**2021 Leaving Cert Physics Solutions (Higher Level)**

**2021 Question 1**

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

correct arrangement of bob

string

split cork or similar / timer / metre stick

1. **Indicate on the diagram the fixed point of suspension**  
   bottom of split cork or similar (3)
2. **Indicate on the diagram the the distance *l*.**from fixed point of suspension to midpoint of bob
3. **Why did the student measure the time for 20 oscillations rather than the time for one oscillation?**   
   to get an average / to get a larger value (for time) / greater accuracy / it is difficult to know when an oscillation starts or finishes
4. **Use the data to draw a suitable graph to calculate the acceleration due to gravity, *g*.**   
   values for (t/20)2

labelled axes

correct points plotted

line of best fit

1. **Hence determine *g*.**

slope formula

g (≈ 9.8 m s-2)

**2021 Question 2**

1. **Why did the student first make an approximate measurement of the focal length?**   
   to ensure that the object was placed outside the focal point / so that a real image would be formed / so that the image can be formed on a screen / to check final answer
2. **How did the student determine the image positions?**   
   moved a screen until a sharp image was seen
3. **Draw a labelled diagram of how the apparatus was arranged.**
4. **On your diagram, indicate *u* and *v*.**   
   object, mirror, screen, correct arrangement
5. Use all of the data to calculate the focal length of the mirror.   
   **formula**

**average value for f (≈ 12.1 cm)**

1. **Sketch a suitable graph that might have been drawn.**   
   correct x-axis (1/u) // correct x-axis (u)

correct y-axis (1/v) // correct y -axis (v)

correct shape of curve (straight line with m = −1) // correct shape of curve

1. **How could this graph be used to calculate the focal length?**  
   intercept(s) // point on curve

= 1/f // substitute into formula

**2021 Question 3**

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

newtonmeter / weights and pan

metre stick / bridge(s) / paper rider

tuning fork

1. **Describe how the student used the apparatus.**held (vibrating) tuning fork to string and changed T

paper rider fell off / loud sound

1. **Draw a suitable graph to show the relationship between *f* and *T*.**values for f2 or √T

labelled axes

correct points plotted

line of best fit

1. **Use your graph to calculate the mass per unit length (linear density) of the string.**slope formula

value of slope (e.g. ≈ 64.8)

formula

μ (≈ 1.4 × 10–4 kg m–1

**2021 Question 4**

1. **Draw a labelled diagram of how the apparatus was arranged in this experiment.**resistor (in liquid), ohmmeter, source of heat, thermometer
2. **How did the student make the temperature of the wire 0 °C?**   
   ice bath
3. **Draw a suitable graph to show the relationship between *R* and *Ɵ*.**   
   labelled axes

correct points plotted

line of best fit

1. **Use your graph to determine the temperature when the resistance is 6 Ω.**   
   value consistent with graph (≈ 55.5 °C)
2. **How did the student measure the diameter of the wire?**   
   micrometer / digital callipers / vernier callipers
3. **Calculate the resistivity of the metal at a temperature of 20 °C.**  
   formula

substitution / area = 4.52 × 10–6 m2

ρ = 8.44 × 10–5 Ω m

**2021 Question 5**

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

means of varying current

ammeter in series

thermometer / coil (in water)

1. **Why was the current allowed to flow for a constant period of time?**    
   to remove time as a variable
2. **Draw a suitable graph to verify Joule’s law.**   
   values for I2

labelled axes

correct points plotted

line of best fit

1. Use your graph to calculate the average resistance of the heating coil.    
   slope formula
2. value of slope (≈ 2.03)
3. I2Rt / mcΔθ
4. I2Rt = mcΔθ
5. R ≈ 3.71 Ω

**2021 Question 6**

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

1. **Define acceleration.  Hence derive the expression *v* = *u* + *at*.**    
   rate of change of velocity / equation plus notation

a = (v – u)/t

rearrangement

1. **Calculate the horizontal distance it travels in 1.2 seconds.***s* = *ut*

*u* = 20Cos50° = 12.86 m s–1

15.43 m

1. **State the laws of equilibrium for a set of co‐planar forces.**sum of the forces (in any direction) is zero

sum of the moments (about any axis) is zero

1. **State an expression for the acceleration due to gravity at a distance of 2R above the surface of a planet of mass M and radius R.**

