PHYSICS

Units 3 & 4 – Written examination

(TSSM's *2011 trial exam updated for the current study design*)

<u>SOLUTIONS</u>

SECTION A – Multiple Choice questions (1 mark each)

Question 1

Answer: B

Explanation:
Field lines come out of a positive charge and into a negative, hence B.

Question 2

Answer: C

Explanation:
In order to accelerate south the field will be acting in the opposite direction due to the particle being negative – hence north.

Question 3

Answer: A

Explanation:
The masses have increased by a factor of 4 and the distance has increased by a 16, hence the force will be 0.25 of the original.

Question 4

Answer: A

Explanation:
As the potential energy is dependent on the distance between the sun and the commet as the distance is minimum the potential energy decreases not increases, all other responses are correct.

Question 5

Answer: C

Explanation:
With a weight of 39.2 N downwards and a tension of 44 N the tension is greater than the weight, hence the motion is opposing gravity therefore upwards. The net force on the system is 4.8 N hence accelerating at 1.2 m s^{-2}

Question 6

Answer: C

Explanation:
By standard definition

Question 7

Answer: C

Explanation: Rotation would lead to acceleration and a non-inertial reference frame.

Question 8

Answer: D

Explanation: $v = \frac{RBq}{m} = \frac{0.1 \times 4.2 \times 10^{-3} \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}} = 7.38 \times 10^{7}\ ms^{-1}$

Question 9

Answer: C

Explanation: Use the RH slap rule for moving charge, ensuring that the "current" is moving in the opposite direction to the negatively charged electron.

Question 10

Answer: C

Explanation:
Sound travels as a series of compressions and rarefractions hence it is a longitudinal wave.

Question 11

Answer: D

Explanation:
Light from a laser is of the same frequency, are in phase with one another and is a narrow beam. They do not have a higher energy that photons of light of the same frequency as $E = hf$

Question 12

Answer: D

Explanation: $f = \frac{v}{\lambda} = \frac{3\times10^8}{600\times10^{-9}} = 5\times10^{14}$ Hz

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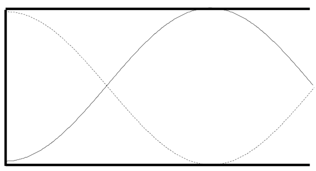
Question 13

Answer: B
Explanation: First quiet point corresponds to the first node, which implies a wavelength of
$\lambda = \frac{4L}{3}$
So the resonant frequency is
$f = \frac{3v}{4L} = \frac{3\times340}{4\times2.4} = 106\,Hz$

Question 14

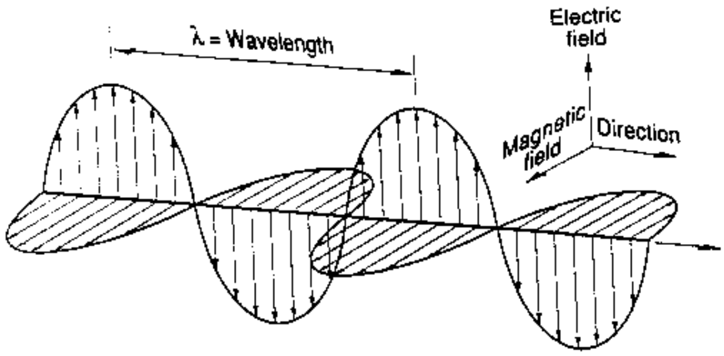
Answer: C
Explanation: With a node at one-third along the tube closed at one end, this is the third harmonic.



Question 15

Answer: B

Explanation:



Question 16

Answer: B

Explanation:
As the wave is travelling from a more dense to less dense medium it will bend away from the normal.

Question 17

Answer: C

Explanation:
In order for an electron to orbit the nucleus it must be forming a standing wave – to do this a whole number of its wavelengths must equal the circumference of the orbit.

Question 18

Answer: A

Explanation:
The uncertainty principle is a relationship between position and momentum

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Question 19

Answer: B

Explanation:
A transformer only operates if there is a changing flux to induce a magnetic field, the only device that does this is an AC device.

