**2022 Leaving Cert Physics Solutions**

**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**

Answer any **eight** of the following parts, (*a)*, (*b*), (*c*), etc.

1. **Calculate the radius of the sphere in cm.**  
   *ρ* = *m/V* therefore *V*= *m/ρ*  
   V = (4/3)πr3

V = 500/7.87 = 63.53 cm3

r = 2.475 cm

1. **Calculate how many electronvolts are in a kilowatt-hour.**  
   1 eV = 1.6 × 10–19 J

1 kW-hour = 1000(60)(60) = 3.6 × 106 J

(3.6 × 106)/(1.6 × 10–19) = 2.25 × 1025 eV

1. **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

1. **State the thermometric property of (*i*) a thermocouple, (*ii*) a mercury thermometer.**  
   (i) voltage/emf (ii) height/length/volume
2. **Transverse waves can be polarised. Explain what is meant by polarisation.**  
   oscillations/vibrations in one plane
3. **Calculate the power of the source.**  
   Sound intensity = Power/area  
   P = (SI)(area)

area = 4π(32) = 113.1 m2

P = 0.02 W

1. **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

1. **Calculate the magnetic flux density of the field.**  
   F = BIL

B = 0.00013/(0.2 × 0.055) = 0.0118 T

1. **Calculate the resistivity of tungsten.**  
   ρ = RA/*l*

ρ = (0.0000028 × 0.022)/0.02 = 5.6 × 10–8 Ω m

1. **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*

1. **What is thermionic emission? Where does it occur in an X-ray tube?**  
   emission of electrons from a hot surface

cathode

1. **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.**  
   *F = –kx*

(0.2)(9.8) = k(0.185 – 0.15)

k = 56 N m–1

1. **Calculate the period of oscillation of the object.**  
   *T = 2π/ω*

*ω* = √(*k/m*) or *ω* = √280 = 16.73 s–1

*T* = 2π/16.73 = 0.375 s

1. **Calculate the maximum acceleration of the object.**  
   *a = –ω2x*

amax. = (280)(0.2 – 0.185) = 4.2 m s–2

1. **What is the speed of the body when it has maximum acceleration?**  
   zero
2. **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

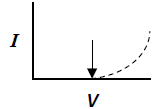
positively charged in n-type close to the interface

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.**

**Indicate 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**

(*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.**   
    .

E = F/q

E = (6 × 10–6)/(4π × 8.854 × 10–12 × 0.0552) = 1.78 × 107 N C–1

(*b*)

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
   1. **the charge on each plate of the capacitor,**  
      2*W/V*
   2. **the distance between the plates.**   
      (b) *εAV2/2W*

(*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**  
   1/RYZ = ⅙ + ⅓  
   RYZ = 2 Ω

RXYZ = 1 + 2 = 3 Ω

I = 12/3 = 4 A

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.**  
   T½ = (ln 2)/λ

λ = 0.693/(432 × 365 × 24 × 60 × 60) = 5.09 × 10–11 s–1

1. **Calculate the activity of the americium in the smoke detector.**  
   A = λN

0.29 μg has (0.29 × 10–6/241)(6.0 × 1023) = 7.22 × 1014 nuclei

(5.09 × 10-11) × (7.22 × 1014) = 3.67 × 104 Bq or s–1

**2022 Question 11**

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.**  
   mcΔθ

(750)(4180)(x – 4) or (50)(8500)(280 – x)

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 etc.
2. **Draw a labelled diagram to represent a stretched string vibrating at its third harmonic.**  
   node at both ends

three anti-nodes

1. **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.**
2. **Convert this mass to kg. (Give your answer to six decimal places.)**  
   (1.007825)(1.6605402 × 10–27) = 1.673534 × 10–27 kg
3. **Explain the discrepancy . . .**  
   the nuclide mass [on page 83] contains the mass of the electron
4. **Calculate the kinetic energy of the proton as it collided with the metal**  
   E = qV

(1.60217653 × 10–19)(70000) = 1.12152357 × 10–14 J

1. **Calculate the mass lost (in kg) during the interaction**  
   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.**   
   *E* = ½*mv*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
2. **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

1. **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**

Answer any **two** of the following parts, (*a*), (*b*), (*c*), (*d*).

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

*f’ = fc/(c ± u)*

*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 // E = dφ/dt

proportional to rate of change of flux // notation

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
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 currents flow in plastic