**Leaving Cert Physics Worked Solutions 2022**

**2022 Question 1**

1. **Describe how the student determined the centre of gravity**   
   suspended from a thread / balanced on a pivot
2. **Describe how the student determined the weight of the metre stick.**  
   weighing scales / mass balance × *g*
3. ***Why* was it necessary to determine the centre of gravity of the metre stick?**   
   to know where the weight acted / to calculate the moment [state/imply]
4. **Indicate on a labelled diagram how these vertical forces were applied to the metre stick.**weights [for downward forces]

newtonmeters / weights and pulleys [for upward forces]

1. **How was it ensured that the metre stick was in equilibrium?**  
   not moving
2. **What was the principal advantage of ensuring that the metre stick was horizontal?**   
   distances read are perpendicular/correct / trigonometry not needed
3. **Calculate the net moment about the 0 cm position.**(2 × 0.321) + (1.2 × 0.506) + (3 × 0.722) = 3.4152 N m

(2.85 × 0.225) + (3.4 × 0.813) = 3.40545 N m

3.4152 – 3.40545 = 0.00975 N m

1. **Calculate the net vertical force acting on the metre stick.**Explain how these results verify the laws of equilibrium.
2. **Explain how these results verify the laws of equilibrium.**net moment ≈ 0

net force ≈ 0

**2022 Question 2**

1. **State Boyle’s law.***p* is inversely proportional to *V* / *pV* = constant

for a fixed mass of gas at constant temperature

1. **Draw a labelled diagram of how the apparatus was arranged in this experiment.**  
   means of measuring *p*

means of measuring *V* or *l*

means of changing *p* or *V* or *l*

1. **Why is it necessary for the column of air to have a uniform diameter?**   
   so that *V* is proportional to *l* [state/imply]

**Draw a suitable graph to verify Boyle’s law.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1/*l* (cm-1) | 0.067 | 0.05 | 0.04 | 0.033 | 0.029 | 0.025 |
| 1/*p* (kPa-1) | 0.0028 | 0.0044 | 0.0047 | 0.0056 | 0.0065 | 0.0074 |

labelled axes

correct points plotted

line of best fit

1. **Explain how your graph verifies Boyle’s law.**   
   straight line through origin
2. **Which of the data points is inconsistent with the others?**  
   the second data point, i.e. when *l* = 20.0 cm
3. **How did you treat this data point when you drew your graph?**

ignored it

**2022 Question 3**

1. **Draw a labelled diagram of how the apparatus was arranged in this experiment.**  
   transparent block

ray box / laser / pins

detail e.g. paper, ruler, protractor

1. **Describe how the student determined the angle of refraction.**   
   draw incident/emergent ray

draw refracted ray

draw normal [at point of incidence]

measure angle with protractor

1. **Draw a suitable graph to verify Snell’s law.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| sin *i* | 0.5 | 0.64 | 0.77 | 0.87 | 0.94 | 0.98 |
| sin *r* | 0.33 | 0.45 | 0.53 | 0.59 | 0.64 | 0.69 |

1. **Use your graph to calculate the refractive index of the glass.**  
   slope formula

*n* = 1.4

1. **What would be observed if the angle of incidence was zero degrees?**  
   no refraction / ray travels straight through

**2022 Question 4**

In an experiment to determine the speed of sound in air a student measured the length *l* of acolumn of air when it was vibrating at its fundamental frequency *f*. This process was repeated for six different values of *f*.

The following data were recorded.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *f* (Hz) | 256 | 288 | 320 | 341 | 384 | 480 |
| *l* (cm) | 29.2 | 25.5 | 22.6 | 20.9 | 18.1 | 13.7 |

1. **Draw a labelled diagram of how the apparatus was arranged in this experiment.**  
   tube

means of changing length

means of measuring length

tuning fork[s]

1. **How did the student determine the length of the column of air for a particular frequency?**  
   hold [vibrating] tuning fork over the mouth of the pipe

change the length of the pipe

until [the loudest] sound is heard

measure length from closed end to open end of the pipe

1. **Draw a graph to show the relationship between *l* and 1/*f*.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1/*f* (Hz-1) | 0.0039 | 0.0035 | 0.0031 | 0.0029 | 0.0026 | 0.0021 |

labelled axes

correct points plotted

line of best fit

1. **Use your graph to calculate the speed of sound in air.**slope formula

*c* = 4 × 85 = 340 m s–1

1. **Explain why the line of best fit on the graph does not go through the origin.**   
   end correction term / wave exists above the opening of the pipe

