**2009 Leaving Cert Physics Solutions (Higher Level)**

1.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *s*/ cm | 30 | 50 | 70 | 90 | 110 | 130 | 150 |
| *t*/ms | 247 | 310 | 377 | 435 | 473 | 514 | 540 |

In an experiment to measure the acceleration due to gravity, the time *t* for an object to fall from rest through a distance *s* was measured. The procedure was repeated for a series of values of the distance *s*. The table shows the recorded data.



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

Timer, ball, release mechanism, trap door

1. **Indicate the distance *s* on your diagram.**

(Perpendicular) distance indicated between bottom of ball and top of trap door.

1. **Describe how the time interval *t* was measured.**

Timer starts when ball leaves release mechanism

Timer stops when ball hits trap door.

1. **Calculate a value for the acceleration due to gravity by drawing a suitable graph based on the recorded data.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *s*/ cm | 30 | 50 | 70 | 90 | 110 | 130 | 150 |
| *t*/ms | 247 | 310 | 377 | 435 | 473 | 514 | 540 |
| t 2 / s2 | 0.0610 | 0.0961 | 0.1421 | 0.1892 | 0.2237 | 0.2642 | 0.2916 |

* Axes correctly labelled
* At least 6 points correctly plotted
* Straight line with a good distribution
* Correct slope method
* Slope = 5.02 // 0.198
* g = (10.04 ± 0.20) m s–2
1. **Give two ways of minimising the effect of air resistance in the experiment.**

Small (object)/ smooth(object)/ no draughts/ in vacuum/ distances relatively short **/ h**eavy (object) / dense / spherical/ aerodynamic

2.

A student was asked to measure the focal length of a converging lens. The student measured the image distance *v* for each of three different object distances *u*. The student recorded the following data.

|  |  |  |  |
| --- | --- | --- | --- |
| *u*/cm | 20.0 | 30.0 | 40.0 |
| *v*/cm | 65.2 | 33.3 | 25.1 |

1. **Describe how the image distance was measured.**

****Object, (converging) lens, screen /search pin

Sharp image (state/imply) // no parallax (between image and search pin)

Measure (distance) from image/screen to (centre of) lens

1. **Give two precautions that should be taken when measuring the image distance.**

Measure from the centre of the lens (to the screen) / measure perpendicular distance /avoid parallax error

1. Use all of the data to calculate the focal length of the converging lens.

1/u + 1/v = 1/f

Correct substitution (once)

f = 15.3 cm, 15.8 cm, 15.4 cm

fave = (15.5 ± 0.4) cm

1. **What difficulty would arise if the student placed the object 10 cm from the lens?**

Object would be inside the focal point so an image cannot be formed on a screen

**Alternative (graphical method):**

|  |  |  |  |
| --- | --- | --- | --- |
| 1/u  | 0.050 | 0.033 | 0.025 |
| 1/v  | 0.0153 | 0.0300 | 0.0398 |

Inverse values for u and for v

Plot points

Read intercept(s)

f = (15.87 ± 0.40) cm

3.

A student investigated the variation of the fundamental frequency *f* of a stretched string with its tension *T.*

The following is an extract of the student’s account of the experiment.

“I fixed the length of the string at 40 cm. I set a tuning fork of frequency 256 Hz vibrating and placed it by the string.

I adjusted the tension of the string until resonance occurred. I recorded the tension in the string. I repeated the experiment using different tuning forks.”

1. **How was the tension measured?**

A newton balance // weight of pan + contents

1. **How did the student know that resonance occurred?**

Paper rider jumped vigorously / the string vibrated at maximum amplitude

The following data were recorded.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *f* /Hz | 256 | 288 | 320 | 341 | 384 | 480 | 512 |
| *T* /N | 2.4 | 3.3 | 3.9 | 4.3 | 5.7 | 8.5 | 9.8 |

1. **Draw a suitable graph to show the relationship between the fundamental frequency of a stretched string and its tension.**
* Six correct values for √T
* Both axes correctly labelled
* Six points correctly plotted
* Straight line with a good fit
1. **State this relationship and explain how your graph verifies it.**

f is proportional to square root of T because the graph was a straight line through the origin.

1. Use your graph to estimate the fundamental frequency of the string when its tension is 11 N

If tension is 11 N ⇒ √T = 3.32

Use the graph to get f = 542 Hz

1. **Use your graph to calculate the mass per unit length of the string.**

Compare to the formula y = mx ⇒ slope = 1/(2l√μ), where l = 0.4 m

Mass per unit length (μ) = 5.86 × 10–5 kg m–1

4.

