PHYSICS

Units 3&4 – Written examination

TSSM
Creating VCE Success

(TSSM's *2013 trial exam updated for the current study design*)

SOLUTIONS

SECTION A - Multiple Choice (1 mark each)

Question 1

Answer: D

Explanation:

$$d = \frac{Vq}{F} = \frac{4000 \times 1.6 \times 10^{-19}}{2 \times 10^{-15}} = 0.32\, m = 32\, cm$$

Question 2

Answer: A

Explanation:

$$F = \frac{qV}{d} = \frac{5\times10^{3}\times8\times10^{-19}}{0.02} = 2 \times 10^{-13}\text{N}$$

Question 3

Answer: B

Explanation:

$$v = \frac{Bqr}{m} = \frac{0.03 \times 1.6 \times 10^{-19} \times 0.025}{9.1 \times 10^{-31}} = 1.32 \times 10^{8}\, m\, s^{-1}$$

Question 4

Answer: C

Explanation:

Use RH slap rule: Force = South, Current = West (moving electron), Field = Into the page

---

Question 5

Answer: D

Explanation:

$F = nBIL$ therefore double I double F

Question 6

Answer: D

Explanation:

2.5 wavelengths in 70 ms

$f = \frac{1}{0.07/2.5} = 35.7 \sim 36\ Hz$

Question 7

Answer: C

Explanation:

$V_{RMS} = \frac{V_{PEAK}}{\sqrt{2}} = \frac{4.5}{\sqrt{2}} = 3.2\ V$

Question 8

Answer: A

Explanation:

Step up peak voltage

$V = 4.5 \times \frac{1500}{200} = 34$ V

Question 9

Answer: A

Explanation:

The amount of flux into the page in the loop is changing - decreasing, in order to oppose the change in flux the loop will induce a flux into the page. Using the RH rule the current will be clockwise.

Question 10

Answer: A

Explanation:

$$F = \frac{GMm}{r^2} = \frac{6.67\times10^{-11}\times6\times10^{24}\times7.35\times10^{22}}{(3.83\times10^{8})^2} = 2 \times 10^{20}\ \text{N}$$

Question 11

Answer: A

Explanation:
Horizontal:
$s = ut$
$70 = 23\cos\theta \times 3.5$
$\theta = 30°$

Question 12

Answer: C

Explanation:

Inertial Reference Frames are ones in which the normal laws of physics apply. This means that no acceleration of the frame can be detected by an observer in the frame.

Question 13

Answer: B

Explanation:

Light was previously considered to travel in a medium known as the aether, which was subsequently debunked by the Michelson-Morley experiment.

Question 14

Answer: A

Explanation:

$\lambda = \frac{v}{f} = \frac{340}{680} = 0.5\ m$

Question 15

Answer: B

Explanation:

Synchrotron has a wider spectrum, but opposite characteristics to those listed in A, B & D.

Question 16

Answer: B

Explanation:

Coherent photons are in phase by definition.

Question 17

Answer: A

Explanation:

An LED involves spontaneous emission (laser is stimulated) from conduction to valence bands.

Question 18

Answer: D

Explanation:
Increasing the intensity for both metals will increase the number of incoming photons hence the number of photoelectrons ejected. As the kinetic energy of the photoelectrons is proportional to the frequency of the light their energy would not change.

Question 19

Answer: A

Explanation:
Heisenberg's theory states we cannot simultaneously know both the exact position, and the velocity of a subatomic particle.

Question 20

Answer: B

Explanation:
The variable being changed is the independent variable hence the strength of the magnet.

SECTION B- Short Answer

Question 1 (6 marks)

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

$2.5 \times 10^3 = \frac{V}{0.1}$

$V = 250$ V

2 marks

b. $F = qE = 1.6 \times 10^{-19} \times 2.5 \times 10^3 = 8.0 \times 10^{-16}$N

2 marks

c. $F = ma$

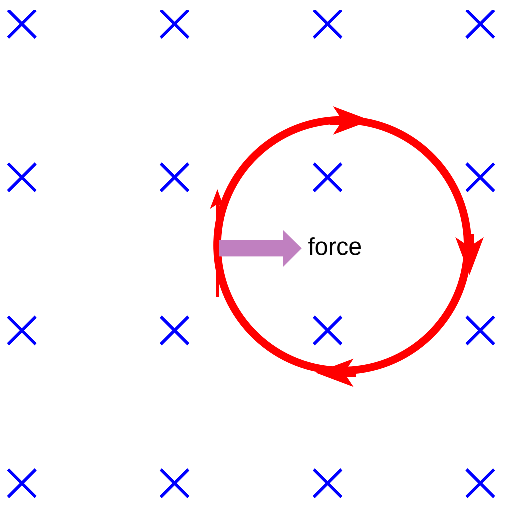
$8.0 \times 10^{-16} = 9.1 \times 10^{-31} \times a$