**2022 Question 5**

1. **Draw a labelled diagram of how the apparatus was arranged in this experiment.**  
   heating coil

power supply / battery

ammeter in series

thermometer

1. **How was the mass of the olive oil determined?**subtract mass of empty calorimeter from mass of full calorimeter / tare mass of empty calorimeter before adding oil

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| I2 (A2) | 1.0 | 4.0 | 9.0 | 12.25 | 16.0 | 20.25 |
| (K) | 2.2 | 9.1 | 19.6 | 27.4 | 36.1 | 45.1 |

1. **Draw a suitable graph to verify Joule’s law.**

labelled axes

correct points plotted

line of best fit

1. **Calculate the slope of your graph.**  
   slope formula

*m* = 0.447 [no units required]

1. **Hence calculate the specific heat capacity of olive oil.**  
   *mcΔθ = I2Rt*

(0.447)(8.5)(180)/0.35 = 1954 J kg–1 K–1

**2022 Question 6**

|  |  |
| --- | --- |
| Iron has a density of 7.87 g cm–3.  An iron sphere has a mass of 500 g.  Calculate the radius of the sphere in cm. | *Density ρ* = 7.87 g cm–3.  m = 500 g.  = 63.53 cm3    *r* = 2.475 cm |
| Calculate how many electronvolts are in a kilowatt-hour. | 1 kW hour = 1000(60)(60) = 3.6 × 106 J  And there are 1.6 × 10–19 J in 1 eV.  So total number of electronvols =  (3.6 × 106) ÷ (1.6 × 10–19) = 2.25 × 1025 eV |
| Draw a labelled diagram to show the forces acting on a piece of wood floating at rest. | weight labelled downwards  buoyancy/upthrust labelled upwards  equal and opposite force vectors |
| State the thermometric property of (*i*) a thermocouple, (*ii*) a mercury thermometer. | (i) voltage/emf (ii) height/length/volume |
| Transverse waves can be polarised. Explain what is meant by polarisation. | oscillations/vibrations in one plane |
| The sound intensity is 0.18 mW m–2 at a distance of 3 m in any direction from a source of sound. Calculate the power of the source. | *r* = 3 m  Sound intensity = 0.18 mW m–2  = 0.18 × 10-3 W m-2  Power = (sound intensity)(area)  Power = (0.18 × 10-3)(4π32)  P = 0.02 W |
| Describe how an insulated metal sphere can be charged by induction using a nearby charged rod. | earth sphere [when rod is close]  de-earth sphere [while rod is close]  then remove rod |
| A current-carrying wire of length 20 cm is placed in a magnetic field.  When a current of 55 mA flows in the wire the maximum force it can experience is 130 μN.  Calculate the magnetic flux density of the field. | F = BIL B = F/IL  B = 0.00013/(0.055 × 0.2)  B = 0.0118 T |
| A tungsten cube of side 2 cm has a resistance of 2.8 μΩ.  Calculate the resistivity of tungsten. | R = 2.8 × 10-6 Ω, L = 0.02 m, A = 0.022 m2  = 5.6 × 10–8 Ω m |
| Describe how the Bohr model of the atom explains emission line spectra. | Electron falling from one energy level to another  / E2 – E1 / ΔE  produces light of a particular frequency/wavelength/energy/colour/hf |
| What is thermionic emission? Where does it occur in an X-ray tube? | emission of electrons from a hot surface  Cathode |
| Pair annihilation of an electron and a positron occurs in a positron emission tomography (PET) scanner.  Write an equation for this annihilation. | e- + e+ / 2mec2 = 2γ / 2hf |

**2022 Question 7**

1. **State Hooke’s law.**  
   extension // F = –kx

proportional to force // notation

1. **Calculate the elastic constant of the spring.**

|  |  |
| --- | --- |
| New length = 0.185 m  Original length = 0.150 m  m = 0.2 kg | *Force down = Force up*  *mg* = *k (extension)*  (0.2)(9.8) = (k) (0.185 – 0.15)  k = 56 N m–1 |