In an experiment to measure the resistivity of nichrome, the resistance, the diameter and appropriate length of a sample of nichrome wire were measured.

The following data were recorded:

Resistance of wire = 7.9 Ω

Length of wire = 54.6 cm

Average diameter of wire = 0.31 mm

1. **Describe the procedure used in measuring the length of the sample of wire.**

Straighten the wire, clamp it to a bench and measure the distance between the points for which the resistance was measured.

1. **Describe the steps involved in finding the average diameter of the wire.**
* Zero the micrometer / digital callipers
* Place wire between jaws
* Tighten jaws and take reading
* Repeat at different points on wire
* Get average diameter
1. **Use the data to calculate the resistivity of nichrome.**

A = πr2 ⇒ A = π(0.155 × 10-3)2 = 7.55 × 10-8 m2

ρ = RA/l ⇒ ρ = (7.9)(7.55 × 10-8)/0.546) ⇒ ρ = 1.09 × 10-6 Ωm

1. **The experiment was repeated on a warmer day. What effect did this have on the measurements?**

Resistance increased / length increased (or wire expands) / diameter increased

**2009 Question 5**

1. **State Boyle’s law.**

For a fixed mass of gas at constant temperature, pressure is inversely proportional to volume.

1. **The moon orbits the earth.**

**What is the relationship between the period of the moon and the radius of its orbit?**

The period squared is proportional to the radius cubed

1. **Why is it necessary to have a standard thermometer?**

Different types of thermometer have different thermometric properties which can cause them to give slightly different readings for the same temperature.

1. **The sound intensity level at a concert increases from 85 dB to 94 dB when the concert begins. By what factor has the sound intensity increased?**

If sound intensity doubles ⇒ sound intensity *level* increases by 3 dB.
When the sound intensity level increased from 85 to 88 dB, it meant that the sound intensity doubled (or was multiplied by 2).

When the sound intensity level increased from 88 to 91 dB, it meant that the sound intensity doubled again (or was multiplied by 2).

When the sound intensity level increased from 91 to 94 dB, it meant that the sound intensity doubled again (or was multiplied by 2).

So sound intensitynew = sound intensityold ×2×2×2

So if the original *sound intensity* *level* has increased by 9 dB then the *sound intensity* must have increased by a factor of 8.

1. **Draw a ray diagram to show the formation of an image in a convex mirror.**

See diagram

1. **Define electric field strength.**

Electric field strength is defined as force per unit charge.

1. **When will an RCD (residual current device) disconnect a circuit?**

When the magnitude of the current flowing in is different from that flowing out.

1. **What is the average emf induced in a coil of 20 turns when the magnetic flux cutting it decreases from 2.3 Wb to 1.4 Wb in 0.4 s?**

Induced emf = = = 45 V (we can ignore the ‘minus’ sign).

1. **How are X-rays produced?**

Accelerated (fast moving) electrons strike a (heavy) metal (target) causing electrons in the target to rise to a high orbital level. When these electrons fall back down to a lower lever they emit they energy as X-rays.

1. **Arrange the fundamental forces of nature in increasing order of strength.**

Gravitational, weak, electromagnetic, strong.

**2009 Question 6**

1. **State Newton’s laws of motion.**
* *Newton’s First Law of Motion* states that every object will remain in a state of rest or travelling with a constant velocity unless an external force acts on it.
* *Newton’s Second Law of Motion* states that the rate of change of an object’s momentum is directly proportional to the force which caused it, and takes place in the direction of the force.
* *Newton’s Third Law of Motion* states that when body A exerts a force on body B, B exerts a force equal in magnitude (but) opposite in direction (on A).
1. **Show that *F = ma* is a special case of Newton’s second law*.***

From Newton II: force is proportional to the rate of change of momentum

Force ∝ rate of change of momentum

*F ∝ (mv – mu)/t* *F ∝ m(v-u)/t* *F ∝ ma* *F = k (ma)* [but *k* = 1] *F = ma*

1. **Calculate the average acceleration of the skateboarder on the ramp.**

*v* = 12.2 m s-1 *u* = 0 *a* =? *s* = 25 m

*v2= u2 + 2as* ⇒ (12.2)2 = 0 +2a(25) a = a = 2.98 m s–2

1. **Calculate the component of the skateboarder’s weight that is parallel to the ramp.**

See diagram.
Component that is parallel to the ramp = mg sin200 = 234.63 N

1. **Calculate the force of friction acting on the skateboarder on the ramp.**

Here we’re going to use the expression *net force* = *big force* – *small force*

We can work out the *net force* using Fnet = ma where we know *m* and *a*

We have just worked out the *big force* because this is the component of the weight that is parallel to the ramp.

