**Leaving Cert Physics Worked Solutions 2018**

**2018 Question 1**

1. **Draw a labelled diagram of the apparatus used in the experiment.**

Two trolleys, means of coalescing trolleys, timing apparatus

1. **State the two principal external forces that were minimised. How were they minimised?**   
   Gravitational and frictional force {note that the word “gravity” may not be acceptable}

By sloping the track slightly so that the gravitational force = frictional force

OR by using a level air-track

1. **Calculate velocities *u* and *v*.**

= 1.342 m s-1

= 0.692 m s-1

1. **Use the data to verify the principle of conservation of momentum.**

*p* = *mv*

Momentum before collision = (0.3607)(1.342) = 0.484 kg m s-1

Mass afterwards = combined mass of A + B = (0.3607 + 0.3409) =

Momentum after collision = (0.7016)(0.692) = 0.485 kg m s-1

*p*1 is approximately equal to *p*2

1. **Calculate the loss of kinetic energy in the bodies during the collision.**

E = ½ *mv*2

Kinetic energy *before* collision = ½ (0.3607)( 1.342)2 = 0.325 J

Kinetic energy *after* collision = ½ (0.7016)(0.692)2 = 0.168 J

Loss in energy = 0.325 – 0.168 = 0.157 J

1. **What form of energy could account for this loss of kinetic energy?**   
   Sound and heat

**2018 Question 2**

1. **Describe, with the aid of a labelled diagram, how the student determined the angle of refraction.**   
   diagram of block, pins / ray box / laser (labelled)   
   correct method of finding refracted ray (state/imply)   
   draw normal in block at point of incidence   
   measure angle between normal and refracted ray with a protractor
2. **Draw a suitable graph to show the relationship between the angle of incidence and the angle of refraction.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *i* (degrees) | 20 | 30 | 40 | 50 | 60 | 70 |
| *r* (degrees) | 14 | 20 | 26 | 31 | 35 | 38 |
| *sin i* | 0.34 | 0.5 | 0.64 | 0.77 | 0.87 | 0.94 |
| *sin r* | 0.24 | 0.34 | 0.44 | 0.52 | 0.57 | 0.62 |

**Graph:**

Labelled axes

6 points plotted correctly

Straight line with good fit

1. **State this relationship and explain how your graph verifies it.**

*sin i* ∝ *sin r*, verified by getting a straight line through the origin

1. **Use your graph to determine the refractive index of the material used.**slope calculated using two points on line

The slope corresponds to the refractive index (assuming *sin i* is plotted on the y-axis).

Refractive index = 1.50

1. **What would be observed if the incident ray was perpendicular to the block?**

The ray wold pass straight through

**2018 Question 3**

1. **Draw a labelled diagram of the apparatus that the student used in this experiment.**  
   Screen, diffraction grating, laser OR spectrometer, diffraction grating, sodium lamp

Describe how the angle between the two first order images was obtained.   
s1 = distance between grating and screen

s2 = half the distance between the two first order images

OR

s2 = distance between zero order and first order image

1. Calculate the wavelength of the beam of light.

d = = 2 × 10–6 m

*θ* = 17.050

n = 1

nλ = d sinθ

λ = (2 × 10–6)(sin17.05)

λ = 5.9 × 10–7 m

**Describe the effect on the size of the angle *ϕ*, the angle between the two first order images, if the diffraction grating above was replaced with a diffraction grating of 80 lines per mm.**  
nλ = d sinθ

The left hand side of the equation above is unchanged, therefore the total on the right hand side must be unchanged. But if we’re going from 500 lines per mm to 80 lines per mm then the distance between lines ‘*d*’ is getting bigger.

Therefore *ϕ* (the angle between the first order images) must get smaller.

1. **Hence determine which grating would give a more accurate value for *λ*.**  
   500 lines per mm grating
2. **Justify your answer.**

A *larger* angle for *θ* would result in a *smaller* percentage error.