1. **Explain why this happens.**different thermometric properties
2. **Draw a labelled diagram to represent the second harmonic of a stationary wave in a pipe that is open at both ends.**antinode shown at both ends

one full wave shown (i.e. antinode-node-antinode-node-antinode)

1. **Calculate the sound intensity 6 m from a loudspeaker of power 20 mW.**I = P/A

substitution / A = 4πr2

4.4 × 10–5 W m−2

1. **What colour of light is produced when equal intensities of these two primary colours are mixed?**red and blue // blue and green // green and red   
   magenta // cyan/turquoise // yellow
2. **Distinguish between earthing and bonding in domestic electricity.**earthing means providing a (conducting) path to Earth, i.e. joining to Earth

bonding means providing a (conducting) path between objects, i.e. joining objects

1. **Draw a circuit diagram to show how voltage and current are measured for a diode in reverse bias.** diode shown in reverse bias

(micro)ammeter in series with diode

voltmeter across diode and microammeter

1. **Write a nuclear equation for this decay.**
2. **In terms of how they interact with the neutrons in a fission reactor, distinguish between a  moderator and a control rod.**a moderator slows down neutrons

a control rod absorbs/stops/blocks neutrons

**2021 Question 7**

1. **State Newton’s second law of motion.**   
   force is proportional to // expression

rate of change of momentum // notation

1. **State the principle of conservation of momentum.**   
   momentum before interaction = momentum after interaction / formula and notation
2. **State the principle of conservation of energy.**   
   energy is not destroyed or created (just converted into a different form)
3. **Calculate the force exerted by B on A.**  
   F = (mu – mv)/t (3)

F = 0.045(6.2 + 1.1)/0.025 = 13.14 N

1. **Calculate the maximum velocity of B.**  
   0.045(6.2) = 0.045(–1.1) + 0.08(*v*)

*v* = 4.11 m s−1

1. **Calculate the magnitude and direction of the maximum centripetal force on B.**   
   F = mv2/r

F = 0.08(4.11)2/1.2 = 1.12 N

1. **Calculate the maximum height gained by B.**  
   ½m*v*2 / m*gh*

*h* = 0.86 m

1. **Calculate the maximum angular displacement of the string**.  
   cosα = (1.2 – *h*)/1.2

α = 73.6°

1. **Draw a labelled diagram to show the force(s) acting on B when it is at its maximum height.**   
   downward arrow, labelled as weight (3)

labelled tension arrow in correct direction

1. What is the magnitude and direction of the acceleration of B after the string is cut?  
   9.8 m s–2

downwards

**2021 Question 8**

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

through a gap / around an obstacle

1. A diffraction experiment can be used to demonstrate the wave nature of light.  Describe such an experiment.      
   **apparatus, method, observation**
2. **What is a diffraction grating?**  
   a series of (transparent) gaps
3. **Derive the diffraction grating formula, nλ = dsinθ**.    
   *d* indicated

*θ* indicated as angle between straight through and higher order image

extra path length = *d*sin*θ*

for constructive interference, extra path length = nλ

1. **Calculate the angular separation.**  
   *d* = 1.67 × 10−6 m

sin*θ* = 3(442 × 10−9)/*d* = 0.7956

2*θ* = 105.4°

1. **Calculate the distance between these images on a screen placed 50 cm from the grating.**    
   tan*θ* = *x*/0.5

2*x* = 1.31 m

1. **What changes would be observed if the blue light was replaced with red light?**  
   greater angular separation / fewer images
2. **What changes would be observed if the blue light was replaced with white light?**    
   spectrum (on either side of white zero-order image)
3. **Compare the wavelengths of radio waves with those of visible light.**      
   radio waves have longer wavelengths (than visible light)
4. **Why are radio waves not observed to undergo diffraction when incident on a diffraction grating of 600 lines per mm?**  
   d is too small / λ is too big

