PHYSICS

Units 3 & 4 – Written examination

2023 Trial Examination

SOLUTIONS

SECTION A: Multiple-choice questions (1 mark each)

Question 1

Answer: A

Explanation:
Electric field lines point away from positive charges, which is occurring for both charges here. Therefore, it must be two positive charges. Gravitational fields are always attractive and magnetic fields around conductors are circular.

Question 2

Answer: D

Explanation:
The gravitational force between two masses is given by

$$F = \frac{GM_1M_2}{r^2} = \frac{(6.63 \times 10^{-11})(1.30 \times 10^{22})(1.55 \times 10^{21})}{(6 \times 10^5)^2} = 3.73 \times 10^{21} \text{ N}.$$

Question 3

Answer: A

Explanation:
Electric field direction goes from positive to negative so the top plate must be positively charged.

Question 4

Answer: C

Explanation:

Strength of electric field:
$E = \frac{V}{d} = \frac{1000}{0.08} = 1.25 \times 10^4 \text{ N C}^{-1}$

Question 5

Answer: B

Explanation:
$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{40}{13} = \frac{3}{1}$

Question 6

Answer: B

Explanation:
$F = nBIl = (1)(0.4)(1.5)(0.1) = 0.06$ N
Using the right hand slap rule, the force on side JK will be downwards.

Question 7

Answer: D

Explanation:
The force (and therefore rotation speed) can be increased by increasing the number of turns as per $F = nBIL$.

Question 8

Answer: C

Explanation:
Both girls will accelerate downwards at the same rate and therefore hit the water at the same time.

Question 9

Answer: C

Explanation:
$a = \frac{F_{net}}{m} = \frac{30 - 80}{14 + 7} = -2.38 \text{ m s}^{-2}$

Question 10

Answer: C

Explanation:
Total amount of work done $= F_{net}d = (80 - 30)(3) = 150$ J

Question 11

Answer: D

Explanation:
3.8×10^{26} W $= 3.8 \times 10^{26}$ J s^{-1}
$E = (\Delta m)c^2$
$3.8 \times 10^{26} = (\Delta m)(3 \times 10^8)^2$
$\Delta m = 4.22 \times 10^9$ kg

Question 12

Answer: B

Explanation:
$v = \sqrt{gr} = \sqrt{(9.8)(20)} = 14 \text{ m s}^{-1}$

Question 13

Answer: A

Explanation:
Doppler effect. Frequency and pitch increase as the source of the sound moves towards the observer.

Question 14

Answer: B

Explanation:
Amplitude is the distance of maximum displacement from resting position. In this example it is equal to 1.5 m. The frequency is the number of waves that pass per second. $f = \frac{1}{T} = \frac{1}{6} =$ 0.17 Hz.

Question 15

Answer: B

Explanation:
Diffraction is $\propto \frac{\lambda}{w}$. Waves that are closer together have a lower wavelength, therefore will diffract less than the longer wavelength waves.

Question 16

Answer: C

Explanation:
$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{(9.1 \times 10^{-31})(8.6 \times 10^{6})} = 8.47 \times 10^{-11} \text{ m}$$

Question 17

Answer: A

Explanation:
Widening the slit increases the uncertainty in the x position which decreases the uncertainty in the y direction. Therefore, there is less diffraction.

Question 18

Answer: D

Explanation:
Laser light is coherent and monochromatic.

Question 19

Answer: D

Explanation:
Independent variable is on the x axis (magnetic field strength) while the dependent variable is on the y axis (force). The relationship between these variables is $F = nBIL$ so the length of the wire should be a controlled variable.

Question 20

Answer: B

Explanation:
It can be said that a trendline is suitable if it passes through all uncertainty bars.

SECTION B: Short-answer questions

Question 1 (3 marks)

Half a mark for each correct response

	Gravitational field	**Electric field around a point mass**	**Magnetic field around a bar magnet**
Can be attractive or repulsive		✓	✓
Can exist as diploes or monopoles		✓	
Static	✓	✓	✓
Uniform			

3 marks

Question 2 (9 marks)

a. $g = \frac{GM}{r^2}$ All three planets have the same radius, so the planet with the largest 'g' value at the surface must have the greatest mass. This is planet C.