1. **What would the student observe if the source of monochromatic light was replaced with a source of white light?**  
   A spectrum

**2018 Question 4**

1. **Draw a diagram of the apparatus used in this experiment.**   
   A power supply, means of varying voltage, coil, ammeter in series, thermometer and coil in water
2. **Draw a suitable graph to verify Joule’s law**.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| I (A) | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.5 | 5.5 |
| *θ* (°C) | 20.0 | 22.0 | 24.0 | 27.5 | 30.5 | 38.0 | 49.5 |
| *I*2 | 2.25 | 4.00 | 6.25 | 9.00 | 12.25 | 20.25 | 30.25 |
| Δ*θ* | 2.0 | 4.0 | 6.0 | 9.5 | 12.25 | 20.0 | 31.5 |

Labelled axes, 6 points plotted correctly, straight line with good fit through the origin

1. **Calculate the slope of the graph and hence calculate the resistance of the heating coil.**

Slope = 1.04

Electrical energy lost = heat energy gained

R*I*2 t = mcΔθ

*Rt* = *mc*(Δ*θ*/*I*2)

But (Δθ/ I2) corresponds to the slope of the graph (assuming Δ*θ* is plotted on the y-axis)

*Rt* = *mc*(slope) *R* = *mc*(slope)/*t* *R* = (0.090)(4180)(1.04)/180

*R* = 2.2 Ω

**2018 Question 5**

|  |  |
| --- | --- |
| Draw a labelled diagram to show the forces acting on a skydiver falling with a constant velocity. | A person skydiving with arms outstretched  Description automatically generated  Note that for questions such as this one the marking scheme requires that you make the arrows of equal length to reflect that they are equal in size. |
| A picture containing shape  Description automatically generated  A horizontal metre stick is in equilibrium when a weight of 8 N hangs from the 10 cm mark, a weight of 12 N hangs from the 60 cm mark and an unknown weight (X) hangs from the 82 cm mark. The metre stick is supported at its centre of gravity, 50 cm. Calculate X. | Moment of force anticlockwise = (8)(40)  Moment of force clockwise = (12)(10) + (X)(32)  (8)(40) = (12)(10) + (X)(32)  X = 6.25 N m |
| Distinguish between the three methods of heat transfer. | Conduction: no net movement of medium  Convection: circulation of a fluid  Radiation: electromagnetic / photons / through a vacuum |
| A fire‐engine travelling at a speed of 30 m s–1 emits a sound of frequency 2.3 kHz as it approaches an observer. Calculate the frequency observed.  (speed of sound in air = 340 m s–1) | *c* = 340 m s–1  *u* = 30 m s–1  *f* = 2.3 kHz = 2300 Hz  = 2523 Hz |
| The refractive index of a material is 2.4. Calculate the speed of light in this material. | Refractive index =  2.4 =  *Speed of light in medium*  = 1.25 × 108 m s-1 |
| Explain how electrons are  (i) produced,  (ii) accelerated in an X‐ray tube. | They are produced as a result of thermionic emission (at cathode)  They are accelerated via a high voltage |
| Write an expression for the electric field intensity E at a distance *d* from a charge Q. | E = |
| What are the charge carriers in (i) metals, (ii) gases, (iii) semiconductors? | metals: electrons  gases: ions and electrons  semiconductors: electrons and holes |
| Calculate the effective resistance of a 5 Ω resistor and a 7 Ω resistor when they are connected in parallel. | R = 2.9 Ω |
| State (i) a physical quantity that is the same for a quark and its anti‐quark and (ii) a physical quantity that is different for a quark and its anti‐quark. | same: mass and the magnitude of charge different: (sign of) charge |

**2018 Question 6 (a)**

1. **Derive an expression to show the relationship between the radius, velocity and angular velocity of an object moving in uniform circular motion.**

See notes for derivation

1. **Calculate the angular velocity of the discus immediately prior to its release.**

|  |  |
| --- | --- |
| *v* = 20.4 m s–1  *r* = 1.2 m | = 17 rads s-1 |

1. **Calculate the centripetal force acting on the discus just before Ashton releases it.**

|  |  |
| --- | --- |
| *m* = 2 kg  *r* = 1.2 m  = 17 rad s-1 | F = mrω2 = (2)(1.2)(17)2 = 693.6 N |

1. **In what direction does this force apply?**   
   Towards the centre

**2018 Question 6 (b)**

1. **Calculate his velocity in the horizontal direction**

*vh* = *v* cos *θ* = 10.9 Cos 430 = 7.97 m s-1

1. **Calculate the length of the jump.**   
   *s* = (*v*)(*t*) = (7.97)(1.03) = 8.21 m

