**2022 Deferred exam – Worked Solutions**

**1.**

1. **Draw a labelled diagram of the experimental arrangement that the student could have used.**  
   runway/air‐track with two trolleys/riders  
   means of getting trolleys to stick to each other, e.g. pin and cork

means of measuring distance and time, e.g cards and light gates

1. **Describe how the student could have made these measurements.**   
   description of how distance was determined   
   description of how time was determined  
   description of how velocity was calculated, i.e. velocity = distance divided by time
2. **What additional steps could the student have taken in order to make these measurements more accurate?**clean the track to minimise friction, tilt the track slightly to offset friction etc.
3. **Why should body A be moving with a constant velocity before the collision?**So that the velocity measured is the impact velocity / so its velocity on impact is known
4. **How did the student check this?**   
   Measure the initial velocity of body A twice [e.g. by comparing different sections of the tape]
5. **What velocity would you expect body A to have had before the collision?**   
   The mass of body A was twice that of body B. So massA = 2 massB  
   total momentum before collision = total momentum after collision.

m1u1  + m2u2  = m1v1  + m2v2

Body B is at rest before collision and both bodies move off together with a common velocity v3 afterwards:

mAu1 + 0 = (mA+mB)(v3)

But mA = 2 mB so total mass afterwards = 3 mA

mAu1 = (3mA)(v3) u1 = (3)(v3)

v3 = 0.18 m s–1 u1 = (3)(0.18) = 0.54

1. p = mv = 3 × 0.18 = 0.54  kg m s-1

0.54 ÷ 2 = 0.27 m s–1

**2.**

1. **Draw a labelled diagram of the apparatus that the student could have used in the experiment.**  
   means of producing steam    
   means of delivering (dry) steam [e.g. steam trap, lagging of delivery tube]   
   water in calorimeter (with lagging or lid)  
   thermometer in water
2. **Calculate the specific latent heat of vaporisation of water.**   
   mwater = 49.7 g    msteam = 1.3 g  
   Δθwater = 14 °C Δθsteam = 74 °C   
   ΔE = ml  
   ΔE = mcΔθ    
   (25.6 × 910 × 14) + (49.7 × 4180 ×14) = (1.3 × lv) + (1.3 × 4180 × 74)    
   lv = 2.18 × 106  J kg–1
3. **Why did the student use water that that had been cooled to below room temperature?**   
   so that heat lost ≈ heat gained
4. **Discuss one advantage and one disadvantage of using a greater mass of steam.**  
   advantage: less % error [in msteam or in any Δθ] disadvantage: water gets too hot / loss of heat to surroundings

**3.**

1. **What is meant by the focal length of a concave mirror?**   
   distance from the focal point/focus to the [back of] the mirror
2. **How did the student find an approximate value for the focal length?**measured the image distance for a distant object
3. **Why did the student find an approximate value for the focal length?**to make sure the object was not placed inside the focal length
4. Describe how the position of the image was determined.**move screen/mirror/object until sharpest image is formed**
5. **Use the data in the table to calculate the focal length.**1/*u* + 1/*v* = 1/*f*    
   one value calculated for *f*

Average *f* calculated

1. **Sketch the shape of a converging lens.**correct shape
2. **How does the arrangement of the apparatus differ between the two experiments?** screen is on the same side of the mirror as the object    
   screen is on the other side of the lens as the object

**4.**

1. **What is meant by the word “monochromatic”?**one colour/wavelength/frequency

1. **Describe how the apparatus was arranged in this experiment.**   
   experiment.

diffraction grating

screen/spectrometer

correct arrangement

1. **Explain how the value of *d* was determined.**

read from diffraction grating

1. **Explain how the value of *θ*** **for each image, was determined.**

protractor // spectrometer // meter stick

for angle with straight through // subtract zero order angle // correct trigonometry

1. **Why would the student have wanted this?**   
   less % error
2. **State one way in which the student could have achieved a larger angular separation of the images** without changing the light source.   
   images without changing the light source.

move grating and screen apart / decrease d

1. **If the grating being used had 400 lines per mm, calculate the wavelength of the light.**    
   3λ = (1/400000) × sin 50

λ = 6.38 × 10–7 m

1. **Draw a diagram of what is observed when a beam of white light is passed through a diffraction grating.**