**2021 Question 9**

1. **What is meant by specific heat capacity?**

energy to change temperature of 1 kg of a substance // equation for c

by one kelvin // notation

1. **Why does the high specific latent heat of fusion of ice make it a good coolant?**   
   takes in a lot of energy

when melting

1. **Suggest two reasons why the walls of a picnic box are made from hollow plastic rather than solid plastic.**  
   better insulator, lower heat capacity, lighter, lower environmental impact
2. **Calculate the final temperature inside the picnic box when its contents have reached thermal equilibrium.**     
   mcΔθ or CΔθ

(0.25 × 2100 × 18) + (0.25 × 330000) + (0.25 × 4180 × θ) = 17800(10.5 – θ)

θ = 5.04 °C

1. **Draw a labelled diagram of a heat pump.**      
   compressor indicated

(expansion) valve indicated

correct arrangement of liquid/vapour indicated

1. **Explain how a heat pump works.**   
   heat taken in by liquid evaporating

heat given out by vapour condensing

1. **What observations did the student make?**      
   ice didn’t melt / bottom of the tube stayed cold
2. **What conclusion could the student have made?**  
   water is a poor conductor of heat

**2021 Question 10**

1. **What is a magnetic field?**      
   the region where magnetic forces can be experienced
2. **Describe an experiment to show the magnetic field around the conductor.**    
   apparatus, method, observation
3. **Draw the shape and direction of this magnetic field.**

correct shape

correct direction

1. The magnitude of this force depends on a number of factors.  Name three of them.      
   **magnetic flux density, current, length, angle**
2. **Derive an expression** . . .  
   *F* = *BIl*

*I* = *q/t* and *l* = *vt*

*F* = *qvB*

1. **Use Faraday’s law of to calculate the average emf induced in the loop as it enters the field.**

|  |  |
| --- | --- |
| V = dΦ/dt  Φ = BA = 0.001 Wb  t = s/v = 0.00833 s | V = dΦ/dt  V = BA/t = BAv/s  V = Bsv |
| V = 0.12 V | V = 0.12 V |

1. **The other law of electromagnetic induction is Lenz’s law. State Lenz’s law.**      
   the direction of an induced current

is such as to oppose the change that caused it

1. **Explain how Lenz’s law is a special case of the principle of conservation of energy.**  
   otherwise energy would be created

**2021 Question 11**

* 1. **Write the nuclear equation for this event.**
  2. **Calculate the increase in kinetic energy during this event.**    
     E = mc2

conversion between a.m.u. and kg

mass defect calculation

conversion to J (9.13 × 10−13 J)

* 1. **A G‐M tube and a solid‐state detector have the same function.  What is this function?**      
     to detect (ionising) radiation
  2. **Describe, with the aid of a labelled diagram, the principle of operation of a detector of this sort.**

|  |  |  |
| --- | --- | --- |
| gas / anode  ionisation  current | semiconductor  electron-hole pair  current | charged gold leaf electroscope ionisation  ionisation  leaves collapse |

* 1. **Describe with the aid of a labelled diagram the gold foil experiment.**    
     alpha source and gold target

flashes of light on detector

* 1. **What observations were made during the experiment?**      
     most particles went straight through, some were slightly deflected, a few went almost straight back
  2. **What did Rutherford conclude about the structure of the atom?**     
     mostly empty space with positive nucleus
  3. **How did Niels Bohr improve Rutherford’s model to explain emission line spectra?**   
     electrons in energy levels   
     photon emitted when electrons move between energy levels / hf = En – Em

**2021 Question 12**

1. **Describe a laboratory experiment to demonstrate charging by induction.**  
   charged object

charged object brought close to conductor

conductor earthed

earth removed

(last 3 marks not awarded if charged object removed before or at the same time as earth)

1. **Explain how point discharge occurs.**    
   charge accumulates at a point

the air around the point is ionised / ions in the air neutralise the point

1. Calculate the relative permittivity of the capacitor’s dielectric.  
   C = εA/d (3)

ε = 2.4 × 10−11 (F m−1) (3)

εr = 2.71

1. **What would be the effect on the capacitance if the distance between the plates was doubled?**   
   decreased by a factor of 2
2. **Explain why the effective capacitance of this combination is 9.6 pF.**   
   (common) area increases by a factor of 3 (and C is proportional to A)
3. **Draw the electric field pattern in a charged parallel plate capacitor.**   
   parallel field lines (3)

from + to −

1. **Why is the cathode of an X‐ray tube hot?**     
   for thermionic emission to occur / so that electrons will be released
2. **Calculate the maximum speed of an electron as it moves between the cathode and the anode**.      
   ½mv2 / qV

½mv2 = qV

v = 8.4 × 107 m s−1

1. **What happens to the energy of the electrons when they hit the anode?**  
   converted into heat

converted into X-rays

**2021 Question 13 (a)**

Answer either part (a) or part (b).