Question 20

Answer: C

Explanation:
$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$\frac{100}{10} = \frac{110}{V_p}$$

$$V_p = 11\text{V}$$

SECTION B

Question 1 (3 marks)

a. Force is to the right.

1 mark

b. Force causes the electron to accelerate to the right.

2 marks

Question 2 (5 marks)

a. $E = \frac{V}{d} = \frac{1400}{15\times10^{-3}}$

$E = 9.3\times10^{4}$ V m^{-1}

2 marks

b. $F = Eq = ma$

$a = \frac{9.3\times10^{4}\times1.6\times10^{-19}}{9.11\times10^{-31}}$

$a = 1.64\times10^{16}$ m s^{-2}

3 marks

Question 3 (6 marks)

a. Use Newton's law of Gravitation, remembering that **r** is measured from the centre of mass of each body:

$$F = \frac{GMm}{r^2} = \frac{6.67\times10^{-11}\times2.9\times10^{23}\times7.2\times10^{3}}{\left(R_{Tritonius} + Altitude\right)^2} = 2.06\times10^{4}\,N$$

$$\therefore Altitude = 2\times10^{5}\,m$$

2 marks

b. Use Newton's law of Gravitation, rearranged for satellites:

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

$$T = \sqrt{\frac{R^3\times4\pi^2}{GM}} = \sqrt{\frac{\left(2.6\times10^{6}\right)^3\times4\pi^2}{6.67\times10^{-11}\times2.9\times10^{23}}} = 5989\,\text{sec}$$

T = 5989 / 60 = 100 mins.

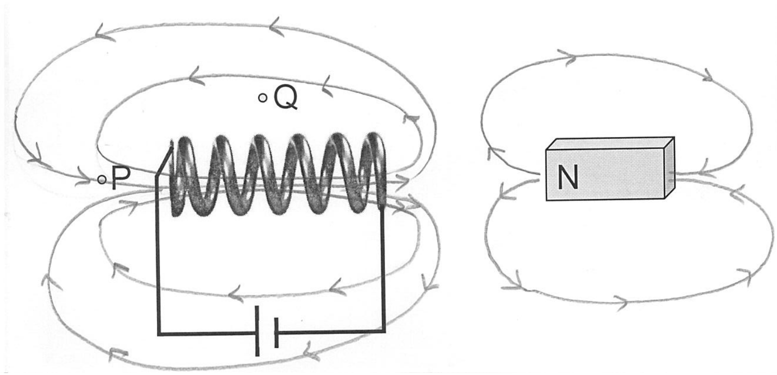
2 marks

c. Bill is correct, as the occupants of the orbiter would feel weightless (ie. Experience apparent weightlessness) as the net force on all orbiting material would be constant towards the centre of Tritonus, as would be the weight force. Unlike when on Earth, there would be no reaction force from the floor of the orbiter pushing on the occupants and they would appear to float around the cabin.

2 marks

Question 4 (6 marks)

a. **Refer to pic below.** Note lines should be continuous and not touch.



2 marks

b. *Answer:* **A**
Explanation: As per diagram, field lines around solenoid found through RH Grip rule. Field lines run from left to right inside the solenoid and right to left outside.

1 mark

c. Use RH Slap rule to determine direction of current at P.
$F = nBIL$

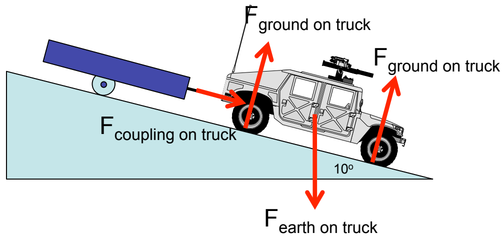
$$I = \frac{F}{nBL} = \frac{0.08}{1 \times 0.6 \times 0.04} = 3.33A$$

Direction: Out of the page.

3 marks

Question 5 (7 marks)

a. Note the compression in the coupling leads to a force acting on the truck down the inclined plane.