2 marks

b. Change in GPE = area under the graph
There are approximately 41 squares. Each square is 400 km x 0.2 N kg^{-1}
Therefore, the area is $= (41)(4 \times 10^5)(0.2) = 3.28 \times 10^6$ J kg^{-1}

Energy $= (3.28 \times 10^6)(800) = 2.62 \times 10^9 J$ (Variations on answer based on counting squares and/or area calculation)

2 marks

c. $g = \frac{GM}{r^2}$

$3 = \frac{(6.67 \times 10^{-11})(M)}{(4 \times 10^6)^2}$

$M = 7.20 \times 10^{23}$ kg

3 marks

d. $T = \sqrt{\frac{4\pi^2 r^3}{GM}} = \sqrt{\frac{(4)(\pi^2)(5\times10^6)^3}{(6.67\times10^{-11})(7.20\times10^{23})}} = 1.0 \times 10^4\ s$ (Consequential Answer on part c)

2 marks

Question 3 (5 marks)

a. $r = \frac{mv}{qB}$

$0.6 = \frac{(1.67 \times 10^{-27})(v)}{(1.6 \times 10^{-19})(0.05)}$

$v = 2.87 \times 10^6$ m s^{-1}

1 mark

b. Arrow curving downwards. Force at three different locations always perpendicular to motion.

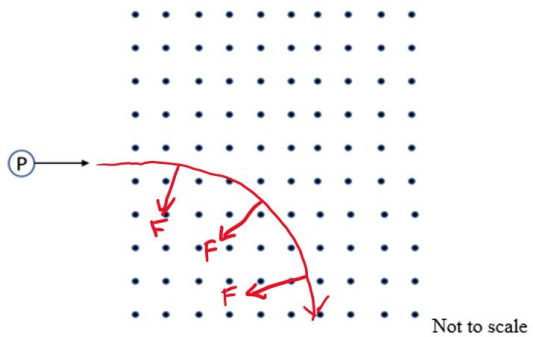


Figure 6.

2 marks

c. $F = qvB = (1.6 \times 10^{-19})(2.87 \times 10^6)(0.05) = 2.30 \times 10^{-14}$ N

2 marks

Question 4 (4 marks)

a. Strength of electric field $E = \frac{kQ}{r^2} = \frac{(8.99\times10^9)(3.2\times10^{-19})}{(20\times10^{-6})^2} = 7.19$ N C^{-1}

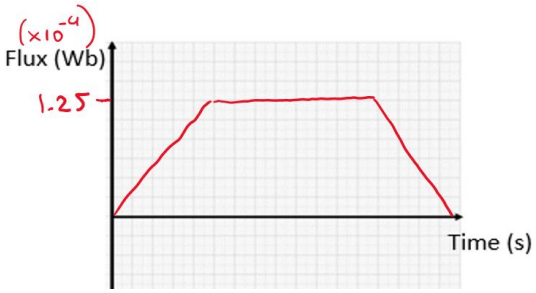
2 marks

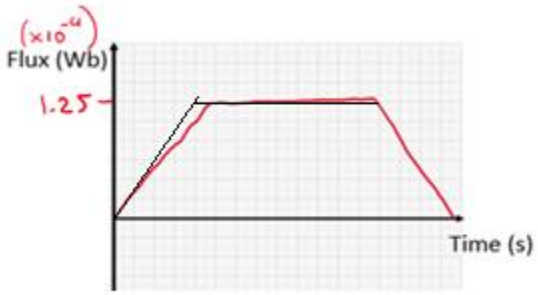
b. Force $F = \frac{kQ_1Q_2}{r^2} = Eq = (7.19)(1.6 \times 10^{-19}) = 1.15 \times 10^{-18}$ N

2 marks

Question 5 (7 marks)

a. $\phi = BA = (2.0 \times 10^{-3})(0.25^2) = 1.25 \times 10^{-4}$ Wb





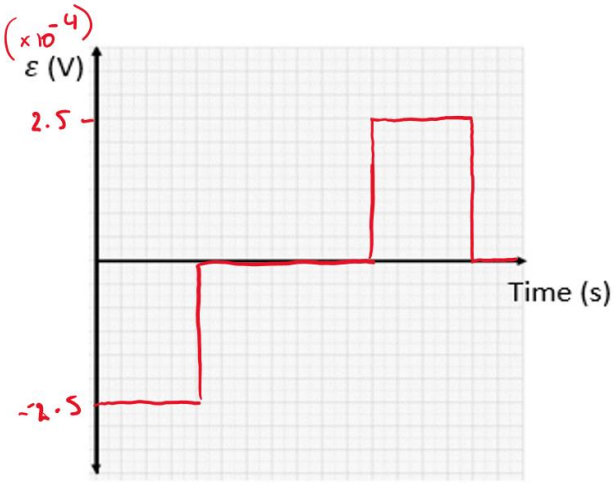
2 marks

b. Time to enter field $speed = \frac{distance}{time}$

$0.5 = \frac{0.25}{time}$

$time = 0.5\ s$

$emf = N\frac{\phi}{t} = (1)\left(\frac{1.25 \times 10^{-4}}{0.5}\right) = 2.5 \times 10^{-4}$ V



2 marks

c. Anticlockwise.