1. **Calculate the period of oscillation of the object.**

|  |  |
| --- | --- |
| m = 0.2 kg  k = 56 N m–1 | so we first need to find *ω*  ω = 16.73 s–1  T = 0.375 s |

1. **Calculate the maximum acceleration of the object.**

|  |  |
| --- | --- |
| ω = 16.73 s–1 | Remember that when using the expression a = -ω2s, ***s represents the distance between the new length and the equilibrium position.***  Secondly, acceleration is proportional to displacement so acceleration will be a maximum when displacement is a maximum.  Maximum displacement = (0.2 – 0.185)= 0.015 m  *a = –ω2x*  amax = (280)(0.015) = 4.2 m s–2 |

1. **What is the speed of the body when it has maximum acceleration?**

What is the speed of the body when it has maximum acceleration?

The object has maximum acceleration at the extreme position, which is also where the velocity is zero.

1. **Derive an expression . . .**  
   *θ = s/r*

*v = s/t = rθ/t*

*ω = θ/t*so *v = rω*

1. **Calculate (*a*) the angular velocity, (*b*) the linear velocity of the object.**  
   (a)   
   *T = 2π/ω*

*ω* = 2π/0.5 = 12.57 rad s–1

(b)   
*v* = 0.11 × 12.57 = 1.38 m s–1

1. **Calculate the minimum tension in the string.**  
   FC = mrω2  / FC = mv2/r

Tmin. = (0.2 × 0.11 × 12.562) – (0.2 × 9.8) = 3.47 – 1.96 = 1.51 N

1. **Draw a labelled diagram of the forces acting on the object when the string has its minimum tension.**  
   weight acting downwards

tension acting downwards

**2022 Question 8**

1. **Distinguish between conductors, insulators and semiconductors.**  
   conductors are good at allowing current to flow / high conductivity / low resistivity

insulators are poor at allowing current to flow / low conductivity / high resistivity

semiconductors are in-between

1. **What is meant by doping?**  
   addition of [a small amount of] impurity to increase conductivity / to decrease resistivity
2. **How does p-type doping differ from n-type doping?**  
   p-type doping introduces [excess] holes / e.g. adding B

n-type doping introduces [excess] electrons / e.g. adding P

1. **Describe a depletion layer and explain how it forms.**  
   insulating region / region with no free charge carriers

between p-type and n-type semiconductors

holes/electrons migrate and combine/neutralise each other

1. **Indicate on a diagram the sections of a p-n junction that are positively charged, negatively charged and neutral.**  
   negatively charged in p-type close to the interface

positively charged in n-type close to the interface

neutral in remainder

1. **Draw a circuit diagram to show this arrangement.**  
   diode in forward bias

[variable] voltage source

1. **Sketch a graph to show the variation of current with voltage for this arrangement.**

**Diagram

Description automatically generatedIndicate the junction voltage on your graph.**  
axes labelled

correct shape

junction voltage indicated

1. **Explain why this may be necessary.**  
   to protect the diode / to limit the current / to prevent overheating

**2022 Question 9**

Diagram

Description automatically generated**2022 Question 9 (*a*)**

1. **Draw the electric field around the sphere.**  
   radial shape of field

direction of field towards centre

1. **Calculate the electric field strength at a distance of 3 cm from the surface of the sphere.**

To calculate the distance we need to add the 3 cm to the radius of the sphere (because the distance is to the centre of the sphere). 3 cm + 2.5 cm = 5.5 cm = 0.055 m  
 = 1.78 × 107 N C–1

**Describe an experiment to demonstrate that a charged capacitor stores energy.**  
method to charge capacitor e.g. across battery

* method to discharge capacitor e.g. across bulb/buzzer
* observation  
  1. **Write an expression for the charge on each plate of the capacitor**

and rearrange to get Q = CV

but there is no C (capacitance) in the variables above so we have so find an expression for

capacitance that we can substitute in.

