PHYSICS

Units 3 & 4 – Written examination

TSSM
Creating VCE Success

(*TSSM's *2010 trial exam updated for the current study design)

<u>SOLUTIONS</u>

SECTION A - Multiple Choice (1 mark each)

Question 1

Answer: C

Explanation:
The electric field strength is represented by the arrows on the diagram. Doubling the field strength would be reflected by double the amount of field lines

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Question 2

Answer: C

Explanation:
Using the right hand palm rule, thumb represents the direction of the motion hence pointing right, fingers represent the field out of the page, palm of the hand represents the force on the positive particle hence down the page.

Question 3

Answer: A

Explanation:

$$\frac{F_1}{F_2} = \left(\frac{R_2}{R_1}\right)^2$$

Therefore by doubling the distance the force becomes diminished by a factor of 4 – if the original force was 12 N the new force will be 3N

Question 4

Answer: D

Explanation:
The ball has no horizontal or vertical velocity as it was thrown straight upwards, hence the velocity is zero. The ball is still under the influence of gravity which is a non-zero constant of 9.8 ms^{-2} downwards

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Question 5

Answer: A

Explanation: III is consistent with Galilean ideas of motion. Whilst I, II & IV are all necessary for Einstein's relativity ideas

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Question 6

Answer: D

Explanation: The event will not appear simultaneous due to the relative motion of the observers.

Question 7

Answer: B

Explanation:

When AC supply is given to DC motor, the direction of the magnetic field as well as the direction of the current in the armature will be reversed in the second half of the AC cycle so, the direction of the torque will remain the same in both the halves of the AC cycle, hence clockwise

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Question 8

Answer: B

Explanation:
There is decreasing flux into the page. Using Lenz' law the wire will induce a current to produce an increasing flux into the page. Using the right hand rule the current will be clockwise.

Question 9

Answer: B

Explanation:
$V_{peak} = 100$ V from graph
$V_{rms} = \frac{100}{\sqrt{2}} = 71$ V

Question 10

Answer: A

Explanation:
$V_{peak\ primary} = 100V$
$V_{peak\ secondary} = 10V$
Ratio is 10:1

Question 11

Answer: B

Explanation:
As the current is being varied due to the strength of the magnet the magnetic field strength is the independent variable.

Question 12

Answer: A

Explanation:
The potential hazard in this experiment is the flying projectile, one appropriate safety consideration would be to wear safety glasses.

Question 13

Answer: D

Explanation: A is incorrect as there is constructive interference, not destructive. C is incorrect as the waves reflect off the ends, not the sides. C is incorrect as the standing wave is created within the tube, rather than entering.

Question 14

Answer: D

Explanation:
$n_i \sin\theta_i = n_r \sin\theta_r$
$1.0 \sin 30 = 1.65 \sin\theta_r$
$\theta_r = 17.63^o$

Question 15

Answer: C

Explanation:
Within the photoelectric effect experiment the intensity of light determines the number of incoming photons while the energy is dependent on the energy. By increasing the frequency but keeping the intensity the same, the same number of photoelectrons will be released, they will have an increased kinetic energy

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Question 16

Answer: A

Explanation:
$\lambda = \frac{h}{\rho}$
Hence doubling the momentum will decrease the wavelength by a factor of 2

Question 17

Answer: D

Explanation: Other answers are incorrect as the radiation has very low divergence, is very intense and has a short wavelength.

Question 18

Answer: D

Explanation:
There are 6 transition levels back to the ground state.

Question 19

Answer: A

Explanation:
The interference pattern produced is a result of constructive and destructive interference which is a wavelike phenomena

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Question 20

Answer: D

Explanation:
radio waves, infrared, visible light, X-rays is the correct order from longest to shortest wavelength.

SECTION B- Short Answer

Question 1 (6 marks)

a. $E = \frac{V}{d} = \frac{2000}{5\times10^{-3}} = 4.0 \times 10^5$ Vm^{-2}

2 marks

b. $F = qE = 10 \times 1.6 \times 10^{-19} \times 4 \times 10^5 = 6.4 \times 10^{-13}$N

2 marks

c. $W = Fd = 6.4 \times 10^{-13} \times 2.5 \times 10^{-3} = 1.6 \times 10^{-15}$ J

2 marks

Question 2 (7 marks)

a.