Flux is increasing into the page. To oppose the change in flux (as per Lenz's law), need to create flux out of the page. Using right hand rule, current flows anticlockwise.

3 marks

Question 6 (6 marks)

a. High voltage transmission of electricity means that the current will be reduced. This reduces power loss as per the equation $P_{loss} = I^2R$.

2 marks

b. $\frac{V_1}{V_2} = \frac{I_2}{I_1}$

$$\frac{20000}{200} = \frac{10}{I_1}$$

$I_1 = 0.1$ A

2 marks

c. AC can be stepped up and down using transformers, which is most suitable for transmitting electricity over large distances. Stepping up the voltage reduces power loss in the wires. DC cannot be stepped up or down, so it is not suitable for transmitting over large distances.

2 marks

Question 7 (7 marks)

a. Time for one rotation = 20 ms

$$f = \frac{1}{T} = \frac{1}{20 \times 10^{-3}} = 50 \text{ Hz}$$

2 marks

b. $V_{peak} = 170\ V$

$$V_{RMS} = \frac{V_{peak}}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120\ V$$

RMS stands for Root Mean Squared. It is the equivalent of the direct current that would produce the same power output as the given alternating current.

2 marks

c. Peak voltage in positions B and D. In these positions, as the coil rotates there is the largest rate of change in flux therefore there will be largest induced EMF as per Faraday's Law ($\epsilon = \frac{\Delta\phi}{\Delta t}$).

3 marks

Question 8 (5 marks)

a. In the vertical direction: $u = 46.\sin(35) = 26.4\ m\ s^{-1}$ $s = -50m$ $t = ?$ $a = -9.8\ m\ s^{-2}$

$v^2 = u^2 + 2as = (26.4)^2 + (2)(-9.8)(-50)$

$v = 41.0\ m\ s^{-1}\ downwards$

$v = u + at$

$-41 = 26.4 + (-9.8)t$

$t = 6.88$ s
This is the time of flight.
In the horizontal direction: $u = 46\cos(35) = 37.7$ m s^{-1}
$s = ut = (37.7)(6.88) = 259\ m$
This is shorter than 285 m therefore the rock will not hit Jimmy.

3 marks

b. Air resistance always opposes the motion. The effect of air resistance would be to decrease the range and maximum height of the rock.

2 marks

Question 9 (5 marks)

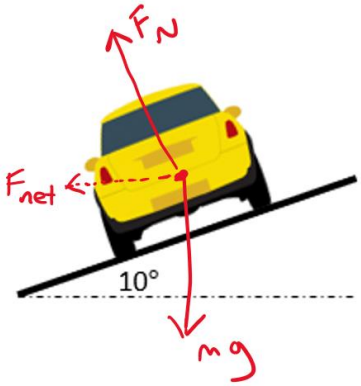
a. Centripetal force is caused by the frictional force.
Convert km h^{-1} to m s^{-1}:

$$v = \frac{150}{3.6} = 41.7 \text{ m s}^{-1}$$

$$F = \frac{mv^2}{r} = \frac{(900)(41.7)^2}{70} = 2.2 \times 10^4 \text{ N}$$

2 marks

b. Normal and weight force labelled as follows



1 mark

c. The horizontal component of the normal force acts towards the centre of the circular path, contributing to the net force (and therefore the centripetal force). At low enough speeds, the horizontal component of the normal force is enough to keep the car moving in a circular path without the need for friction to keep the car moving in a circle. This reduces the chance that the car will slide out on a slippery surface.

2 marks

Question 10 (6 marks)

a. The muon's half-life of 2.0×10^{-6} s is the proper time. The scientists on Earth will observe a dilated time.

$t = t_0\gamma$

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} = \frac{1}{\sqrt{1-0.988^2}} = 6.47$$

$t = t_0\gamma = (2.0 \times 10^{-6})(6.47) = 1.29 \times 10^{-5}$ s

2 marks

b. Relativistic kinetic energy

$E_k = (\gamma - 1)mc^2 = (6.47 - 1)(1.88 \times 10^{-28})((3 \times 10^8)^2) = 9.26 \times 10^{-11}$ J

2 marks

c. The same as c. Einstein's second postulate states that the speed of light is constant independent of the relative motion of the source and the observer.