We start withand rearrange to get

Now substitute in this value for C into Q = CV to get Q = V

Cancel one V above ane below the line to get Q =

* 1. **Write an expression for the distance between the plates.**

rearrange to get And again sub into for

**2022 Question 9 (c)**

1. **Derive an expression for the effective resistance of two resistors in parallel.**  
   IT = I1 + I2

V/RT = V/R1 + V/R2

1/RT = 1/R1 + 1/R2

1. **Calculate the current flowing in resistor X**

**Total resistance**

Rparallel = 2 Ω

We now have to add the 1 Ω resistor which is in series to give a total resistance of 3 Ω

**Total voltage: 12 V**

**Total current flowing in the circuit**

= 4 A.

This will also be the current flowing through the 1 Ω resistor.

1. **Calculate the current flowing in resistor Y**  
   voltage across 1 Ω resistor: V = IR = (4)(1) = 4 volts

So voltage across resistors in parallel = 12 – 4 = 8 volts

Resistor Y: R = 6 Ω, V = 8 volts

I = V/R = 8/6 = 1.33 A

Or you could use the ratio method: 3/9 of total current of 4A goes through the 6 Ω resistor: = 1.33 A

**2022 Question 10**

1. **What is meant by *radioactivity*?**

[spontaneous] emission of [one or more types of] radiation from a nucleus

1. **What is meant by *ionisation*?**

removing/adding electron(s) from/to an atom / charging a particle

1. **Write a nuclear equation for the conversion of plutonium–239 into plutonium–241.**
2. **Write a nuclear equation for the conversion of plutonium–241 into americium–241.**
3. **Outline the differences between nuclear fission and nuclear fusion.**fission is splitting of a nucleus

fusion is joining of [two] nuclei

1. **What is the function of a moderator?**  
   slows down neutrons / increases the rate of fission
2. **State one example of a moderator.**  
   water / graphite / beryllium
3. **Why are nuclear fusion reactors not yet viable?**

Too much energy needed [to overcome electrostatic repulsion between nuclei] / scarcity of tritium

1. **Why are the alpha particles produced in the detector not considered a health hazard?**  
   easily stopped / not very penetrating / short range
2. **Calculate the decay constant for americium–241.**

λ = 5.09 × 10–11 s–1

1. **Calculate the activity of the americium in the smoke detector.**

= 5.09 × 10–11 s–1

A = λN

Next we need to calculate *N* - the number of nuclei

241 g contains 6.0 × 1023 nuclei so 1g contains .

0.29 μg = = 7.22 × 1014 nuclei

A = λN (5.09 × 10-11) × (7.22 × 1014) = 3.67 × 104 Bq

**2022 Question 11**

50 stones were taken from the fire, at a temperature of 280 °C, and placed into the water. The stones had an average heat capacity of 8.5 kJ K–1 each.

1. **What is meant by heat capacity?**  
   energy to change the temperature of an object by 1 K
2. **What is meant by specific heat capacity?**  
   energy to change the temperature of 1 kg of a material by 1 K
3. **Calculate the highest temperature the water could have reached.**  
   **Notes**
4. The key to all of these questions is that heat lost by one substance (in this case the stones) = the heat gained by the second substance (in this case the water).
5. The second assumption is that the stones and the water will be at the same temperature at the end.
6. In this case we are given the *heat capacity* of the stones – this is represented by capital ‘*C*’, whereas for the water we are given its *specific heat capacity* – represented by lower case ‘*c*’.

**Heat lost by stones**

Heat capacity of each stone = 8.5 kJ K-1 = 8500 J K-1.

The initial temperature of the stones is 280 °C and they cool to some unknown final temp *X* °C.

Δθ = (285 – *X*)

Heat lost by each stone = (heat capacity)(change in temperature) = (C)(Δθ)

*Total* heat lost = (50)(C)(Δθ) = (50)(8500)(280 – *x*)

**Water**

There are 750 litres of water and each litre = 1 kg, so total mass of water = 750 kg

Specific heat capacity of water = 4180 J kg–1 K–1

The initial temperature of the stones is 4 °C and they heat up to some unknown final temp *X* °C.