**2018 Question 6 (c)**

1. **State the principle of conservation of energy.**  
   Energy cannot be created or destroyed
2. **What is meant by the centre of gravity of a body?**  
   the point of a body where its weight appears to act
3. **What is the maximum height above the ground to which he can raise his centre of gravity?**

Gain in potential energy = loss in kinetic energy

mghtop - mghbottom = (½)(m)(9.2)2 – (½)(m)(1.1)2

ghtop - ghbottom = (½)(9.2)2 – (½)(1.1)2

(9.8)htop – (9.8)(0.98) = (½)(9.2)2 – (½)(1.1)2

*h* = 4.26 m

So the height above the ground is 4.26 + 0.98 = 5.24 m

1. **Draw a diagram to show any forces acting on Ashton when he is at his highest point.**  
   One arrow downwards, labelled “gravitational force”.

**2018 Question 7**

1. **Resonance is a phenomenon that is associated with musical instruments. What is resonance?**

Resonance is the transfer of energy between two bodies of the same natural frequency

1. **Describe an experiment to demonstrate resonance.**

One of many possible demonstrations:

Stand two tuning forks of the same frequency on a wooden board

Set one tuning fork vibrating   
Stop the first one vibrating and notice that the second tuning fork has started vibrating.

1. **Calculate the tension in the string**

*µ* = mass per unit length = = 3.84 × 10-4 kg m-1

*f* = 600 Hz

*l* = 0.328 m

*µ* = 3.84 × 10-4 kg m-1





4*l*2*f*2 =  4*l*2*f*2 = *T* *T* = (3.84 × 10-4)(4)(0.328)2(600)2

**Answer:** T = 72 N

1. **Calculate the speed of sound in the string.**

A violin string is tied (and so has a node) at both ends, so when plucked it sets up a standing wave whose length corresponds to half a wavelength  
Distance between nodes = = 328 mm = 0.328 m.  
λ = 2(0.328) = 0.656 m and *f* = 600 Hz

*v* = *fλ v* = (600)(0.656) = 433 m s-1

1. **Draw a labelled diagram to represent the fundamental frequency of a stationary wave in a pipe that is closed at one end.**See diagram
2. **Define sound intensity.**

Power per unit area

1. **Describe the effect of doubling the distance from the source to an observer on the sound intensity measured.**

I = =

Intensity is therefore inversely proportional to the *square* of the distance, so if the distance goes up by a factor of 2 (“doubles”) then the sound intensity goes down by a factor of 4.

So the sound intensity gets 4 times smaller.

1. **Describe the effect of doubling the distance from the source to an observer on the sound intensity *level* measured.**

If the sound intensity gets two times bigger (doubles) then the sound intensity level *goes up by 3 decibels*.

If the sound intensity *halves* (gets two times smaller) then the sound intensity level *goes down by 3 decibels*.

In this question the sound intensity gets 4 times smaller so it halved and halved again.

So the sound intensity level went down by 3 dB and then down by 3 dB again.

Answer:

The sound intensity level went down by 6 decibels

OR

Sound Intensity so if the radius or distance increases by a factor of 2 (doubles) then the sound intensity will decrease by a factor of 4 (get 4 times smaller)

**2018 Question 8**

1. **Explain the term *nuclear fission*.**   
   Nuclear fission is the splitting of a large nucleus into two similarly sized smaller nuclei with the emission of energy/neutrons.

Note that you will lose marks if you use the term *atom* instead of *nucleus*.

**Explain the term *specific heat capacity*.**   
Specific heat capacity is the energy required to change the temperature of 1 kg of a substance by 1 K.

1. **What effect does a moderator have on the rate of fission?**  
   It increases the rate of fission
2. **How does a moderator have this effect?**  
   The moderator slows down the neutrons which increases the rate of capture by neighbouring nuclei.
3. **Calculate the energy absorbed by the water.**Energy absorbed = energy required to heat water by 70 K + energy required to convert water to steam

= (mcΔθ) + (ml)steam

= (5000)(4180)(70) + (5000)(2.23×106)

= 1.26 ×1010 J

1. **Write a nuclear equation for this reaction.**
2. **Calculate the energy released, in MeV, in this reaction.**

mass of barium–139 nucleus = 138.90884 u

mass of krypton–94 nucleus = 93.93436 u

mass of uranium–235 nucleus = 235.04393 u

mass of neutron = 1.67493 × 10-27 kg

Loss in mass = 3.0 × 10-28 kg

*E* = mc2

*E* = 2.74 × 10-11 J

To convert from J to eV we need to divide 2.74 × 10-11 J by the charge on an electron (1.6 × 10-19)