Spectrum

multiple spectra

red diffracted most / blue diffracted least

central white order

**5.**

1. **Draw a labelled diagram of the experimental arrangement used and describe how the data in the table were obtained.**   
   conductor in liquid

heat source and thermometer

ohmmeter / multimeter (set to read ohms) / ammeter and voltmeter

heat water and read thermometer and ohmmeter

1. **Use the table to draw a suitable graph that shows the relationship between the resistance of the conductor and its temperature.**   
   labelled axes

points plotted

straight line of best fit

1. **Describe the relationship between resistance and temperature shown by your graph.  
   slope formula**  
   resistance increases linearly with temperature
2. **Use your graph to find the rate of change of resistance with respect to temperature for the metallic conductor.**   
   dR/dθ  ≈ 0.047 Ω C–1
3. **Estimate the resistance of the metallic conductor when its temperature is –10 °C**.   
   R ≈ 6.7 Ω / answer consistent with graph or dR/dθ calculation
4. **How would the results of the two experiments differ?**  
   resistance decreases for a thermistor

non‐linear relationship for a thermistor

**6.**

* 1. **calculate the average power generated by the athlete.**  
     P = W/t / P = Fs/t / P = Fv  
     P = (850 × 2.5) ÷ 6 = 354 W
  2. **State Archimedes’ principle.**   
     upthrust/buoyancy is equal to the weight of displaced fluid/liquid
  3. **Calculate the length of a pendulum that has a period of one second.**   
     T = 2π√(l/g)  
     l = 0.248 m
  4. **Explain why this occurred.**   
     different thermometric properties  change differently with temperature changes
  5. **Sketch the first two harmonics that are produced when the string is plucked.**   
     first harmonic:  node – antinode – node second harmonic:  node – antinode – node – antinode – node
  6. **What is meant by sound intensity?**   
     power / rate of change of energy per unit area
  7. **Calculate the effective focal length of two thin lenses in contact**   
      1/fT = 1/f1 + 1/f2 or PT = P1 + P2 [3] f1 = 5 (cm); f2 = –15 (cm)  [1 + 1]  fT = 7.5 cm
  8. **Explain the role of a fuse.**   
     breaks the circuit when current is too high
  9. **Find the pressure exerted by the cube on the table.**   
     P = F/A   ρ = m/V W = mg

P = 8960 × 0.05 × 9.8 = 4390.4 Pa  

* 1. **What is meant by the U‐value of a material?**   
     Rate of energy transfer through 1 m2  of a surface when a temperature difference of 1 K across the surface.
  2. **How are X‐rays produced?**   
     high speed electrons [4]  hit a metal
  3. **Name the metal used as a target in the Cockroft and Walton experiment.**lithium   
     **or**
  4. **What determines the colour of the emitted light?**   
     material used / energy gap between free electrons and holes

**7.**

1. **Define displacement.**  
   distance in a given direction
2. **Define velocity.**   
   rate of change of // speed

displacement // in a given direction

1. **What is a vector quantity?**   
   a quantity with magnitude and direction
2. **What is the resultant velocity of the swimmer?**   
   magnitude: √((2.5)2 + (4)2 = 4.72 m s–1

direction: tan–1 (4/2.5) = 58° [3]

1. **How long will it take the swimmer to reach the opposite bank of the river?**   
   t = s/v = 75/2.5 = 30 s
2. **What will be the displacement of the swimmer from his starting position when he has reached the opposite bank?**

s = vt

s = 4.72 × 30 = 141.6m

1. **Describe a laboratory experiment to find the resultant of two co‐planar forces.**   
   application of two known or measureable forces

application of third known or measureable force to counteract first two forces

lines drawn to indicate magnitude and direction of the forces

find the resultant of the first two forces

1. **If the frictional force on the car as it moves down the slope is a constant 550 N, calculate the acceleration of the car.**   
   Wsin10° = mgsin10° = 1000 × 9.8 × sin10°= 1702 N

F = 1702 – 550 = 1152 N

F = ma

a = 1152 ÷ 1000 = 1.152 m s−2

**8.**

1. **What is the Doppler effect?**(apparent) change in frequency due to the (relative) motion between the source and the observer [3]
2. **Explain how the Doppler effect occurs.**   
   as source moves towards observer // as source moves away from observer

shorter λ // longer λ

increased f // decreased f

1. **What is meant by the emission line spectrum of an element?**   
   specific frequencies of e.m. radiation emitted by an element
2. **How is the emission line spectrum of an element related to the energy levels of the electrons in an atom of that element?**   
   Electron moves to a higher level (when given energy)

Electron falls to a lower level

E2 – E1 = hf

1. **Describe how you would show the emission line spectrum of hydrogen in the laboratory.**   
   hydrogen vapour lamp [with energy source, e.g. electric current]

diffraction grating / prism

1. **Calculate its frequency.**

c =fλ

f = (3 × 108) ÷ (656 × 10–9) = 4.57 × 1014 Hz

1. **Calculate the frequency they observed.**   
   f’ = cf/(c ± u)

substitution

f’ = 4.15 × 1014 Hz

1. **Use this data to calculate a value for the radius of the orbit of the Sun about the centre of**