$a = 8.79 \times 10^{14}$ m s^{-2}

2 marks

Question 2 (4 marks)

a.



1 mark

b. Circle indicates the motion of the particle.

1 mark

c. $r = \frac{mv}{qB} = \frac{9.1\times10^{-31}\times5\times10^{5}}{1.6\times10^{-19}\times4} = 7.1 \times 10^{7}\text{m}$

2 marks

Question 3 (3 marks)

a. LEFT

According to the direction of the current in the solenoid, then applying the RH grip rule, the direction of the field lines emerging from the end of the coil will be left.

1 mark

b. $F = nBIL = 1 \times 0.12 \times 0.3 \times 0.03 = 1.1 \times 10^{-3}\text{N}$

2 marks

Question 4 (7 marks)

a. UP

Use RH slap rule: Current out of page, Field to the left, so Force is up.

2 marks

b. $F = nBIL = 10 \times 0.4 \times 1.3 \times 0.06 = 0.312$ N.

2 marks

c. The commutator is a mechanical device that simply changes the direction of the current in the coil every half-turn (by allowing a brush connected to the DC supply to touch a different side of a split ring). The change in current direction changes the direction of the force (RH slap rule) which in turn allows the torque on the coil to remain constant in direction (though not in magnitude) at the point of change in direction, current is zero momentarily, so the momentum of the moving coil is required to ensure it continues to rotate into the next half-turn.

3 marks

Question 5 (9 marks)

a. First, find voltage on secondary side of transformer: V = 400 × 5 = 2000 V.
Then, find total current in system: $I = \frac{V}{R} = \frac{2000}{20} = 100$ A .
Then $P_{LOSS} = I^2R = 100^2 \times 3 = 30000$ W

2 marks

b. $V_{factory} = V_{GEN} \times 5 - V_{lines} = 2000 - 100 \times 3 = 1700$ V

2 marks

c. First, establish current at generator by using transformer: $I_{GEN} = 100 \times 5 = 500\ A$
P = VI = 2×10^5 W

2 marks

d. If the resistance of the load is decreased, the current in the lines (and subsequent power and voltage losses) will increase. Greater voltage losses leave less supply voltage for the load, so it will drop from 1700 V to 1538 V (exact calc. not required but adds weight to an explanation)

3 marks

Question 6 (3 mark)

If the current in the lower ring is increased by switching on, a downwards magnetic field will be made in the ring. The upper ring will thus experience a change in flux downwards as it is adjacent to the field. According to Lenz's Law an opposite, upwards directed field will be induced in the upper ring, with associated anticlockwise current.

3 marks

Question 7 (4 marks)

a. X = South
There are various methods for determining the direction of the field. One is as follows:
If one imagines a small positive charge in the section of wire AB moving 'up' in space due to the initial rotation, this can be deemed 'positive upwards current'. Using the RH slap rule, this would require a left to right magnetic field to push the charge from AB as per the required clockwise current in the question. Thus X is a south pole to match this field.

2 marks

b. $\phi = BA = 0.2 \times 12 \times 10^{-4} = 2.4 \times 10^{-4}$ Wb

2 marks

Question 8 (7 marks)

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

$$R = \sqrt[3]{\frac{T^2 GM}{4\pi^2}} = \sqrt[3]{\frac{(16 \times 60 \times 60)^2 \times 6.67 \times 10^{-11} \times 4 \times 10^{23}}{4\pi^2}} = 1.31 \times 10^7 \text{m}$$

$Alt = 1.31 \times 10^7 - 4.2 \times 10^6 = 8.89 \times 10^6\ m = 8.89 \times 10^3$ km

3 marks

b. $v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{6.67 \times 10^{-11} \times 4 \times 10^{23}}{1.31 \times 10^7}} = 1428 \text{ m s}^{-1}$