*E* = 1.71 ×108 eV = 171 MeV

1. **Explain why fusion reactors are not yet a practical source of energy on Earth.**   
   Too much energy is required (to overcome force of repulsion between nuclei).
2. **Give one other advantage that a fusion reactor would have over a fission reactor.**

Raw material readily available / less radioactive waste

**2018 Question 9**

1. **List the primary colours of light**  
   red, green, blue
2. **Name a pair of complementary colours of light.**

Blue & yellow, green & magenta, red & cyan

1. Diagram, shape

   Description automatically generated**What is a magnetic field?**  
   A magnetic field is any region where magnetic forces are felt
2. **Draw labelled diagram to show the magnetic field about a long straight current‐carrying wire.**

See diagram

1. Diagram

   Description automatically generated**Draw labelled diagrams to show the magnetic field about a current‐carrying solenoid.**
2. **State Faraday’s law of electromagnetic induction.**  
   Faraday’s law states that the size of the induced emf is proportional to the rate of change of magnetic flux.
3. **Describe an experiment to demonstrate this law.**

1. Move the magnet in and out of the coil slowly and note a slight deflection.

2. Move the magnet quickly and note a greater deflection.

1. **What is the average emf induced in the coil when it is rotated through 90° in ¼ of a second?**

***A picture containing building, window

Description automatically generated****(The axis of rotation connects the midpoints of opposite sides of the square, as shown.)*

Φ = BA = (50 × 10-3)(0.2)2 = 2 × 10-3 webers

Induced emf = (N)[(final flux – initial flux)/(time taken)]

E = (40)[(2 × 10-3 – 0)/0.25] E = 0.32 V

1. **Where in the eye is light detected?** The retina
2. **List two invisible parts of the electromagnetic spectrum that have a shorter wavelength than visible light.**

Ultraviolet, X‐rays, gamma rays

**2018 Question 10 (a)**

1. **Name the particle which Pauli predicted and explain how it solved the problem.**The neutrino; it had the missing energy and momentum
2. **Write a nuclear equation for beta‐decay.**
3. **Why did Pauli think that the particle could not be detected?**   
   It had no charge and very little mass.
4. **Why are two gamma‐ray photons produced?**To conserve momentum
5. **Explain how charge is conserved in the annihilation.**  
   Net charge beforehand = 0 (since the particle and antiparticle have equal and opposite charges)

Photons have no charge so charge afterwards = 0.

1. **Calculate the maximum frequency** **of each emitted photon.**  
   Mass of electron = 9.1093826 × 10-31 kg

Energy ‘released’ when one electron is annihilated = mc2

We only need to look at one electron because two electrons are annihilated to produce two photons, so it’s as if one electron is responsible for producing one photon.

E = (9.1093826 × 10-31)(3 × 108)2

E = 8.198444 × 10-14 J

This energy now goes on to create a photon

Energy associated with a photon = hf

*f* = 1.24 × 1020 Hz

1. **Electrons are negatively charged leptons. List the two other negatively charged leptons.**  
   muon, tau
2. **List the three forces that these leptons can experience, in decreasing order of strength.**   
   electromagnetic, weak, gravitational

**2018 Question 11**

1. **Calculate the minimum frequency of the radio waves detected by I‐LOFAR.**  
   c = 3 × 108 m s-1 *c* = *f λ*

Diagram

Description automatically generatedIt tells us in the question that the wavelength is between 1.3 m and 30 m.

so the smallest frequency will occur with the largest wavelength which in this case is 30 m.

*= f* = 1 × 107 Hz

1. **Draw a diagram of the magnetic field around the Earth.**See diagram
2. **Explain how information is transmitted using optical fibres.**
3. Light enters one end of the fibre and strikes the boundary between the two materials *at an angle greater than the critical angle,* resulting in total internal reflection at the interface.
4. This reflected light now strikes the interface on the opposite wall and gets totally reflected again.

This process continues all along the glass pipe until the light emerges at the far end.