**the galaxy.**  
T = 2π/ω

T = 7.57 × 1015 s

v = rω

r = 2.65 × 1020 m

**9.**

1. **State Faraday’s law of electromagnetic induction.**  
   emf induced is proportional to the rate of change of [magnetic] flux
2. **State Lenz’s law. of electromagnetic induction.**  
   the direction of the induced current/emf is such that it opposes the change which caused it
3. **Describe how you would demonstrate each of these laws in the laboratory.**

means of changing magnetic flux

means of measuring induced emf

correct observation

suitable apparatus  
correct observation

1. **Calculate the magnetic flux through the coil.**   
   Φ = BA [3]

Φ = (1.5 × 10–3) × (0.2)2 = 6 × 10–5 Wb

1. **If the speed at which the coil is moved is 2.5 m s–1, calculate the emf induced in the coil.**   
   emf = –N(dΦ/dt)

t = s/v = 0.2/2.5= 0.08 s

emf = 4 × (6 × 10–5/0.08) = 0.003 V

1. **What happens in coil B when an alternating voltage is applied to coil A?**   
   voltage/current
2. **What is the purpose of a transformer?**   
   to change the (size of an alternating) voltage
3. **Describe the principle of operation of a transformer.**  
   alternating voltage in primary coil

changing magnetic field (induced in core)

[alternating] voltage induced in secondary coil

**10.**

(a)

1. **Explain, with the aid of a labelled diagram, the operation of a cathode ray tube.**

cathode and anode

cathode heated

emission of electrons at cathode   
application of electric/magnetic field (to change direction of electron beam)

screen

1. **State two of the disadvantages of cathode ray tubes that led to their replacement by flat‐screen displays.**Heat loss, size etc.

(b)

1. **What information does the photoelectric effect give about the nature of light?**   
   quantised/photonic nature of light
2. **What effect does the frequency of the incident light have on the current flowing in a photocell?**no current flows if frequency is below a certain (threshold) frequency
3. **Describe how you would show this effect in the laboratory.**   
   e.m. radiation source of varying frequency (incident on photocell)

ammeter/galvanometer

change in current detected

1. **What effect does the intensity of the incident light have on the current flowing in a photocell?**    
   current increases with intensity [above threshold frequency]
2. **Describe how you would show this effect in the laboratory.**   
   e.m. radiation source of varying intensity (e.g. distance incident on photocell)

ammeter/galvanometer

change in current detected

1. **Calculate the energy of a photon of the incident light.**  
   E = hf   
   E = (6.6 × 10–34) × (7.6 × 1014) = 5.04 × 10–19 J
2. **Calculate the energy of the most energetic electron emitted.**  
   Φ = 2.1 eV = 3.36 × 10–19 J

E = 5.04 × 10–19 – 3.36 × 10–19 = 1.68 × 10–19 J

**11.**

1. **Define potential difference.**  
   work // formula

per unit charge // notation

1. **Define resistance.**   
   voltage // formula

divided by current // notation

1. Derive an expression for the total effective resistance of resistors R1 and R2 shown in the diagram on the right.   
   IT = I1 + I2

V/RT = V/R1 + V/R2

1/RT = 1/R1 + 1/R2

1. **Describe an experiment to show how the resistance of an LDR varies with the intensity of the light falling on it.**   
   light falling on it.

apparatus

method

observation

1. **Sketch a graph to show the relationship between the resistance of an LDR and the intensity of the light falling on it.**   
   labelled axes

correct shape

1. **Calculate the total resistance of the circuit.**   
   1/1100 + 1/900 = 1/495

495 [Ω] [3]

495 + 500 = 995 Ω

1. **Calculate the current flowing through the 900 Ω resistor.**   
   12/995 = 0.012 [A]

(11/20)(0.012) = 0.0066 A

1. **Explain what happens to the potential difference across the 500 Ω resistor.**   
   potential difference across 500 Ω resistor increases because resistance of parallel section decreases

12.

Answer either part (a) or part (b).

(a)

**Explain what is meant by the following terms:**

1. **Quark**: elementary/fundamental particle [3] found in hadrons / feels strong force/ [3]
2. **Lepton**: elementary/fundamental particle does not feel strong force [3]
3. **Meson**: quark anti‐quark pair
4. **Baryon**: three quarks
5. **State the quark composition of the proton and the neutron.**

proton: up up down

neutron: up down down

1. **Why is it that the pi meson that is formed in the collision must be neutral?**   
   So that charge is conserve
2. **Assuming that the pi meson produced has a negligible speed, and that both protons have an equal speed of *v* after the collision, calculate *v*.**   
   E = mc2

mπ = 264 × 9.1 × 10–31 = 2.4 × 10–28 kg

Eπ = (2.4 × 10–28) × (3.0 × 108) = 2.16 × 10–11 J

EK = ½mv2 = (1.67 × 10–27)*v*2 = (1.67 × 10–27) × (0.5 × 3.0 × 108)2 – 2.16 × 10–11