Δθ = (*X* - 4)

Heat energy lost by stones = heat energy gained by water

(mCΔθ)stones = (mcΔθ)water

(50)(8500)(280 – *X*) = (750)(4180)(*C* – 4)

*X* = 36.95 °C

1. **Suggest a way of improving the design of the** ***fulacht fiadh* to make it more efficient.**   
   e.g. lid, fire closer to the water, put the *fulacht fiadh*in a microwave, drop in some dynamite etc etc

**2022 Question 11 [middle section]**

1. A pair of glasses

   Description automatically generated with low confidence**Draw a labelled diagram to represent a stretched string vibrating at its third harmonic.**  
   node at both ends

three anti-nodes

1. A 65 cm string of mass 0.21 g is stretched between two points of a lyre which are 34.1 cm apart.   
   It is required to vibrate at a fundamental frequency of 440 Hz.

**Calculate the tension that is applied to the string.**  
f = (1/2l)√(T/μ)

μ = m/l

[ = 0.00021/0.65 = 0.000323 kg m-1]

T = 29.1 N

1. **Determine the frequency of the string if the tension is now reduced by a factor of four.**

220 Hz

1. **What are isotopes?**  
   atoms with the same number of protons / atoms with the same atomic number / atoms of the same element

with different number of neutrons / with different mass number

1. **Is the artefact from the Bronze Age?**   
   no
2. **Justify your answer.**   
   two half-lives [> time since the beginning of the Bronze Age]

**2022 Question 12**

1. **Draw a labelled diagram of their apparatus**

* hydrogen discharge tube
* linear accelerator with voltage applied correctly
* target [at 45°]
* screen/scintillations/microscope

1. **Write a nuclear equation for the interaction between a proton and a nucleus of lithium–7.**   
   ** +  →  + K.E.**
2. **Convert 1.007825 u to kg. (Give your answer to six decimal places.)**u = 1.6605402×10–27 kg.  
   (1.007825)(1.6605402×10–27) = 1.673534×10–27 kg
3. **Explain the discrepancy . . .**  
   This one is nuts. Page 83 lists the nuclides. These are atoms which are listed by their mass number (A) and the atomic number (Z) and because they are atoms they also include the mass of the electrons.   
   So a ‘1H nuclide’ is a hydrogen atom which has a mass number of 1, so 1 proton and no neutron – but because it’s an atom it also has one electron! There is nothing on the syllabus (that I am aware of) that suggested this needed to be known. The other source of confusion is the word ‘nuclide’ sounds similar to ‘nucleus’ and could lull some students into confusing one with the other. At least that’s what happened to me ☹.
4. **Calculate the kinetic energy of the proton as it collided with the metal**  
   kinetic energy of proton at the end = potential energy of the proton at the start

= QV

= (1.60217653×10–19)(70000)

= 1.12152357×10–14 J

1. **Calculate the mass lost (in kg) during the interaction**

Mass lost = [total mass at the beginning] – [total mass at the end]

= [mass of proton + lithium] – [mass of 2 helium nuclei]  
= [7.016005 + 1.007825] – [2(4.002603)]

= 0.018624 u

(0.018624)(1.6605402×10–27) = 3.09259007×10–29 kg

1. **Calculate the energy produced (in J) during the interaction**  
   E = mc2

(3.09259007×10–29)(2.99792458 × 108)2 = 2.77948134 × 10–12 J

1. **Calculate the speed of the alpha particles formed during the interaction.**

The energy ‘produced’ (2.77948134 × 10–12 J) takes the form of kinetic energy of the alpha particles moving off afterwards

*kinetic energy*  = ½*mv*2

2.77948134 × 10–12 J = ½(mass of 2 alpha particles) *v*2

2.77948134 × 10–12 J = ½(2)(6.6446565×10–27)*v*2

*v* = 2.05 × 107 m s–1

1. **A proton may be classified as a *hadron*. Explain why.**

it experiences the strong force / it is composed of quarks.

1. **A proton may also be classified as a *baryon*. Explain why.**  
   baryons are composed of three quarks.