2 marks

b. Apply Newton's second law to the 7000 kg truck:
$F = ma = 7000 \times 2 = 1.4 \times 10^4\ N$

2 marks

c. Vector addition of all forces acting on the truck.
Note that the net force is negative, as positive acceleration is being defined as up the slope.

$$F_{NET} = ma = 7000 \times -2 = 1.4 \times 10^4 \text{ N}$$
$$F_{NET} = 1.4 \times 10^4 = W \sin\theta + F_{couple} - F_{friction} - F_{brake}$$
$$F_{brake} = 7000 \times 9.8 \times \sin 10 + 4000 - 7000 \times 9.8 \times 0.15 + 1.4 \times 10^4$$
$$F_{brake} = 19622 \text{ N}$$
$$F_{brake} = 1.96 \times 10^4 \text{ N actin up the slope.}$$

3 marks

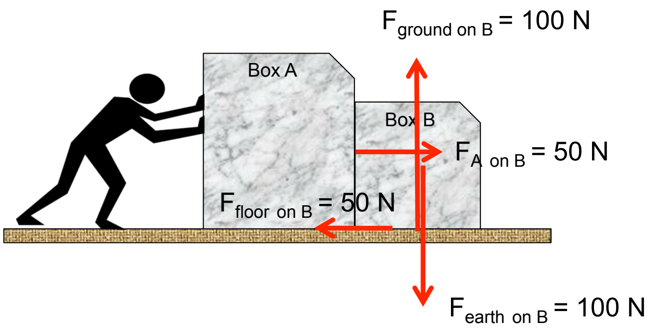
Question 6 (7 marks)

a. Forces in all directions should be balanced as both Boxes are travelling at a constant speed. Thus: $F_{Ivan\ on\ Box\ A} = 0.5 \times 9.8 \times 20 + 0.5 \times 9.8 \times 10 = 147$ N

2 marks

b. Forces in all directions should be balanced as Box B is travelling at a constant speed. Thus, vectors should be shown with appropriate matching lengths

2 marks



c. $F_{\text{of A on B}} = 50$ N to the left (so that horizontal forces are balanced)
According to Newton III, $\boldsymbol{F}_{\text{Box A on Box B}} = -\boldsymbol{F}_{\text{Box B on Box A}}$.

3 marks

Question 7 (8 marks)

a. $v = \dfrac{2\pi r}{T} = \dfrac{2\pi \times 3.5}{3.1} = 7.1 ms^{-1}$

1 mark

b. $F = \dfrac{mv^2}{r} = \dfrac{25 \times 7.1^2}{3.5} = 359\,N$

2 marks

c. Use pythagoras to find hypotenuse of triangle with W (vertical) and F_{net} (horizontal) sides. $T = \sqrt{(25 \times 9.8)^2 + 359^2} = 435$ N

3 marks

d. *Answer:* B, C, D
Explanation: Increasing the speed of the ride would decrease the period, so A is incorrect. All other options are correct. The net force would increase with the square of the speed, the angle and radius would also increase.

2 marks

Question 8 (4 marks)

a.

$v_{\text{vert}} = 0$ at 1.8 sec after launch:

$v = u + at$

$0 = u - 9.8 \times 1.8$

$u = 17.64 \text{ m s}^{-1}$

Then, use trignometry to determine total v at 35°:

$v \times \sin 35 = 17.64$

$v = 30.7 \text{ m s}^{-1}$

2 marks

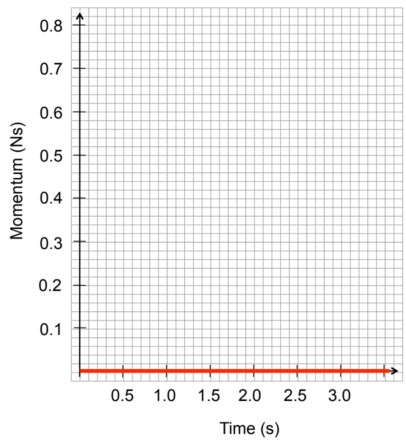
b. $v_{horiz} = v \times \cos 35 = 25.2 \text{ m s}^{-1}$

$x = v_{horiz} \times t = 45.35 \text{ m}$

2 marks

Question 9 (4 marks)

a. See graph below – total momentum is zero as it is effectively an isolated collision with no external forces.