2 marks

Question 11 (4 marks)

a. Gradient $= \frac{rise}{run} = \frac{60}{0.12} = 500$ N m^{-1}

1 mark

b. All elastic potential energy converted into gravitational potential energy.

$$E_s = \frac{1}{2}k\Delta x^2 = (0.5)(500)(0.04^2) = 0.4 \text{ J}$$

$$0.4 = mg\Delta h = (0.3)(9.8)(\Delta h)$$

$$\Delta h = 0.14\ m$$

The ball rises 14 cm into the air (or 10cm above the top of the unstretched spring).

3 marks

Question 12 (7 marks)

a. Longitudinal wave

1 mark

b. velocity of the wave = 340 m s^{-1} wavelength from graph = 0.4 m

$v = f\lambda$

$340 = f(0.4)$

$f = 850$ Hz

2 marks

c. Interference of sound waves from the two speakers will result in areas of constructive interference (where the waves are in phase and combine to increase in amplitude and give a louder sound) and areas of destructive interference (where the waves are out of phase and combine to decrease in amplitude and give a softer sound).

2 marks

d. 2nd quiet region occurs when the path difference is 1.5 wavelengths.

$pd = 1.5\lambda = (1.5)(0.4) = 0.6$ m

2 marks

Question 13 (4 marks)

a. fringe separation:

$$\Delta x = \frac{\lambda L}{d}$$

$$0.01 = \frac{(550 \times 10^{-9})(L)}{8.9 \times 10^{-5}}$$

$L = 1.62$ m

2 marks

b. The relationship is: $\Delta x = \frac{\lambda L}{d}$

Decrease the 'd' value will increase the fringe separation and make the bands easier to see.

Therefore, Stanley is correct.

2 marks

Question 14 (7 marks)

a. Gamma ray

1 mark

b. Electromagnetic waves travel at the same speed through the same medium. Increasing the frequency decreases the wavelength but has no effect on the speed. Therefore, Dhimanya is correct.

2 marks

c. i. Diffraction is the bending of waves around an object or through a gap.

ii. Superposition is the combining of two or more waves in the same medium.

iii. Refraction is the bending of waves at the interface between two mediums when approaching the interface at an angle.

iv. Dispersion is the spreading out a white light into its components based on their wavelengths as a result of diffraction or refraction.

(1+1+1+1=4 marks)

Question 15 (8 marks)

a. i. Reducing the intensity of the incoming light reduces the number of photons per second. This will decrease the number of electrons emitted per second.

2 marks

ii. Reducing the intensity of the incoming light reduces the number of photons per second but each photon still carries the same amount of energy which they pass onto the electrons. Therefore, the electrons are emitted with the same average velocity as before.

2 marks

b. i. Decreasing the wavelength (increasing the frequency) has no effect on the number of photons emitted per second so has no effect on the number of electrons emitted per second.

2 marks

ii. Decreasing the wavelength (increasing the frequency) increases the energy of each photon of light (as per $E = \frac{hc}{\lambda}$) which increases the energy passed onto each electron which increases the average velocity of the emitted electrons.

2 marks

Question 16 (6 marks)

a. The black bands are an absence of colour. These represent the wavelengths of light that have been absorbed by electrons in the hydrogen atoms to jump up energy levels. Only specific amounts of energy (and therefore wavelengths) can be absorbed equivalent to the transitions between energy levels for the electrons.

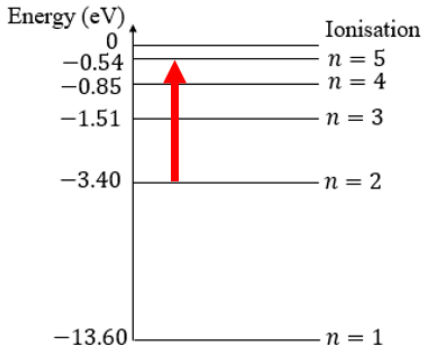
2 marks

b. $E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3\times10^{8})}{434\times10^{-9}} = 4.58 \times 10^{-19}$ J

2 marks

c. Convert Joules to eV $= \frac{4.58\times10^{-19}}{1.6\times10^{-19}} = 2.86\ eV$ corresponds to a transition from n=2 to n=5

Arrow as shown:



2 marks

Question 17 (6 marks)

a. Momentum $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{4.2\times10^{-9}} = 1.58 \times 10^{-25}$ N s

2 marks

b. Significant diffraction occurs when $\lambda \geq w$

For a gap width of 0.4 nm, wavelength is greater than the width so significant diffraction will occur.

For a gap width of 56 nm, wavelength is less than the gap width and so significant diffraction will not occur.

2 marks

c. Same diffraction pattern therefore same wavelength and same momentum.