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

$$\frac{6.67\times10^{-11}\times5.98\times10^{24}}{4\pi^2} = \frac{R^3}{(120\times60)^2}$$

$$R = 8.06\times10^6\ m$$

$$Altitude = R - R_e = 8.06\times10^6 - 6.37\times10^6 = 1.69\times10^6\ m$$

2 marks

b. $g = \frac{GM}{R^2} = \frac{6.67\times10^{-11}\times5.98\times10^{24}}{(8.06\times10^6)^2} = 6.14\,Nkg^{-1}$

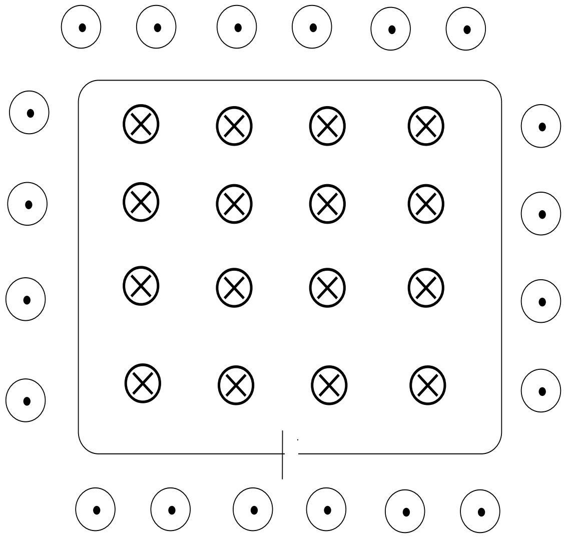
2 marks

c. The astronauts are not truly weightless because they are still within the earth's gravitational field (6.1 Nkg^{-1} at their orbital radius). However, because they and their craft are in a constant free fall around the earth (in a circular orbit with acceleration due to *g*), there will be no reaction force between them and their craft. The lack of a reaction force (which is the Normal force we are used to feeling on the surface of the earth), gives the impression of weightlessness – ie. Apparent weightlessness.

3 marks

Question 3 (5 marks)

a.



Field is directed into the page within the loop and out of the page external of the loop via the right hand grip rule

3 marks

b. F = BIL = $2 \times 10^{-2} \times 2.5 \times 0.04$.
Direction is found using RH slap rule.

2 marks

Question 4 (4 marks)

a. Net Force = mass x acceleration

4000 (driving) – 1500 (friction locomotive) – 3 × 600 (friction carriages) = 1100a
700 = 900a
a = 0.64 ms^{-2}

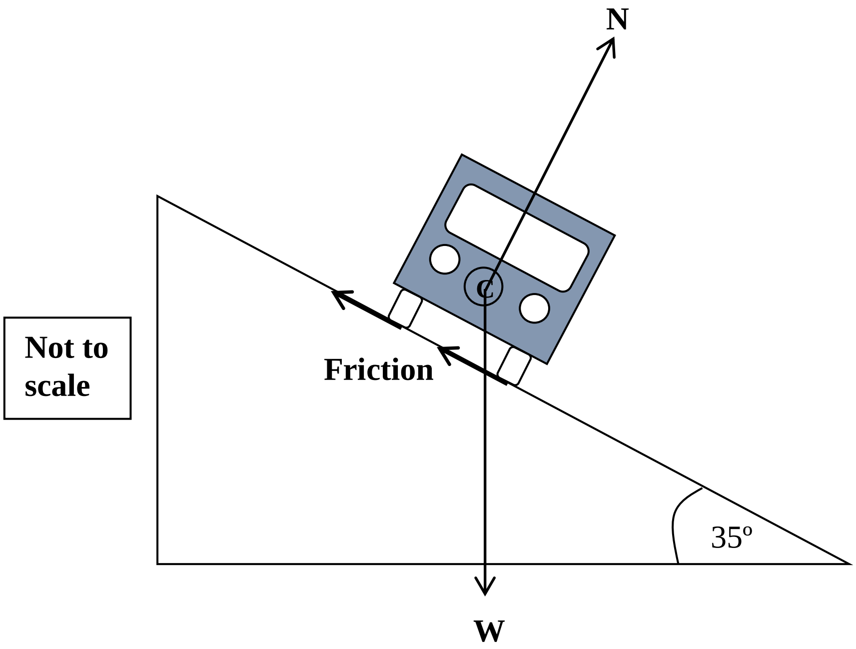
2 marks

b. Net Force = mass x acceleration
4000 – 1500 – T = 500 × 0.64
T = 2182 N

2 marks

Question 5 (5 marks)

a.