As a result we can work out the small force which corresponds to the force of friction.

Fnet = ma = 70(2.98) = 208.38 N

Force down (due to gravity) = 234.63 N

Net force = force down (due to gravity) – force up (due to friction)

208.38 = 234.63 - friction force

Friction force = 208.38 – 234.63 = - 26.25 N
*{the negative sign indicates that this force is opposite to the direction in which the person is moving}*

1. **What is the initial centripetal force acting on him?**

** =**  = 771.75 N

1. **What is the maximum height that the skateboarder can reach?**
Here we use conservation of energy:

kinetic energy at the bottom = potential energy at the top

½ mv2 = mgh

 = h = h = 5.63 m

1. **Sketch a velocity-time graph to illustrate his motion.**

As shown

**2009 Question 7**

1. **Explain *diffraction***

Diffraction is the spreading out of a wave when it passes through a gap or passes by an obstacle.

1. **Explain *dispersion*.**

Dispersion is the splitting up of white light into its constituent colours.

1. **Derive the diffraction grating formula.**

 From the diagram we can see that

(i) For constructive interference to occur, the extra path length that the top ray travels must be an integer number of wavelengths (nλ) {Eqn (1)}

(ii) Using trigonometry, this extra path length is equal to d sin θ, where d is the slit width {Eqn (2)}

Equating (1) and (2) gives us nλ = d Sin θ

1. An interference pattern is formed on a screen when green light from a laser passes normally through a diffraction grating. The grating has 80 lines per mm and the distance from the grating to the screen is 90 cm. The distance between the third order images is 23.8 cm.

**Calculate the wavelength of the green light.**

d = = 1.25 × 10-5 m

θ =

From the diagram we can see that the adjacent is 0.90 m, while the opposite is = 0.119 m

θ = =

n = 3

nλ = d sin θ  λ = =  λ = 551 (± 5) × 10-9 m.

1. **Calculate the maximum number of images that are formed on the screen.**

For maximum number θ = 900  sin θ = 1

nλ = d sin θ  nλ = d n= =

* n = 22.7 so the greatest whole number of images is 22.

But this is on one side only.

In total there will be 22 on either side, plus one in the middle, so total = 45

1. **The laser is replaced with a source of white light and a series of spectra are formed on the screen.**

**Explain how the diffraction grating produces a spectrum.**

Different colours have different wavelengths so constructive interference occurs at different positions (different angles) for each separate wavelength.

1. **Explain why a spectrum is not formed at the central (zero order) image.**

At central image θ = 0 so constructive interference occurs for all separate wavelengths at the same point so no separation of colours.

**2009 Question 8**

1. **What is a photon?**

A photon consists of a discrete (specific) amount of energy/electromagnetic radiation.

1. **Draw a labelled diagram of the structure of a photocell.**

See diagram

1. **Using the graph, calculate the work function of the metal.**

The graph indicates that current only flows when the frequency of the radiation reached 5.2 × 1014 Hz, so this corresponds to the threshold frequency (f0).

φ = hf0 = (6.6 × 10-34)(5.2 × 1014) = 3.432 × 10-19 J

1. **What is the maximum speed of an emitted electron when light of wavelength 550 nm is incident on the photocell?**

hf = φ + ½mv2

We don’t know f but we can work it out using = = 5.45 ×1014 Hz

hf = φ + ½m*v*2

(6.6 × 10-34)(5.45 ×1014) = 3.432 × 10-19  + ½ (9.1× 10-31)(v)2

 *v* = 1.922 × 105 m s-1

1. **Explain why a current does not flow in the photocell when the frequency of the light is less than 5.2 × 1014 Hz*.***

Because the frequency is less than the threshold frequency so the individual photons do not contain enough energy to cause an electron to be released from an atom.

1. **Draw a sketch of the graph obtained.**

Current is directly proportional to Intensity *{each photon releases an electron, so if you have twice as many photons you will have twice as many electrons},* so a straight line graph with the line going through the origin is required.

1. **How was the intensity of the light varied?**

Vary the distance between the light source and the photocell.

1. **What conclusion about the nature of light can be drawn from these investigations?**

Light is made up of discrete amounts of energy called photons.

**2009 Question 9**

1. **Define potential difference**

Potential difference is the work done in moving unit charge from one place to another.

1. **Define capacitance**

The capacitance of a conductor is the ratio of the charge on the conductor to its potential.