$p_{electrons} = 1.58 \times 10^{-25}$ kg m s^{-1}

$$\frac{1}{2}mv^2 = \frac{p^2}{2m}$$

$$\left(\frac{1}{2}\right)(9.1 \times 10^{-31})(v^2) = \frac{(1.58 \times 10^{-25})^2}{(2)(9.1 \times 10^{-31})}$$

$v = 1.74 \times 10^5$ m s^{-1}

Can also solve using the wavelength

$$\lambda_{electrons} = \frac{h}{\sqrt{2mE_k}}$$

$$4.2 \times 10^{-9} = \frac{6.63 \times 10^{-34}}{\sqrt{(2)(9.1 \times 10^{-31})(E_k)}}$$

$E_k = 1.37 \times 10^{-20}$ J

$E_k = \frac{1}{2}mv^2$

$1.37 \times 10^{-20} = \left(\frac{1}{2}\right)(9.1 \times 10^{-31})v^2$

$v = 1.74 \times 10^5\ m\ s^{-1}$

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

$$v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 4.2 \times 10^{-9}}$$

$v = 0.173 \times 10^6$

$v = 1.73 \times 10^5$ m s^{-1}

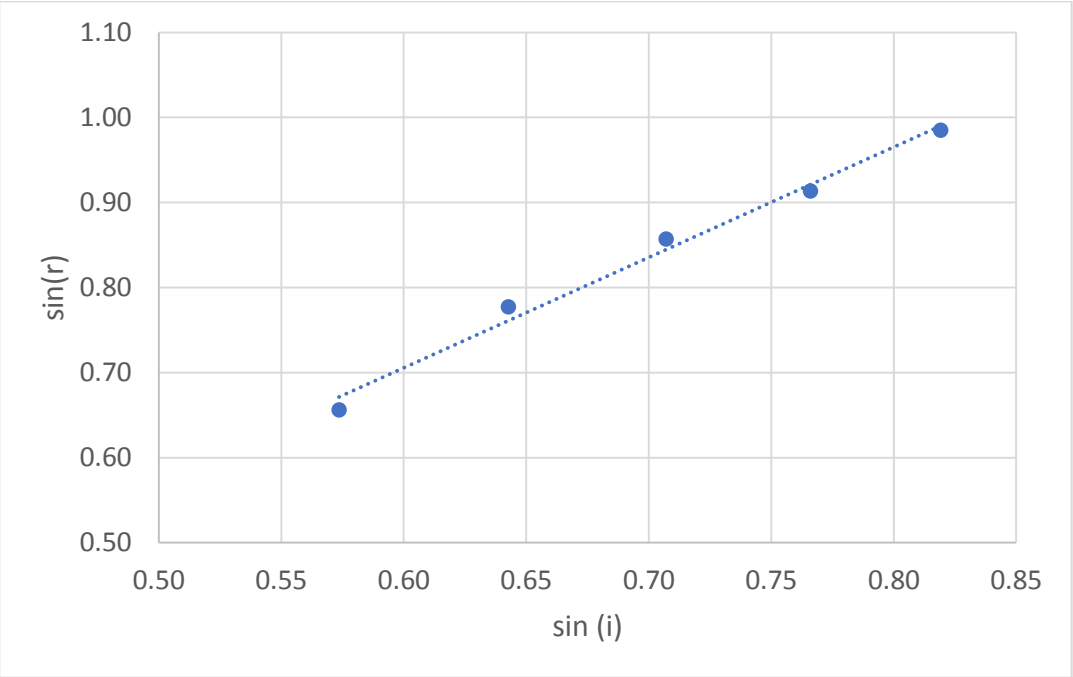
2 marks

Question 18 (11 marks)

a. 60 degrees is above the critical angle and so the light totally internally reflects instead of refracting.

2 marks

b. Graph as below



4 marks

c. $Gradient = \frac{rise}{run} = \frac{0.98-0.68}{0.82-0.57} = 1.2$

Snell's law $n_1 \sin(i) = n_2 \sin(r)$

$$n_2 = \frac{n_1 \sin(i)}{\sin(r)} = \frac{n_1}{gradient}$$

$$n_2 = \frac{1.5}{1.2} = 1.25$$

2 marks

d. Uncertainty $= \pm 0.5°$ Half of the smallest division.

1 mark

e. Percentage error $= \frac{difference}{actual} \times 100 = \frac{1.25-1.10}{1.10} \times 100 = 13.6\,\%$

This would be considered a high percentage error and so the data could be considered inaccurate. further measurements would need to be taken to determine the reason for such a high discrepancy from the accepted value.

2 marks