2 marks

b. The centripetal force must be due solely to the horizontal component of the reaction force.

$$\frac{mv^2}{r} = N\sin\theta$$

$$\frac{mv^2}{r} = \frac{mg}{\cos\theta}\sin\theta$$

So $$\frac{v^2}{r} = g\tan\theta$$

$$v = \sqrt{rg\tan\theta}$$

$$v = \sqrt{200 \times 9.8 \times \tan 35}$$

$$v = 37.04 ms^{-1}$$

3 marks

Question 6 (5 marks)

a. Max height occurs at t = 1.75 s (mid-flight)

$$s = vt - \frac{1}{2}at^2$$
$$s = 0 - \frac{1}{2} \times -9.8 \times 1.75^2$$
$$s = 15.01m$$

2 marks

b. Vertical component of velocity (consider start to apex)

$$u = v - at$$
$$u = 0 - (-9.8) \times 1.75$$
$$u = 17.15ms^{-1}$$

Horizontal component of velocity (consider total range)

$$v = \frac{x}{t}$$
$$v = \frac{75}{3.5}$$
$$v = 21.4\,ms^{-1}$$

Using trig:

$$\theta = \tan^{-1}\left(\frac{17.5}{21.4}\right) = 39.3^o$$

3 marks

Question 7 (9 marks)

a. $p = mv$ (only car is moving, so single momentum calculation)
$p = 700 \times 12 = 8400$ kgms^{-1} West

2 marks

b. Conservation of momentum for the isolated collision

$$p_i = p_f$$
$$8400 = (m + 700) \times 4.5$$
$$m = 1167kg$$

2 marks

c. For car:
Impulse = change in momentum
= $m \times \Delta v$
=700 (4.5-12)
= -5250 Ns

Hence 5250 Ns East

2 marks

d. To demonstrate that the collision is inelastic, we must show that kinetic energy is not conserved.

$KE_{before} = 0.5mv^2 = 0.5\times 700 \times 12^2 = 50.4$ kJ
$KE_{after} = 0.5mv^2 = 0.5 \times (700+1167) \times 4.5^2 = 18.9$ kJ

$KE_{before} > KE_{after}$, so collision is inelastic

3 marks

Question 8 (6 marks)

a. Assume energy is conserved, but converted from gravitational potential to kinetic energy as the ball falls.

Total energy at 1.5m = mgh = 30 J
Total energy at 0.5m = $mgh + 0.5mv^2$ = 30 J
$2\times 9.8 \times 0.5 + 0.5 \times 2 \times v^2 = 30$
$v = 4.49$ ms^{-1}

2 marks

b. At 0.3m, with the spring fully compressed, we have elastic potential energy, a small amount of gravitational potential energy and no kinetic energy. The total energy remains 30 J

$30 = mgh + 0.5kx^2$
$30 = 2 \times 9.8 \times 0.3 + 0.5 \times k \times 0.2^2$
$k = 1200$ Nm^{-1}

2 marks

c. $\Delta E = mg\Delta h = 2 \times 9.8 \times 0.2 = 3.92$ J
Energy would be converted to heat, sound, permanent deformation of the spring.

2 marks

Question 9 (4 marks)

a.

$$N - mg = \frac{mv^2}{r}$$

$$N = mg + \frac{mv^2}{r}$$

$$N = 1300 \times 9.8 + \frac{1300 \times 25^2}{200}$$

$$N = 16803N$$

2 marks

b. As N = 0 ∑F = W

$v^2 = gr$
$v = \sqrt{150 \times 9.8}$
$v = 38.34$ ms^{-1}

2 marks

Question 10 (10 marks)

a. $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{1}{\sqrt{1 - \frac{(0.85c)^2}{c^2}}} = 1.90$

Actual length = $L_0 = L\gamma = 250 \times 1.90 = 475$ m

2 marks

b. $t = \frac{x}{v} = \frac{4.5}{0.85c}$ = 5.3 years.

2 marks

c. $t_0 = \frac{t}{\gamma} = \frac{5.3}{1.90} = 2.8$ years.

2 marks

d. $L = \frac{L_0}{\gamma} = \frac{4.5}{1.90} = 2.4$ light years.

2 marks

e. $m = m_o\,\gamma = 11 \times 1.90 = 21$ tonnes

2 marks

Question 11 (13 marks)

a. Use RH slap rule to determine the required field direction (right to left). Field lines must run from North to South.
A = South, B = North

2 marks

b. A commutator is required to ensure continuous rotation of the coil. It achieves this by changing the direction of the current every 180^o, which in turn changes the direction of the force on the sides of the coil and allows it to rotate continuously

3 marks

c. The coil is parallel to the field, so the area threaded by B is zero. Thus Φ =BA= 0 Wb

2 marks

d. $\text{emf} = n\dfrac{\Delta\phi}{\Delta t}$ (magnitude only)

$= 20 \times \frac{3\times10^{-2}\times0.05^2}{0.5} = 0.003\ \text{V}$ = 3 mV

3 marks

e. Loop is moving from no flux to full flux hence there is an increasing flux in the loop from North to South. Loop will induce a current to create a flux to oppose this change therefore there is an increasing flux South to North.
As loop spins anti-clockwise X-Y side will be on the bottom of the loop – using right hand rule a small positive charge would be pushed from **Y – X**

3 mark

Question 12 (3 marks)

Switching off the power supply causes a change in flux as the magnetic field from the solenoid is now eliminated. The change in flux is to the right, so the coil responds with a change in flux to the left and an induced current (using RH grip rule) which is anti-clockwise when viewed from A.

