2014 Leaving Cert Physics Solutions (Higher Level)

2014 Question 1

(i) **Draw a labelled diagram of the apparatus used in the experiment.**
Two bodies and track
Labelled means of attaching the two bodies
Timer / motion sensor

(ii) **State what measurements the student took and how these measurements were used to calculate the velocities.**
Measurements: masses
Time for n gaps // time for body to pass through light gate // approp. time
Length of n gaps // length of (card)body // approp. distance
Calculate: distance ÷ time // appropriate slope = velocity

(iii) **Using the recorded data, show how the experiment verifies the principle of conservation of momentum.**
$0.3251 \times 0.84 = 0.273$ kg m s^{-1}
$(0.3251 + 0.3498) \times 0.41 = 0.277$ kg m s^{-1}
0.273 kg m s^{-1} ≈ 0.277 kg m s^{-1}/ or equivalent

(iv) **When carrying out this experiment the student ensures that there is no net external force acting on the bodies.**
What are the two forces that the student needs to take account of to ensure this?
weight (gravitational force)
friction

(v) **Describe how the student reduced the effects of these forces.**
horizontal (air)track / cushion of air / (small) slope / polish runway / oil wheels

2014 Question 2

(i) **One of the recorded angles of refraction is inconsistent with the others. Which one?**
23^0

(ii) **Describe, with the aid of a labelled diagram, how the student found the angle of refraction.**
rectangular block
pins / ray box / laser *(–1 if no label)*
correct incident, normal and refracted rays drawn
angle of refraction indicated
protractor / trigonometry

(iii) **Calculate a value for the refractive index of the substance by drawing a suitable graph based on the recorded data.**
sin *i* and sin *r* calculated
axes labelled
6 points plotted
straight line with good fit
method for finding slope
slope = n ≈ 1.44

Sin i	0.34	0.50	0.64	0.77	0.87	0.94	0.98
Sin r	0.23	0.34	0.45	0.39	0.59	0.64	0.68

(iv) **Give two reasons for this.**
outliers can be identified / slope gives weighted mean / reference to origin / reference to Tan θ

2014 Question 3

(i) **Draw a labelled diagram of the apparatus used in the experiment.**
(Vibrating) tuning fork
Column of air
Means of changing length of column / metre stick and callipers

(ii) **Describe how the first position of resonance was found.**
hold (vibrating) fork over column
Increase length of column (from zero)
Until (loudest) sound is heard (from column)

(iii) **Using the recorded data, calculate the speed of sound in air.**
$v = 4f(l + 0.3d)$
$v = 4f(0.16545)$
$v = 338.8 \text{ m s}^{-1}$

(iv) **Why was it necessary to measure the diameter of the air column?**
Because the wave exists partially above the top of the tube

(v) **Explain how this second student would find the speed of sound in air.**
find distance between first two positions of resonance / $l_2 - l_1$
double this distance for wavelength / $\lambda = 2 (l_2 - l_1)$
Multiply wavelength by frequency (for speed) / $(v =) f\lambda$

2014 Question 4

(i) **Draw a labelled diagram of the apparatus used in the experiment.**
coil in water
Power supply *or* battery with variable resistor, ammeter
Thermometer
Correct circuit diagram

(ii) **Draw a suitable graph to verify Joule's law.**
six I^2 values calculated
axes labelled
6 points plotted
straight line with good fit

I^2 (A^2)	1	2.25	4	6.25	9	12.25
$\Delta\Theta$ (K)	2.0	4.5	8.5	14.0	18.5	25.5

(iii) **Explain how the graph verifies Joule's law.**
straight line through origin / I^2 proportional to rise in temperature / P proportional to I^2

(iv) **Use your graph to estimate the highest temperature of the water when a current of 1.6 A flows through the coil for 4 minutes.**
$I^2 = 2.56$
highest temperature ≈ 25.3 °C

(v) **Explain why a fixed mass of water was used.**
(power required for) temperature rise is proportional to mass / otherwise there would be too many variables

2014 Question 5

(i) **State Boyle's law.**
Pressure and volume inversely proportional for a fixed mass of gas at constant temperature

(ii) **Calculate the mass of Mars.**

$T^2 = \frac{4\pi^2 R^3}{GM}$ $\quad M = \frac{4\pi^2 R^3}{GT^2}$ $\quad M = \frac{4\pi^2(9.4 \times 10^6)^3}{(6.7 \text{ x } 10^{-11})(43200)^2}$ $\quad$ M = 6.57×10^{23} kg

(iii) On what thermometric properties are the following based:
(i) the thermocouple thermometer and (*ii*) the mercury-in-glass thermometer?
(i) emf; (ii) length/height/volume