1. **Describe an experiment to demonstrate that a capacitor stores energy.**
2. Set up as shown.
3. Close the switch to charge the capacitor.
4. Remove the battery and connect the terminals together to ‘short’ the circuit.
5. The bulb will flash as the capacitor discharges, showing that it stores energy.
6. **Calculate the charge stored on each plate of the capacitor.**

 Q = CV  Q = (64 × 10-6)(2500)  Q = 0.16 C

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

E = ½ CV2 = ½ (64 × 10-6)(2500)2 = 200 J

1. **Calculate the average current that flows through the victim when the capacitor discharges in a time of 10 ms.**

 = 16 A

1. **Calculate the average power generated as the capacitor discharges.**

 = = 20000 W

**2009 Question 10** **(a)**

1. **How were the protons accelerated?**

They were accelerated by the very large potential difference which existed between the top and the bottom

1. **How were the alpha particles detected?**

They collide with a zinc sulphide screen, where they cause a flash and get detected by microscopes.

1. **Write a nuclear equation to represent the splitting of a lithium nucleus by a proton.**

** +  →**  + K.E.

1. **Calculate the energy released in this reaction.**

Loss in mass:

Mass before = mass of proton + mass of lithium nucleus

= (1.6726 × 10–27) + (1.1646 × 10–26)

= 1.33186 × 10-26 kg

Mass after = mass of two alpha particles = 2 × (6.6447 × 10–27) = 1.32894 × 10-26 kg

Loss in mass = (1.33186 × 10-26) – (1.32894 × 10-26) = 2.92 × 10-29 kg

E = mc2 = (2.92 × 10-29) (2.9979 × 108)2 = 2.6 × 10-12 J

1. **Most of the accelerated protons did not split a lithium nucleus. Explain why.**

The atom is mostly empty space so the protons passed straight through.

1. **Explain why new particles are formed.**

When the protons collide into each other they lose their kinetic energy and it is this energy which gets converted into mass to form the new particles.

1. **What is the maximum net mass of the new particles created per collision?**

The maximum that can be created would occur if all of the kinetic energy was converted into mass.

Total energy = 4 GeV

G = Giga = × 109

1 eV = 1.6 × 10-19 Joules

4 GeV = (4 × 109) (1.6 × 10-19) = 6.4× 10-10 Joules

E = mc2   m = 7.121 × 10-27 kg

1. **What is the advantage of using circular particle accelerators in particle physics?**

You can achieve greater (particle) speeds with a circular accelerator / They take up less space

(mass of alpha particle = 6.6447 × 10–27 kg; mass of proton = 1.6726 × 10–27 kg;

mass of lithium nucleus = 1.1646 × 10–26 kg; speed of light = 2.9979 × 108 m s–1;

charge on electron = 1.6022 × 10–19 C)

**2009 Question10** **(b)**

In July 1898, at Dun Laoghaire, Guglielmo Marconi used an induction coil to send radio waves from a ship.

The induction coil works on the principle of electromagnetic induction and had been invented earlier in Maynooth.

He was reporting on the annual Kingstown regatta, and it was the first time that radio waves had been used in journalism. Over two days Marconi sent over 700 messages to shore using Morse code.

The messages were then transmitted by telephone to the Dublin office of the *Daily Express* newspaper.

1. What is electromagnetic induction?
2. Who invented the induction coil?
3. What is the function of an induction coil?
4. In an induction coil, a primary coil with a few turns of thick wire and a secondary coil with many turns of thin wire are wrapped on the same soft-iron core.

Why are there a large number of turns in the secondary coil?

1. Explain why the primary coil has thick wire.
2. Why are both coils wrapped on the same soft-iron core?
3. Radio waves are much less energetic than light waves. List two other types of electromagnetic waves with energy less than that of light waves.
4. Give one property that is common to all types of electromagnetic waves.
5. The telephone used to transmit the messages to Dublin contained a moving-coil loudspeaker. Describe, with the aid of a labelled diagram, how a loudspeaker operates.

**2009 Question 11**

* 1. **What is the maximum energy that can fall on an area of 8 m2 in one hour if the solar constant is 1350 W m–2?**

1350 joules of energy fall on one m2 every second.

So the amount of energy falling on **8 m2** in **one hour** corresponds to1350 × 8 × 60 × 60 = 3.9 × 107 J

* 1. **Why is the bottom of a flat-plate collector blackened?**

Dark surfaces are good absorbers of heat/energy/radiation

* 1. **How much energy is required to raise the temperature of 500 litres of water from 20 0C to 50 0C?**

*{There are one thousand litres in one cubic metre, so 1 litre = 1 × 10–3 m}*

  mass = (density)(volume)  mass = (1000)(500 × 10–3) = 500 kg.