2 marks

c. $g = \frac{GM}{R^2} = \frac{6.67 \times 10^{-11} \times 4 \times 10^{23}}{(1.31 \times 10^7)^2} = 0.156 \text{ N kg}^{-1}$

2 marks

Question 9 (7 marks)

a. F_{net} = ma, so $a = \frac{F_{NET}}{m} = \frac{140 - 0.2 \times 9.8 \times 21}{21} = \frac{140 - 42}{21} = 4.71 \text{ m s}^{-2}$

2 marks

b. $v^2 = u^2 + 2as.\ So, v = \sqrt{2as} = \sqrt{2 \times 4.67 \times 4} = 6.1 \text{ m s}^{-1}$

2 marks

c. First, consider forces on B.
$F_{net\ B} = F_{A\ on\ B} - F_{B\ on\ C} - F_{fric\ on\ B}$
$7 \times 4.67 = F_{A\ on\ B} - 26.7 - 14$
$F_{A\ on\ B}$ = 73.4 N
So, $F_{B\ on\ A}$ = 73.4 N

3 marks

Question 10 (4 marks)

a. $F_{NET} = N - mg = 5 \times mg - mg = 4mg = 2940\ N$
The apparent weight is equal to the reaction force, N. In this case N = 5 times the weight force, according to the question.

2 marks

b. $F_{NET} = \frac{mv^2}{r}, so\ r = \frac{75 \times 35^2}{2940} = 31.25$ m

2 marks

Question 11 (6 marks)

a. Consider vertical motion to top of flight: $s = vt - 0.5at^2$
$12 = 0 - 0.5 \times 9.8 \times t^2$
t = 1.56 sec
So, t = 3.13 sec for total flight.

2 marks

b. Consider vertical motion to top of flight: $v = u + at$
$0 = u - 9.8 \times 1.56$
$u = 15.3\ m\ s^{-1}$
$So, V sin\theta = 15.3$
$V = 31$ m s^{-1}

2 marks

c. Horizontal motion: $V cos\theta = 31 \times cos 30 = 26.6$ m s^{-1}
Range = 26.6 × 3.13 = 83.1 m

2 marks

Question 12 (4 marks)

$At\ rest: F = kx$
$mg = k \times 0.12$
$k = \frac{mg}{0.12}$
$At\ lowest\ point: mgh = 0.5kx^2$
$mg \times (0.12 + x) = 0.5k(x + 0.12)^2$
$mg \times (0.12 + x) = 0.5 \times \frac{mg}{0.12}(x + 0.12)^2$
$x = 0.12\ m$

Question 13 (5 marks)

a. Work = Fx = 20 × 0.3 = 6 J

2 marks

b. First, use isolated sticky collision analysis to determine the speed of the 10 kg block as it arrives at the collision.

$\Delta p = 0$

$m_{total} \times v_{final} - v_i \times 10 = 0$

$v_i = \dfrac{0.89 \times 15}{10} = 1.335 \text{ m s}^{-1}$

Then, use conservation of energy to find h.

$mgh = KE$

$10 \times 9.8 \times h = 0.5 \times 9.8 \times 1.335^2$

$h = 0.089 \text{ m}$

3 marks

Question 14 (8 marks)

a. $t = t_0\gamma = \dfrac{2\times10^{-6}}{\sqrt{1-\left(\frac{2.97\times10^{8}}{3\times10^{8}}\right)^2}} = 1.4 \times 10^{-5} \text{ s}$