1. **Calculate the position of the image of a person standing 75 cm from the Leviathan mirror.**

**Diagram

Description automatically generated***v* = 79 cm behind the mirror

1. **Where, with respect to the concave mirror, will an image of the moon be formed? Justify your answer.**  
   At the focal point, because the incoming rays are approximately parallel to the principal axis.
2. **Draw a ray diagram to show the formation of an upright, magnified image in a concave mirror.**

See diagram

1. **Calculate the velocity of the Hubble telescope as it orbits the Earth.**

*To calculate distance*

The telescope travels in a circular path at a height of 570 km above the ground.

Remember that the radius of the earth is 6400 km.

So the radius of this circle = (6400 + 470) km = 6870 km = 6.87 × 106 m

So the distance travelled in one orbit corresponds to the circumference of this circle = 2πr

= 2π(6.87 × 106)

*To calculate time*

The telescope does 15.1 orbits per day. So the time for one orbit is 24 divided by 15.1

= 1.589 hours = 1.589 × 60 × 60 = 5720.4 seconds

= 7650 m s-1

1. **Name one optical phenomenon . . .  
   How does the location of the Hubble telescope eliminate this problem?**

Refraction The Hubble telescope is above the atmosphere.

**2018 Question 12 (a)**

1. **Explain the term *simple harmonic motion.***  
   An object is undergoing simple harmonic motion if its acceleration towards a fixed point is proportional to its displacement.
2. **When does a simple pendulum execute simple harmonic motion?**  
   When it is oscillating at a small angle.
3. **What is the relationship between the period and the length of a simple pendulum?**   
   The period squared is proportional to the length.
4. **Calculate the spring constant**  
    = 7.39

k = = (7.39)2(0.06) = 3.28 N m-1

1. **Calculate the length of the spring when the mass is at rest.**

F = -k (extension)

mg = -k (extension) {we can ignore the minus sign – it exists merely to signify that the restoring force and the extension are opposite in direction}

(0.06)(9.8) = 3.28(extension)

Extension = 0.18 m

Length of string = 0.5 + 0.18 = 0.68 m

**2018 Question 12 (b)**

1. **What is meant by radioactivity?**   
   Radioactivity is the (spontaneous) disintegration of a nucleus with the emission of one or more types of radiation.
2. ***On graph paper, draw a decay curve (a graph of activity against time).***

8 points plotted correctly (activity on the *y* axis)

Curve with good fit

1. **Use the decay curve to determine the half‐life of the isotope.**  
   Pick a point on the activity axis and note the corresponding time.

Pick a second point where the activity is half the previous activity and note the corresponding time.

Note the time it takes to go from one time to the other.  
It should correspond to 3.3 days = 285120 seconds

1. **Calculate the number of nuclei in the sample at the beginning of the investigation.**   
   First we need to calculate the decay constant λ:

Now we can use A = λN to calculate the number of nuclei

= N = 2.5 × 1014 nuclei

**2018 Question 12 (c)**

1. **Define capacitance and state its unit.**   
   Capacitance is the ratio of charge to potential.

The unit is the farad.

1. **Calculate the energy stored in the capacitor.**

=

C = 2.75 × 10-5 farads

E = ½ CV2

E = ½ (2.75 × 10-5)(4000)2

E = 220 J

1. **What is the net charge of the capacitor when it stores this energy?**  
   0 coulombs
2. Chart, line chart

   Description automatically generated**Calculate the average current flowing as the capacitor discharges.**  
    = 7.3 A
3. **Draw a diagram of the electric field between the charged plates of a parallel plate capacitor.**  
   See diagram

**2018 Question 12 (d)**

1. **What is a p‐n junction?**  
   It is where a p–type semiconductor and an n‐type semiconductor meet
2. **Outline his explanation.**

* Light energy coming travels in packets called ‘photons’.
* If the photons contain enough energy they can get absorbed by an electron on the surface of the metal.
* Each photon gives all its energy to one electron
* A certain amount of this energy (known as *the work function*) goes to *liberating* (releasing) the electron. The remainder appears as kinetic energy of the liberated electron.
* The equation relating these variables is: h*f* = ** + ½m*v*2

1. **Calculate the maximum kinetic energy of an emitted electron when ultraviolet radiation of wavelength 200 nm is incident on iron**.

*f* = 1.5×1015 Hz

h*f* = ** + ½m*v*2

½m*v*2 =h*f* - ** ½m*v*2 = (6.67×10-34)(1.5×1015) – (4.7)(1.6×10-19)

½m*v*2 = 2.4×10-19 J