E = mc△θ = (500)(4200)(30) = 6.3 × 107 J

* 1. **The liquid in a vacuum-tube solar collector has a large specific latent heat of vaporisation. Explain why.**

So that the liquid can absorb a lot of energy per kg in the heat exchanger during a change of state.

* 1. **Name the three ways that heat could be lost from a vacuum-tube solar collector.**

Conduction, convection, radiation

* 1. **How is the sun’s energy trapped in a vacuum-tube solar collector?**

Silvered walls prevent radiation and evacuated walls prevent conduction and convection

* 1. **Describe, in terms of heat transfer, the operation of a heat pump.**

Energy is taken from one place (making it colder) by allowing the liquid to change state to a gas.

Then in another place the gas condenses to a liquid releasing the heat to another place making it hotter.

* 1. **Give an advantage of a geothermal heating system over a solar heating system.**

Geothermal system functions all the time whereas a solar heating system works only during sunshine.

**12** **(a)**

1. **State Hooke’s law.**

When a string is stretched the restoring force is proportional to the displacement.

1. **Calculate the spring constant.**

Natural length = *l*0 = 300 mm = 0.3 m

Extension = 30 mm = 0.03 m

m = 0.5 kg

After the mass has been attached it will come to rest at a new equilibrium position where force down = force up

Force down = mg = (0.5)(g)

Force up = k(extension) = (k)(0.03)

Force down = Force up

0.5g = k(0.03)

  k = 163.3 N m-1

1. **The sphere is then pulled down until the spring’s length has increased to 350 mm and is then released.**

**Describe the motion of the sphere when it is released.**

It executes simple harmonic motion because the displacement is proportional to the acceleration.

1. **What is the maximum acceleration of the sphere?**

a = ω2 x so acceleration will be a maximum when displacement from equilibrium position is a maximum.

Displacement is a maximum at the release point, which is a distance of 20 mm or 0.02 m from equilibrium position. So x in this context = 0.02 m

However we also need to calculate

To find we use the relationship =

a = ω2 x  a = )(0.02)  a = 6.532 m s-2

**2009 Question 12** **(b)**

1. **Explain how the presence of phosphorus and boron makes the silicon a better conductor.**

When phosphorus is added more electrons become available as charge carriers.

When boron is added more positive holes become available as charge carriers.

1. **What happens at the boundary of the two adjacent layers?**

Electrons and holes cross the junction cancelling each other out and recombine and as a result there are no free charge carriers.

A depletion layer is therefore formed between the n-type and p-type regions and as a result a junction voltage is created.

1. **Describe what happens at the boundary when the semiconductor diode is forward biased.**

The depletion layer breaks down and the diode conducts.

1. **Describe what happens at the boundary when the semiconductor diode is reverse biased.**

The width of depletion layer gets increased and the region acts as an insulator.

1. **Give a use of a semiconductor diode.**

Rectifier

**2009 Question 12** **(c)**

1. **Explain, with the aid of a labelled diagram, how a ray of light is guided along a fibre.**



1. An optical fibre consists of a glass pipe coated with a second material of lower refractive index.
2. 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.
3. This reflected light now strikes the interface on the opposite wall and gets totally reflected again.
4. This process continues all along the glass pipe until the light emerges at the far end.
5. **Why is each fibre coated with glass of lower refractive index?**

Because total internal reflection can only occur for rays travelling from a medium of higher to lower refractive index.

1. **What is the speed of the light as it passes through the fibre?**

  = = 1.94 × 108 m s-1

1. **What is the power being transmitted by the light after it has travelled 8 km through the fibre?**

After 2 km power has dropped to 5 W; after 4 km power has dropped to 2.5 W; after 6 km power has dropped to 1.25 W; after 8 km power has dropped to 0.625 W.

Answer: 0.625 W

**2009 Question 12** **(d)**

1. **Give the structure of an alpha particle.**

It is composed of 2 protons and 2 neutrons

1. **How are the alpha particles produced?**

α-decay is produced when the americium (which is radioactive) undergoes radioactive decay.

1. **Why do these alpha particles not pose a health risk?**

They have a very short range so are either contained within the smoke detector itself or just travel a cm or two through the air.

1. **Americium-241 has a decay constant of 5.1 × 10–11 s–1.**

**Calculate its half life in years.**

T½ = = 1.36 × 1010 seconds = 430.6 years

1. **Explain why americium-241 does not exist naturally.**

*{I don’t think this was a fair question and shouldn’t have appeared on the paper}*

Its half life is very short (with respect to age of the universe) and because it is not a member of a decay series it is not produced ‘in nature’ (it is created artificially).