3 marks

b. $d = vt = 2.97 \times 10^8 \times 1.4 \times 10^{-5} = 4205.52\, m$

$altitude = 100 - 4.205 = 95.79 \text{ km}$

3 marks

c. $v = dt = 2.97 \times 10^8 \times 2 \times 10^{-6} = 594 \text{ m}$

2 marks

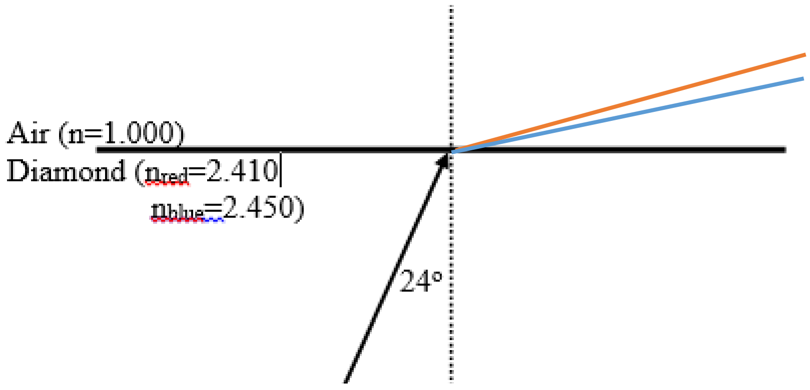
Question 15 (5 marks)

a. Light exiting the diamond would split into the ROYGBIV colours. When the white light enters the diamond it travels at a speed of less than c due to the optical density of the material. The amount at which the light is slowed down depends on the frequency of the incoming light – violet light is slowed down the most hence refracts the most.

2 marks

b. $n_i \sin\theta_i = n_r \sin\theta_r$
$Red = 2.41 \sin 24 = 1 \sin\theta_r$
$\theta_r = 78.59°$

$Blue = 2.45 \sin 24 = 1 \sin\theta_r$
$\theta_r = 85.21°$



3 marks

Question 16 (6 marks)

a. $v = f\lambda$
$295 = 698 \times \lambda$
$\lambda = 0.42$ m

2 marks

b. $f_3 = \frac{3v}{2L}$
$698 = \dfrac{3 \times 295}{2L}$
$L = 0.63$ m

2 marks

c. $f_4 = \frac{4v}{2L}$
$f_4 = \dfrac{4 \times 295}{2 \times 0.63}$

$f_4 = 936.51$ Hz

2 marks

Question 17 (10 marks)

a. Independent = frequency of the incoming light
Dependent = the kinetic energy of the photoelectrons
Controlled = metal type

3 marks

b. The aim of this experiment is to investigate the photoelectric effect in regards to finding the kinetic energy of ejected electrons from a sodium source by using light of known frequency.

2 marks

c. $E_K = hf - W = 6.63 \times 10^{-34} \times 8 \times 10^{14} - 2.18 \times 1.6 \times 10^{-19} = 1.82 \times 10^{-19}\, J$

2 marks

d. Agree. According to the particle (photon) model for light, an increase in light intensity simply increases the number of photons incident upon the sodium surface. More electrons will be ejected, but as each incoming photon has the same energy ($E = hf$), the energy of the fastest electron will not increase, so the voltage required to stop them will remain constant.

3 marks

Question 18 (4 marks)

a. X is positioned such that the path difference from each slit is a half integer multiple of the wavelength of the laser source (precisely: 2.5 λ). As a result of this path difference, previously coherent photons will arrive at X exactly out of phase and due to destructive interference, leading to a dark point at X.

2 marks

b. $Path\ Difference = 2.5\lambda$
$1483 = 2.5\lambda$
$\lambda = 593\ nm$

2 marks

Question 19 (4 marks)

a. $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{0.14\times10^{-9}} = 4.74 \times 10^{-24}\ Ns$

1 mark

b. $p_e = p_{x-ray} = 4.74 \times 10^{-24}$ Ns
$p_e = mv$
$v_e = \frac{4.74 \times 10^{-24}\ Ns}{9.1 \times 10^{-31}} = 5.2 \times 10^6$ m s^{-1}

$KE_e = 0.5mv^2 = 0.5 \times 9.1 \times 10^{-31} 5.2 \times 10^6 = 1.23 \times 10^{-17}$ J
$V_e = \frac{E}{q} = \frac{1.23\times10^{-17}}{1.6\times10^{-19}} = 77$ V

3 marks

Question 20 (4 marks)

a. $E = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3\times10^{8}}{2070\times10^{-9}} = 0.6$ eV
The only transition to yield 0.6 eV is from n = 4 to n = 3.

2 marks

b. If electrons are modeled as standing waves, it stands to reason that they can only take discrete wavelengths as the circumference of the atom is fixed and only certain wavelengths will allow constructive interference to take place and reinforce a particular wavelength. Discrete wavelengths imply discrete momenta and thus energy levels, which we witness in the form of discrete transitions – ie. only certain photons are emitted, not all wavelengths are seen on emission or absorption spectra.

2 marks