2 marks

b. Isolated collision, so $p_A = -p_B$ after release.

$$v_B = \frac{v_A m_A}{m_B} = \frac{0.35 \times 1.3}{0.2} = 2.3 ms^{-1}$$

$$KE_B = 0.5mv^2$$

$$KE_B = 0.5 \times 0.2 \times 2.3^2 = 0.51J$$

2 marks

Question 10 (7 marks)

a. $\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-0.9^2}} = 2.29$

$L = \frac{L_0}{\gamma} = \frac{20}{2.29} = 8.72\text{m}$

3 marks

b. $d = vt$

$8.72 = 0.9 \times 3 \times 10^8 \times t$

$t = 3.23 \times 10^{-8}\text{s}$

2 marks

c. $t = t_0\gamma = 3.23 \times 10^{-8} \times 2.29 = 7.4 \times 10^{-8}\text{s}$

2 marks

Question 11 (4 marks)

a. The angle vector of the coil is at 90° to the magnetic field, so: $\Phi = BA\cos\theta = BA\cos 90 = 0$. An alternate explanation is that no field lines will pass through the coil in its present position, so flux is zero.

2 marks

b. $\xi = n\frac{\Delta\Phi}{\Delta t}$

$\Delta t = n\frac{\Delta\Phi}{\xi} = 10\frac{0.3 \times 0.4}{4} = 0.3s$.

Note change in flux is equal to ***BA*** for a quarter turn as the coil moves from min to max in 90°.

2 marks

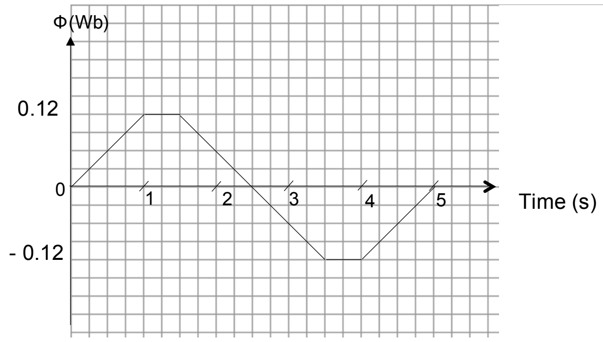
Question 12 (7 marks)

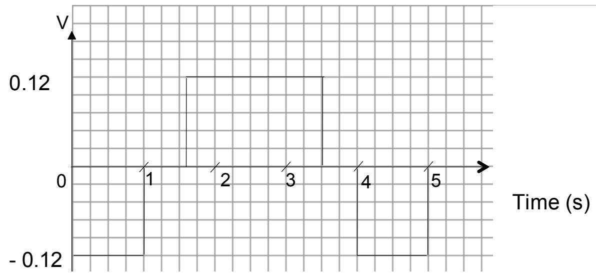
a. Increasing voltage in the solenoid leads to an increasing magnetic field to the left. As per Lenz' Law, the loop responds with an induced field to the right and corresponding clockwise current (as viewed from A using the RH grip rule).

3 marks

b. The flux graph is proportional to the increasing field in the solenoid. The emf graph is the negative derivative $\xi = -n\dfrac{\Delta\Phi}{\Delta t}$, so as flux increases, there will be constant negative voltage and vice versa. Note the positive and negative gradients in the flux graph are the same, so emf values are same in magnitude, positive and negative.

$\Phi_{\max} = BA = 0.4 \times 0.3 = 0.12\,Wb$ $\qquad$ $\xi = -n\dfrac{\Delta\Phi}{\Delta t} = -1\dfrac{0.12}{1} = -0.12\,V$





4 marks

Question 13 (7 marks)

a. $P_{LOSS} = I^2R = 4.5^2 \times 8 = 162\,W$

2 marks

b. $V_A = V_{GEN} - V_{LINE} = 5000 - IR = 5000 - 36 = 4964\,V$

2 marks

c. **B (20:1)**
Explanation: The school would most likely require voltage ~ 240-250 V, so a step down transformer would be most suitable (A or D). D is effectively a 1000:1, which would reduce the voltage to a far lower level than desirable.

For the 20:1, $V_{SCHOOL} = \dfrac{4964}{20} = 248\,V$

3 marks

Question 14 (6 marks)

a. $v = f\lambda$
$3\times10^8 = 5.455\times10^{14}\times\lambda$
$\lambda = 5.5\times10^{-7}\text{m}$

2 marks

b. $n = \frac{c}{v} = \frac{3\times10^8}{1.875\times10^8} = 1.6$

2 marks

c. $n_i \sin\theta_i = n_r \sin\theta_r$
$1.0 \sin 30 = 1.6 \sin\theta_r$
$\theta_r = 18.21^0$

2 marks

Question 15 (5 marks)

a. **With** C as the centre of the pattern, X represents a point which has a path difference of 3.5 wavelengths.
$PD = 3.5 \times \lambda = 1.5 \times 10^{-6}\,m$
$\lambda = 4.29 \times 10^{-7}\,m$

2 marks

b. Young's double slit experiment is clear evidence of the wavelike properties of light. Interaction between two sources of light that leads to a series of nodes (destructive interference) and antinodes (constructive interference) will only occur under wavelike conditions, not particle.

3 marks

Question 16 (14 marks)

a. By increasing the frequency of the incident light on the metal (beyond the threshold frequency) the kinetic energy of the released photoelectrons will increase and therefore so will the required stopping voltage.

2 marks

b. Controlled = metal type, Independent = Incident Frequency, Dependent = Stopping voltage

3 marks

c. Tracing linear line back to y axis = 2.75 V, therefore work function = 2.75 eV hence sodium

2 marks

d. $Gradient = \frac{2.5-0.5}{12\times10^{14}-7\times10^{14}} = 4\times10^{-15}\text{eV}$

3 marks

e. $\%\,error = \frac{4.14\times10^{-15}-4\times10^{-15}}{4.14\times10^{-15}}\times100 = 3.38\%$

2 marks

f. Systematic – error the voltmeter hence the voltage obtained is slightly different to the stopping voltage.
Random errors – human error in taking readings.

2 marks

Question 17 (4 marks)

$$\lambda = \frac{h}{\sqrt{2mKE}} = \frac{6.63\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times400\times1.6\times10^{-19}}}$$

a. $\lambda = 6.14\times10^{-11}m$

2 marks

b. $$E = \frac{hc}{\lambda} = \frac{4.14\times10^{-15}\times3\times10^{8}}{6.14\times10^{-11}}$$

$E = 2.02\times10^{4}\,eV$

2 marks

Question 18 (7 marks)

a. The energy required is the difference between energy levels: 3.4 eV.

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

$$\lambda = \frac{hc}{E} = \frac{4.14\times10^{-15}\times3\times10^{8}}{3.4} = 3.66\times10^{-7}\,m$$

1 mark

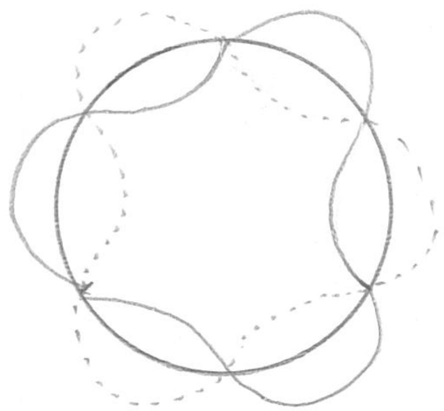
b. *Answer:* **A, C, D**
Explanation: Any transition from a higher to lower energy state below n = 4 is allowed.
A: n = 3 to n = 2
C: n = 3 to n = 1
D: n = 4 to n = 1

1 mark

c. The existence of discrete energy levels is evidence of the wavelike properties of electrons (matter) as they are modelled as standing waves which can only have certain wavelengths
($\lambda = n\times2\pi r$). Discrete wavelengths leads to discrete momenta and energies for the electrons, hence discrete energy levels. The fact that electrons can transition between these levels, emitting and absorbing photons as particles supports the particle model for matter as well.

2 marks

d. For n = 3, there must be 3 complete wavelengths around the circumference of the atom. In the diagram below, the dotted path represents the other half of the standing wave envelope (as per standing wave convention).



1 mark