3 marks

Question 13 (9 marks)

a. $V_{peak} = \sqrt{2}\ V_{RMS} = \sqrt{2} \times 15000 = 21213\ \text{V} = 21.2\text{kV}$

2 marks

b. To find the current in the transmission lines

$$\frac{N_p}{N_s} = \frac{I_s}{I_p}$$

$$\frac{10}{1} = \frac{20 \times 10^3}{I_p}$$
$$I_p = 2000$$

$P_{loss} = IR^2 = 2000^2 \times 2.5 = 10 \times 10^6$ W

3 marks

c. $V_{Loss} = IR = 2000 \times 2.5 = 5000$ V (across transmission lines)
$V_{prim} = 1.5 \times 10^4 - 5 \times 10^3 = 10$ kV (at primary side of town transformer)
$V_{sec} = \frac{10000}{10} = 1.0 \times 10^3$ V (at secondary side of transformer and town)

2 marks

d. In order for the transformer to operate correctly, we require a constantly changing flux on the primary side, which will then induce a current in the secondary side. The changing flux comes as a result of the alternating current, which creates a constantly changing magnetic field in the primary coil. So, if the current were smooth DC, there would be a constant magnetic field, no change in flux and no induced current.

2 marks

Question 14 (4 marks)

a. Transverse waves are waves where the medium vibrates at right angles to the direction of its propagation. 2 marks

b. Light is an electromagnetic wave in which its magnetic and electric fields vary at right angles to its propagation. As the electric field of light can be confined to one direction through polarization and as polarization is a characteristic of transverse waves, light can be classified as a transverse wave.

2 marks

Question 15 (4 marks)

a. 3rd node from the centre has Path Difference of 2.5λ
$2.5 \times 560 = 1400$ nm

2 marks

b. Increasing the gap between the slits will cause the interference pattern to become narrower, whilst remaining distinct in terms of alternating nodes and antinodes.

2 marks

Question 16 (12 marks)

a. Independent variable is the light source, the dependent variable is the stopping voltage.

2 marks

b. One possible controlled variable would be the metal surface. It is important to control this variable as a change in the variable would change the stopping voltage due to a change in binding energy of the material.

2 marks

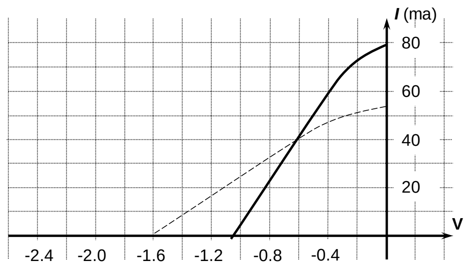
c. $Vq = hf - W$

$0.6 = 2.76 - hf_o$

$f_o = 5.22 \times 10^{14}$ Hz

3 marks

d. Lower frequency leads to a lower stopping voltage, brighter source leads to higher photocurrent.



2 marks

e. The photoelectric effect demonstrates that as the frequency of a light increases, the stopping voltage increases.

- The particle model explains that light with a higher frequency emits photons with greater energy and thus imparts more energy to ejected electrons. Therefore, the voltage required to stop such electrons increases.
- The wave model predicts that as the lights frequency increases, more electrons are being emitted per unit of time so the photoelectric current should increase.

As the intensity of light increases, the photoelectric current increases.

- The particle model explains that increasing the intensity of light means increasing the number of photons emitted per unit of time. Therefore, the number of emitted electrons per unit of time reaching the collector terminal should increase and the photoelectric current increases.
- The wave model predicts that as the intensity of light increases, more energy is carried through the wave and imparted to the electrons at the metal's surface. Thus more energy is required to stop the electrons and a greater stopping voltage is required.

In addition, only the particle model and work function can explain the idea of a threshold frequency and no delay in emission. The wave model would suggest that, even at very low frequencies below the observed threshold frequency, energy from a light source would eventually be able to eject and electron from a metal surface.

Thus, the photoelectric effect confirms light's model as a particle.

3 marks

Question 17 (4 marks)

a. $E = \frac{hc}{\lambda}$ (energy of photon)

$451 \times 10^3 = \frac{4.14\times10^{-15}\times3\times10^8}{\lambda}$

$\lambda = 2.75 \times 10^{-12}$ m

2 marks

b. Given similar diffraction patterns, we can assume that wavelength of the electron and X-Ray are the same.

$\lambda_{electron} = \frac{h}{mv}$

$mv = \frac{h}{\lambda}$

$mv = \frac{6.63\times10^{-34}}{2.75\times10^{-12}} = 2.4\times10^{-22}$ kg ms^{-1}

2 marks