1. **State the quark composition of the proton.**   
   up, up, down
2. **List the forces experienced by a proton in decreasing order of strength.**   
   strong, electromagnetic, weak, gravitational
3. **Express this unit in terms of metres, kilograms and seconds.**   
   kg m2 s−1
4. **Write a nuclear equation for the pair annihilation of a proton and an antiproton.**   
   
5. **A photon produces a muon anti‐muon pair. Calculate the minimum energy of the photon in electronvolts.**   
   *E* = *m*c2

*m* = 2*m*μ

*m* = 2 × 206.9 × 9.109 × 10–31 = 3.769 × 10–28 kg

*E* = 3.388 × 10–11 J

*E* = 2.115 × 108 eV

1. **In the Large Hadron Collider, how are the particles (a) accelerated, (b) maintained in circular motion?**   
   (a) voltage / electric field / magnetic field

(b) magnetic field

1. State two reasons why their experiments using this accelerator were of scientific significance.  
   first experimental verification of E = mc2

first transmutation using artificially accelerated particles

**2021 Question 14 (a)**

1. **What is simple harmonic motion?**  
   acceleration proportional to displacement / equation and notation
2. **Calculate the spring constant.**  
   *T* = 2π/*ω*

*ω* = 8.49 s−1

*ω*2 = k/m

k = 2.88 N m−1

1. **Calculate the acceleration of the sphere when its displacement is 18 mm from its equilibrium position.**   
   *a* = *ω*2*s*

*a* = 1.3 m s−2

1. **Calculate the mass of the magnet.**   
   *mg* / *kx*

*mg* = *kx*

*m* = 4.4 g

**2021 Question 14 (b)**

1. **What is the Doppler effect?**  
   (apparent) change in frequency

due to the relative motion between a source and an observer

1. **Describe how the Doppler effect can be demonstrated in the laboratory.**   
   apparatus, method, observation
2. **Calculate the speed of the source.**  
   f' = cf/(c ± u)

substitution

*u* = 11.02 m s−1

1. **Draw a ray diagram to show the refraction of a sound wave as it travels from water into air.**   
   wave changing direction as it travels from water to air

towards the normal

**2021 Question 14 (c)**

1. ***f* > fo , f is constant and I is increasing,**  
   more electrons emitted

with the same energy/speed

1. ***f* > fo , f is increasing and I is constant,**  
   same number of electrons emitted

but with greater energy/speed

1. ***f* < fo , f is constant and I is increasing.**  
   no electrons emitted
2. **Calculate the threshold frequency of the metal.**  
   hf0 = Φ

f0 = 6.3 × 1014 Hz

1. **Calculate the maximum speed of the emitted electrons.**   
   h*f* = Φ + ½m*v*2

c = fλ

½m*v*2 = 3.5 × 10−20 J

*v* = 2.8 × 105 m s−1

**2021 Question 14 (d)**

* 1. **Draw a ray diagram to show how an inverted image is formed in a lens.**converging lens

object outside *f*

correct rays shown

* 1. **Is the image real or virtual?**   
     the image is real
  2. **What is meant by critical angle?**  
     angle of incidence (in denser medium)  
     such that angle of refraction is 90°/ greater than which total internal reflection occurs
  3. **Calculate the speed of light in the ball lens.**  
     *n* = 1/sinC or *n* = *c1/c2*

1/*sinC* = *c1/c2*

*c2* = 1.98 × 108 m s−1

* 1. **Explain why white light is dispersed as it passes through the ball lens.**  
     different colours of light

travel at different speeds (in glass) / have different refractive indices