks