PHYSICS

Units 3 & 4 – Written examination

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(TSSM's *2015 trial exam updated for the current study design*)

<u>SOLUTIONS</u>

Section A - Multiple Choice (1 mark each)

Question 1

Answer: C

Explanation:

The density of lines at a specific location in space reveals information about the strength of the field at that location.

Question 2

Answer: C

Explanation:
Field lines allow for the direction of the force acting on an object to be determined.

Question 3

Answer: D

Explanation:
Coiling a wire, increasing current or coiling a wire around an iron core will all increase the strength of the magnetic field produced. Changing the thickness of the wire is irrelevant.

Question 4

Answer: B

Explanation:
$v^2 = u^2 + 2as$
$0 = 9^2 + 2 \times a \times 11$
$a = 3.68$ m s^{-2}

Question 5

Answer: B

Explanation:
As $\sum F = W + N$ maximum normal reaction forces will occur at the bottom of the ride as $N = \sum F + W$ where at the top $N = \sum F - W$.

Question 6

Answer: C

Explanation:
For a stationary observer time appears to be running slower due to time dilation.

Question 7

Answer: A

Explanation:
The twin paradox is a thought experiment in special relativity involving identical twins, one of whom makes a journey into space in a high-speed rocket and returns home to find that the twin who remained on Earth has aged more.

Question 8

Answer: B

Explanation:
The output voltage of a DC generator is shown in diagram B as the commutator reverses the direction of the current produced every half cycle.

Question 9

Answer: B

Explanation:
$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$
$$\frac{240}{V_s} = \frac{1}{6}$$
$$V_s = 1440 \text{ V}$$

Question 10

Answer: D

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

$\frac{I_s}{4} = \frac{1}{6}$
$I_s = 0.67$ A

Question 11

Answer: C

Explanation:
Polarised light waves occur in a single plane. This only occurs due to the nature of a transverse wave.

Question 12

Answer: A

Explanation:
When light goes from a less dense to more dense medium it slows down. Due to the change in speed the wavelength shortens but the frequency remains unchanged.

Question 13

Answer: A

Explanation:
$n_i \sin\theta_i = n_r \sin\theta_r$
Blue
$1 \sin 40 = 1.64 \sin\theta$
$\theta = 23.075$
Red
$1 \sin 40 = 1.605 \sin\theta$
$\theta = 23.61$
Difference in angle $0.535°$

Question 14

Answer: B

Explanation:
Newton observed dispersion which is white light splitting into the ROYGBIV colours.

Question 15

Answer: C

Explanation:
$f_3 = 450$ Hz therefore $f_1 = \frac{450}{3} = 150$
$f_7 = 7f_1 = 7 \times 150 = 1050$ Hz

Question 16

Answer: C

Explanation:
Bright bands are a result of constructive interference, hence their path difference is $pd = n\lambda$
Therefore the distance is equivalent to a full wavelength

Question 17

Answer: A

Explanation:
In order to obtain Planck's constant the student needs to plot the kinetic energy vs frequency of the photoelectron. The gradient of this graph will therefore be equivalent to Planck's constant.

Question 18

Answer: B

Explanation:
n = 2 has an energy of 16.7 eV, n = 5 energy is 20.3 eV hence difference is 3.6 eV

Question 19

Answer: A

Explanation:
$3.6 \times 1.6 \div 10^{-19} = 5.76 \times 10^{-19}$J

Question 20

Answer: C

Explanation:
5 → 4
4 → 3
3 → 2
5 → 3
4 → 2
5 → 2

SECTION B

Question 1 (4 marks)

a. $E = \frac{V}{d} = \frac{2000}{0.005} = 4.0 \times 10^5$ V m^{-1}

2 marks

b. $F = qE = 4.0 \times 10^5 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-14}$ N

2 marks

Question 2 (6 marks)

a. $T = 20 \times 60 \times 60 = 72000$s

1 mark

b. $R^3 = \frac{GMT^2}{4\pi^2} = \frac{6.67 \times 10^{-11} \times 8 \times 10^{20} \times 72000^2}{4\pi^2}$
$R = 1.91 \times 10^6$
Altitude = 9.0×10^5 m
Therefore radius of planet = $1.91 \times 10^6 - 9.0 \times 10^5 = 1.01 \times 10^6$ m

3 marks

c. $v = \frac{2\pi r}{T} = \frac{2\pi \times 1.91 \times 10^6}{72000} = 166.67$ m s^{-1}

2 marks

Question 3 (4 marks)

a. Left.
Use the right hand grip rule, using the current as shown in the solenoid. Field is directed to the right *through* the solenoid, and back to the left on the *outside* in the vicinity of P.

2 marks

b. $F = nBIL$

$I = \frac{F}{nBL}$

$I = \frac{0.02}{1 \times 0.13 \times 0.04}$

$I = 3.85$ A

Current is directed into the page (RH slap rule)

3 marks

Question 4 (6 marks)

a. Use Ohm's Law and Faraday's principle to identify voltage and then field strength.

$V = IR$

$V = 0.04 \times 0.3 = 0.012$ V

$\varepsilon = -\frac{n\Delta\phi}{\Delta t}$

$0.012 = -\frac{1 \times (0.05)^2 B}{0.08}$

$B = 0.384$ T

3 marks

b. X is a **south** pole. This is determined using Lenz's Law.

Current is ABCD, which implies a field from left to right.
This means that there has been a change in flux from right to left.
A final flux of zero means the initial flux is left to right, so X is **South**.

3 marks

Question 5 (7 marks)

a. $F = nBIL$

$I = \frac{F}{nBL} = \frac{0.23}{0.08 \times 30 \times 0.16} = 0.599 = 0.6$ A

For direction, the force is upwards, field from right to left, so current must be into the page (A to B)

4 marks

b. As the coil rotates to a vertical position (as per Figure 5), the commutator briefly switches off the current. The coil rolls past vertical under its own momentum and then reconnects to the DC supply with current in the opposite direction

Due to the orientation of the commutator and the brushes, the torque (turning effect of the force) is maintained in the same direction. That is, F_{AB} is now downwards. This process repeats every half turn, so the motor turns continuously

3 marks

Question 6 (7 marks)

a. $T = 40$ ms (Note actual period is 2 half cycles)

$f = \frac{1}{T} = \frac{1}{0.04} = 25$ Hz

2 marks

b. Split-ring commutator is used because the naturally AC output from the coil has been rectified and is now DC.Slip-rings would give an AC output as they do not reverse the direction of the current to the load.

3 marks

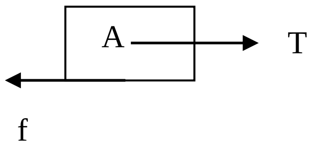
c. The period doubles to 80 ms. V_{max} halves to 0.6 V. V_{max} now occurs at 20 ms and 60 ms (as per the DC output from the commutator).

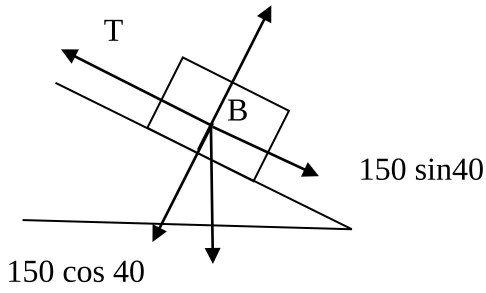
2 marks

Question 7 (6 marks)

a.

m = 15 kg
W = 15 × 9.8 = 147 N
Using Free body diagram for A





T – f = ma

T – 10 = 15 a

T = 15 a + 10 ………eq1

150 sin 40 – T = 15 a ……….eq 2

Sub eq 1 in eq 2 and solve for a
a = 2.82 m s^{-2}

2 marks

b. a = 2.82 ms^{-2} in equation 1
Therefore, T = 52.2 N

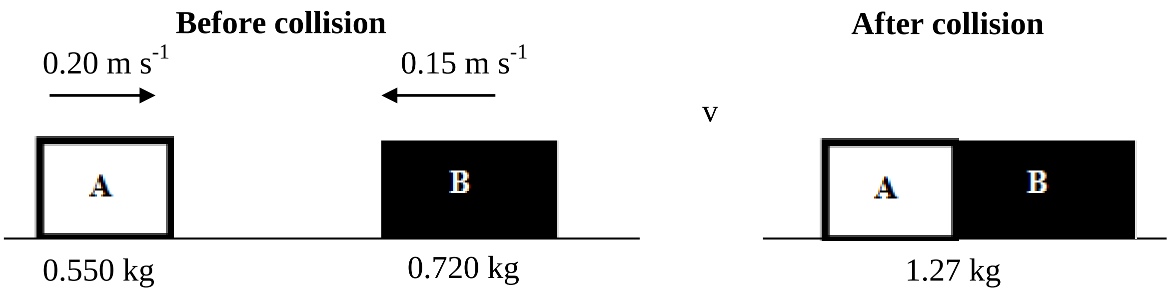
2 marks

c. $s = ut + {}^{1}\!/_{2}\, at^2$
$0.40 = 0 + {}^{1}\!/_{2} \times 2.82 \times t^2$
$t = 0.53$ s

2 marks

Question 8 (7 marks)

a.



$m_1u_1 + m_2u_2 = (m_1 + m_2)v$
$0.550 \times 0.2 + 0.720 \times 0.15 = 1.27v$
$v = 1.57 \times 10^{-3}$m s^{-1}

2 marks

b. Inelastic

1 mark

c. Total initial kinetic energy, before collision = ½ × (0.550) × (0.20)^2 + ½ × (0.720) × (0.15)^2

= 0.011 + 0.081

= 0.0191 J

Total final kinetic energy, after collision = ½ × (1.27) × (1.57 × 10^{-3})^2

= 1.56 × 10^{-6} J

Since initial KE is not equal to final KE, hence it is an inelastic collision.

2 marks

d. Change in momentum = *m (v - u)*

v = to the right *u* = to the left

Hence change in momentum = 0.720 × (1.57 × 10^{-3} + 0.15)

= 0.109 kg m s^{-1}

$F = \frac{m\Delta v}{t}$

$F = \frac{0.109}{0.4} = 0.27$ N

2 marks

Question 9 (6 marks)

a. Horizontal component = 7.5 cos 70 = 2.57 m s^{-1}

1 mark

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

$0 = (7.5 \sin 70)^2 + 2 \times 9.8 \times s$
$s = 2.53$ m
vertical distance $= 2.53 + 1.8 = 4.33$ m

2 marks

c. Time spent in air from shoulder to the highest point.

$v = u + at$
$0 = 7.5 \sin 70 + 9.8t$
$t = 0.72$ s

Time spent from the highest point to the ground:
$s = ut + {}^{1}\!/_{2}\, at^2$
$4.33 = 0 + {}^{1}\!/_{2} \times 9.8 \times t^2$
$t = 0.94$ s

Total time spent in air = 0.72 + 0.94 = 1.66 s

2 marks

d. $s = ut + {}^{1}\!/_{2}\, at^2$
Since horizontal acceleration = 0
$s = 7.5 \cos 70 \times 0.72 = 1.85$ m

1 mark

Question 10 (7 marks)

a. An external force required to keep an object move long a circular path with uniform speed is known as centripetal force.

1 mark

b. $F = \frac{mv^2}{r}$

$200 = \frac{90v^2}{25}$

$v = 7.45$ m s^{-1}

2 marks

c. Centripetal force will be provided by the unbalanced component of the weight force

$v = \sqrt{rg \cdot tan(\theta)}$
$v = 10.34$ m s^{-1}

2 marks

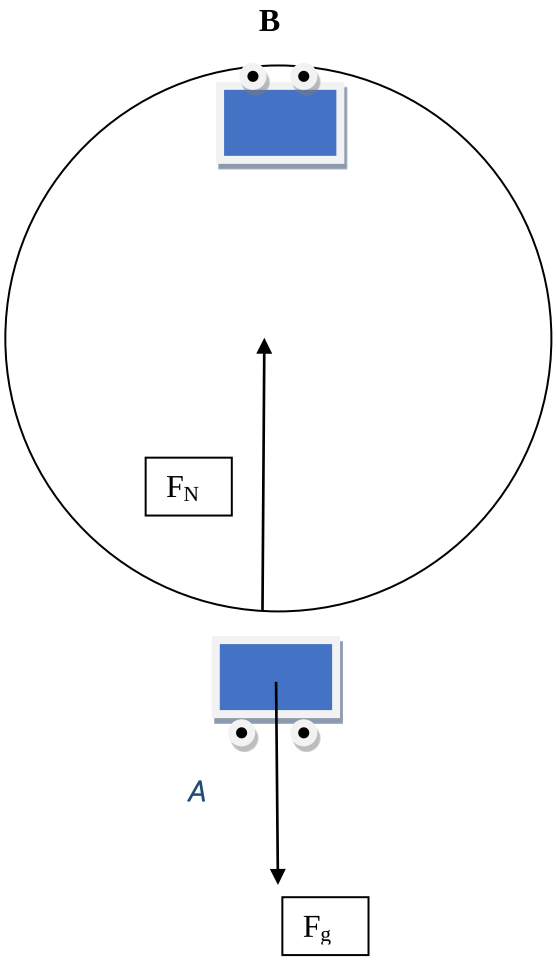
d. Higher speed requires more centripetal force.

The horizontal component of the reaction force will be greater which will make the vertical component of the reaction force greater too. This will give a net upward force on the cyclist.
This would mean that he would be forced to ride in a path of larger radius or rely on friction towards the centre of the circle to keep him at the same radius.

2 marks

Question 11 (5 marks)

a.



1 mark

b. $F_N - Fg = Fc$
$F_N = Fg + Fc$
Seat pushed the person with a greater force than usual thus making the person feel heavier than her normal weight.

2 marks

c. At position A: $F_N = Fg + Fc$ (feels heavier)
At position B: $F_N = Fg - Fc$ (feels lighter)

2 marks

Question 12 (3 marks)

a. $Ek = \left(\frac{1}{2}\right) mv^2$

$4.0 = \left(\frac{1}{2}\right) 0.250\ v^2$

$v = 5.6$ ms^{-1}

1 mark

b. ${}^{1}\!/_{2}\, k\Delta x^2 = {}^{1}\!/_{2}\, mv^2$

${}^{1}\!/_{2}\, k(0.04)^2 = 4$

$k = 5000$ Nm^{-1}

2 marks

Question 13 (2 marks)

$$m = \frac{mo}{\left(1 - \left(\frac{v^2}{c^2}\right)\right)^{\frac{1}{2}}}$$

$m_o = 9.28 \times 10^{-31}$ kg

$v = 0.6 \times 10^8$

$c = 3 \times 10^8$

Therefore,

$m = 9.28 \times 10^{-31}$ kg

2 marks

Question 14 (5 marks)

a. Use relationship between peak and RMS current.

$I_{PEAK} = I_{RMS} \times \sqrt{2}$

$I_{PEAK} = 2.5 \times \sqrt{2} = 3.54$ A

1 mark

b. Calculate RMS current on primary side, using power and voltage relationship. Then apply ratio of current to voltage.

$I_{PRIM} = \frac{P}{V} = \frac{2500}{200} = 12.5$ A

$V_{SEC} = \frac{I_{PRIM}}{I_{SEC}} = \frac{12.5}{2.5} \times 200 = 1000$ V

2 marks

c. Use the voltage ratio to determine the turns ratio.

$$n_{SEC} = \frac{V_{SEC}}{V_{PRIM}} \times n_{PRIM}$$
$$n_{SEC} = \frac{1000}{200} \times 120 = 600 \text{ turns}$$

2 marks

Question 15 (9 marks)

a. Use generator values and then Ohm's Law to determine the voltage loss in the lines.

$$I = \frac{P}{V} = \frac{4000}{1200} = 3.33 \text{ A}$$
$$V = IR = 3.33 \times 12 = 40 \text{ V}$$

2 marks

b. $\eta = \frac{P_{input} - P_{loss}}{P_{input}} \times 100\%$

$$\eta = \frac{4000 - I^2R}{4000} \times 100\%$$
$$\eta = \frac{4000 - (3.33)^2 12}{4000} \times 100\%$$

$$\eta = 96.7\ \%$$

2 marks

c. Use voltage drop found in a. to determine the voltage at the primary side of the step-down transformer, then apply the step down ration of 4:1.

$$V = (V_{GEN} - V_{DROP}) \times \frac{100}{400}$$
$$V = (1200 - 40) \times \frac{1}{4} = 290 \text{ V}$$

2 marks

d. Shop voltage is reduced.
A reduction in the effective resistance of the shop will lead to an increase in current . This will lead to an increased (albeit smaller) current in the transmission lines on the other side of the transformer. The increased current in the lines will lead to a larger voltage drop. Thus, the voltage at the primary side of the transformer will be less ($V = V_{GEN} - V_{LOSS}$). Once stepped down, the voltage at the shop will be less than 290 V.

3 marks

Question 16 (7 marks)

a. In this extended practical investigation Young's Double Slit experiment will be used to investigate the wave-like nature of light. By shining monochromatic light through the double slits an interference pattern will be observed and its characteristics investigated.

2 marks

b. Y is the second bright point (antinode) from the centre, so the path difference is 2 wavelengths.

$P.D. = 2\lambda$
$1 \times 10^{-6} = 2 \times \lambda$

$\lambda = 0.5 \times 10^{-6}$ m
$\lambda = 500$ nm

2 marks

c. X is a dark point (node), where the path difference is 2.5 wavelengths. Thus, light from the two sources is out of phase and destructive interference is occurring. This leads to a "cancellation" of intensity and a dark point on the pattern.

2 marks

d. If the distance between Slit 1 and Slit 2 is reduced, the pattern becomes wider.

1 mark

Question 17 (7 marks)

a. $E_K = hf - W$
$0.8554 = 4.14 \times 10^{-15} \times 6.1 \times 10^{14} - \mathrm{W}$
$W = 1.67$ eV

2 marks

b. $f_0 = \frac{W}{h}$
$f_0 = \frac{1.67}{4.14 \times 10^{-15}}$
$f_0 = 4.04 \times 10^{14}$ Hz

2 marks

c. The particle (photon) model implies that there is only a 1-to-1 interaction between photons and electrons. This contrasts the one-to-many idea for waves. So, if the frequency of an incoming photon is too low (ie. less than f_0), it will have insufficient energy to liberate an electron, even if the intensity (ie. number of photons) is increased.
In contrast the wave model would predict that a threshold frequency could be overcome

by simply waiting for wave energy to accumulate an eject an electron (ie. a delay could be expected) or simply by increasing intensity (which is proportional to energy of the wave). Moreover, a wave could spread or focus its energy on one or many electrons – which would lead to at least one being liberated.
Observations support the particle model and the existence of the threshold frequency.

3 marks

Question 18 (5 marks)

a. $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{0.08\times10^{-9}}$

$p = 8.29 \times 10^{-24}$ N s

2 marks

b. The amount of diffraction (ie. width of pattern) is directly proportional to the wavelength.
So, for x-rays: $\lambda = \frac{hc}{E}$
But for electrons:
$KE = 0.5mv^2$
$2mKE = m^2v^2$
$2mKE = p^2$
$p = \sqrt{2mKE}$
$So, \lambda = \frac{h}{p} = \frac{h}{\sqrt{2mKE}}$
Thus for a given energy (KE in the case of electrons), a different wavelength ensues, and thus a different pattern would be observed.

3 marks

Question 19 (5 marks)

a. $\Delta E = 2.55$ eV
$$\Delta E = \frac{hc}{\lambda}$$
$$\lambda = \frac{hc}{\Delta E} = \frac{4.14 \times 10^{-15} \times 3 \times 10^8}{2.55}$$
$\lambda = 4.87 \times 10^{-7}$ m

2 marks

b. 12.75 eV corresponds to a stable energy state (n = 4) where electrons may exist as a standing wave ($\lambda = \frac{2\pi r}{n}$).
Between 0 (n = 1) and 10.2 eV (n = 2), there are no stable levels where an electron can exist as a standing wave as n must be an integer value (ie. a whole number of wavelengths is needed for a standing wave).

3 marks

Question 20 (2 marks)

Use the accelerating voltage and then de Broglie wavelength.

$$KE = Vq$$
$$KE = 400 \times 1.6 \times 10^{-19}$$
$$KE = 6.4 \times 10^{-17}\text{ J}$$
$$\lambda = \frac{h}{\sqrt{2mKE}}$$
$$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 6.4 \times 10^{-17}}}$$
$$\lambda = 6.1 \times 10^{-11}\text{ m}$$

2 marks