**2022 Question 13**

1. **What is meant by diffraction?**   
   spreading [of a wave]

around an obstacle / through a gap

1. **Draw a labelled diagram of an experiment to demonstrate the wave nature of light.**  
   light source

diffraction grating

screen/spectrometer

1. **What is observed in this experiment?**  
   series of fringes
2. **How do the observations demonstrate the wave nature of light?**   
   interference
3. **Draw a ray diagram to show how a converging lens can produce a virtual image.**   
   converging lens

object inside focal point

apparent intersection of rays to form virtual image

1. **Calculate the length of this pendulum.**   
   *T* = 2π√(*l*/*g*)

*l* = 0.993 m

1. **Calculate the mass of Saturn**  
   T2 = 4π2R3/GM

R = 1.16 × 109 + 58200000 + 2570000 = 1.22 × 109 m or   
T = 15.9 × 24 × 60 × 60 = 1373760 s

M = 4π2(1.22 × 109)3/(6.6742 × 10–11 × 13737602) = 5.7 × 1026 kg

1. **Calculate the acceleration due to gravity on the surface of Saturn**  
   g = GM/d2

*g* = (6.6742 × 10–11)( 5.7 × 1026)/(58200000)2 = 11.2 m s–2

**Calculate the period that Huygens’ clock would have on the surface of Saturn.**   
T = 2π√(0.993/11.2) = 1.87 s

**2022 Question 14 (a)**

1. **Distinguish between a vector and scalar.**  
   vector has [magnitude and] direction

scalar has magnitude only / scalar has no direction

1. **Draw a labelled diagram of the arrangement of the apparatus in an experiment to find the resultant of two vectors.**   
   (See notes for more detailed answer)  
   Three newtonmeters / three systems of weights and pulleys / three displacements [3]

correct arrangement

1. **Resolve the velocity into horizontal and vertical components.**  
   vH = 150cos20° = 141 m s–1

vV = 150sin20° = 51.3 m s–1

1. **Calculate the magnitude and direction of the velocity of the object after 8 s.**   
   vH = 150cos20° = 141 m s–1

*v = u + at*   
vV = 51.3 – (9.8 × 8) = –27.1 m s–1

|v| = 143.5 m s–1

10.9° [below the horizontal]

**2022 Question 14 (b)**

1. **What is the Doppler effect?**  
   [apparent] change in frequency [of a wave]

due to the [relative] motion between the source and the observer

1. **Describe, with the aid of labelled diagrams, how the Doppler effect occurs.**   
   concentric/non-concentric circles drawn [representing wavefronts]

motion of wave source towards/away from observer

shorter wavelength as source approaches observer [or vice versa]

therefore greater frequency [or vice versa]

1. **Calculate the frequency Pierre observes after 3 seconds.**   
   First we have to establish the speed of the sources after 3 seconds

*v = u + at* *v* = (9.8)(3) = 29.4 m s–1

Now use the Doppler effect formula. *f* = 500 Hz, *u* = 29.4 m s–1, *c* *= 340 m s–1*

*Source is moving away so use ‘minus’ version of the formula*

*f’* = 460.2 Hz

**2022 Question 14 (c)**

1. **Describe a laboratory experiment to demonstrate the photoelectric effect.**   
   apparatus [e.g. gold leaf electroscope, metal plate, light source]

method [e.g. charge electroscope, place plate on cap, shine light on plate]

observation [e.g. leaves collapse]

1. **Calculate the maximum speed of the emitted electrons.**  
   *hf = Φ + ½mv*2

*c = fλ* or f = (3 × 108)/(450 ×10–9) = 6.67 × 1014 Hz

*Φ* = (2.4)(1.6 ×10–19)= 3.84 ×10–19 J

*v* = 3.56 ×105 m s–1

1. **Explain these observations.**  
   incident energy decreases

until the incident energy is below the work function / until the incident frequency is below the threshold frequency

**2022 Question 14 (d)**

1. **State the laws of electromagnetic induction.**   
   induced emf is proportional to rate of change of flux

direction of induced current/emf is such as to oppose the change that caused it

1. **Describe what is observed when a sheet of copper metal is placed under the oscillating magnet.**   
   amplitude of oscillations decreases
2. **Explain this observation.**  
   [magnetic field from induced] currents in copper opposes the motion
3. **Describe what would be observed if instead of the copper, a sheet of plastic was placed under the oscillating magnet.**   
   oscillations continue
4. **Explain this observation.**

No induced current flow in plastic so no magnetic field to oppose motion