*v* = 9.8 × 107 m s–1

1. **Name the scientist who predicted the existence of anti‐matter.**   
   Dirac

(b)

1. **Describe an experiment to demonstrate that a current‐carrying conductor experiences a force when placed in a magnetic field.**   
   apparatus

method

observation

1. **Name the parts A, B and C.**   
   A = cone

B = coil

C = magnet

1. **Explain how the moving‐coil loudspeaker emits sound.**   
   current carrying coil experience a force in magnetic field

coil moves

cone moves

1. **Draw a labelled diagram of a simple d.c. motor.**   
   magnet, coil, commutator
2. **What is the function of an electromagnetic relay and how does it carry out that function?**   
   current in one circuit switches on current in second circuit

electromagnet

pivot switch

1. **an ammeter**

low resistance

in parallel

**a voltmeter**

high resistance

in series

13.

* 1. **How do a.c. and d.c. differ?**   
     a.c. changes direction
  2. **Calculate the power of the turbine when the wind speed increases to 15 m s–1.**   
     (15 ÷ 10) = 3.375

200 × 3.375 = 675 kW

* 1. **Calculate the number of units of electrical energy generated by the turbine in that year.**   
     1 year = 8760 hours

300 × 8760 = 2628000 kW hours

* 1. **Name the term used to describe this conversion.**

rectification

* 1. **Draw the electrical circuit symbol for the semiconductor device used in this process.**   
     correct circuit symbol for a diode
  2. **Calculate the rms voltage generated.**   
     reference to √2

690 ÷ √2 = 488 V

* 1. **Calculate the rms current generated.**   
     P = VI

I = (1.5 × 106) ÷ 488 = 3074 A

* 1. **Explain why a very high voltage is required for the efficient transmission of electricity**.   
     low current

small loss in heat/energy

* 1. **State one reason why an insulator is needed in the transmission of electricity.**  
     e.g. plastic

safety

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

(a)

1. **State Hooke’s law.**   
   force proportional to // F = (–)ks

displacement // notation

1. **Calculate the elastic constant of the spring.**   
   F = ( –)ks

0.7 = k(0.06)

k = 11.7 N m–1

1. **Calculate the period of the simple harmonic motion.**   
   T = 2π/ω

ω = √(k/m)

ω = 12.8 s–1

T = 0.49 s

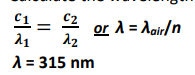
1. **maximum velocity:** at the equilibrium position, i.e. 56 cm
2. **maximum acceleration:** at a position of maximum amplitude

(b)

1. **State Snell’s law of refraction.**

sin i is proportional to sin r

1. **Calculate the refractive index of the glass for blue light.**  
   sin 40° ÷ sin 25° / sin i ÷ sin r   
   n = 1.52
2. **Calculate the speed of this light in the glass.**   
   n = c1 ÷ c2

c = 1.97 × 108 m s–1

1. **Calculate the wavelength of this light in the glass.**   
   or λ = λair/n

λ = 315 nm

1. **Explain why this is happens.**

red light has a different refractive index / red light has a different velocity in the block / red light has a different wavelength in the block

(c)

1. **What is a capacitor?**    
   a device that stores charge / separates charge
2. **Define the unit of capacitance, i.e. the farad.**   
   coulomb per volt
3. **Calculate the charge on plate A.**  
   Q = (3 × 10–6) × 6 = (+)1.8 × 10–5 C
4. **Calculate the charge on plate B.**   
   Q = –1.8 × 10–5 C
5. **Calculate the energy stored in the capacitor.**   
   E = ½CV2 = 5.4 × 10–5 J
6. **Calculate the charge that is now on plate A.**  
   [+]1.8 × 10–5 C
7. **Calculate the charge that is now on plate B.**  
   –1.8 × 10–5 C
8. **Calculate the charge that is now on plate X.**

[+]1.2 × 10–5 C

1. **Calculate the charge that is now on plate Y.**

[-]1.2 × 10–5 C

1. **Calculate the capacitance of a single capacitor**   
   Q = 3 × 10–5 C  
   5 µF

(d)

1. **What is meant by nuclear fission**?   
   the splitting of a large nucleus into two smaller nuclei [with the release of neutrons/energy]
2. **Is this a spontaneous nuclear reaction or an induced nuclear reaction?**  
   induced
3. **What numbers or symbols do X, Y and Z represent in the above equation?**   
   X = 36

Y = n

Z = Ba

1. **Calculate the number of atoms of krypton–89 in a sample of the isotope that emits 2.0 × 105 beta particles per second.**   
   A = λN

N = (2.0 × 105 ÷ (3.67 × 10–3) = 5.45 × 107 atoms

1. **What is the half‐life of krypton–89?**  
   T½ = (ln 2)/λ

T½ = 188.9 s