(iv) **How much energy is lost?**
The clue is in the unit. The U-value is 2.8 W m^{-2} K^{-1}. That means 2.8 Joules are lost every second per square meter for every one degree of a temperature difference.
We are interested in the heat lost through *3 m^2*, over a period of *one hour* when the temperature difference is *9°*.
So total heat lost = 2.8 × 60 × 60 × 3 × 9 = 272160 J

(v) **List a pair of complementary colours of light.**
red and cyan / green and magenta / blue and yellow

(vi) **What are the charge carriers in (*i*) semiconductors and (*ii*) metals?**
(i) electrons and holes; (ii) electrons

(vii) **What do the letters in the acronyms (*i*) RCD and (*ii*) MCB stand for?**
residual current device; miniature circuit breaker

(viii) **Calculate the maximum kinetic energy**
Energy of incident photon = Work function + kinetic energy of electron
5.85 eV = 4.50 eV + kinetic energy of electron

Kinetic energy of electron = 1.35 eV
1 eV = 1.6×10^{-19} J
So 1.35 eV = (1.35)(1.6×10^{-19}) = 2.16×10^{-19} J

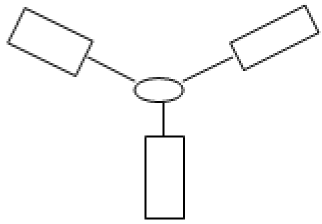
(ix) **Describe Rutherford's model of the atom.**
mostly empty space / dense core / positive core / electron cloud *(any two)*

(x) **Give two reasons why the Cockcroft and Walton experiment was significant to the understanding of particle physics**
first experimental verification of $E = mc^2$ / first transmutation using artificially accelerated particles / first artificial splitting of a nucleus / development of linear accelerator
or
Describe how a galvanometer may be converted into a voltmeter.
Connect a large resistor / multiplier in series

2014 Question 6

(i) **Compare vector and scalar quantities.**
Give one example of each.
Vectors have direction (and scalars have no direction)
Vector: velocity, displacement, force
Scalar: speed, distance, mass

(ii) **Describe an experiment to find the resultant of two vectors.**



- Attach three newton-balances to a knot in a piece of thread.
- Adjust the size and direction of the three forces until the knot in the thread remains at rest.
- Read the forces and note the angles.
- Resolve any two of the forces along the axis of the third force
- Conclusion
  The sum of the components of any two of the forces along the axis of the third force can now be shown to be equal in magnitude but opposite in direction to the third force.

(iii) **Calculate the net force acting on the trolley and bag.**
Net force in the horizontal direction = $F_{forward}$ - $F_{backward}$
Forward force = horizontal force applied by golfer = 277 Cos 24.53° ≈ 252 N
Backward force = force of friction = 252 N
Net force in horizontal direction ≈ 0 N

Net force in the vertical direction = F_{up} - F_{down}
Force up = vertical force applied by golfer = 277 Sin24.53° ≈ 115 N
Force down = weight of trolley and bag = 115 N
Net force in vertical direction ≈ 0 N

{there was a blooper in this question. Going by these numbers there can't be any reaction force between the ground and the cart. And if there's no reaction force then there can't be any friction. But we conveniently ignore this f#*kup.}

(iv) **What does the net force tell you about the golfer's motion?**
The golfer is travelling at constant speed

(v) **Use Newton's second law of motion to derive an equation relating force, mass and acceleration.**
F proportional to (mv – mu)/t

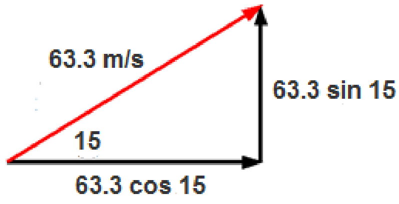
$F \propto ma$
F = kma
k = 1 (by definition of the newton)
F = ma

(vi) **Calculate the speed of the ball as it leaves the club.**
There are a number of ways to do this. The following isn't necessarily the shortest, but it might be the most familiar: we can use $v = u + at$, but first we need to work out the acceleration.
To do this we use $F = ma$
$5300 = .045\ a$
$a = 117777.8$ m s^{-1}
Now use $v = u + at$
$v = 0 + (117777.8)\ (0.54 \times 10^{-3})$
$v = 63.6$ m s^{-1}

(vii) **Calculate the maximum height reached by the ball.**

First we need to calculate the initial velocity of the ball in the vertical direction:

$u_y = u \sin\Theta = 63.3 \sin 15^0 = 16.46 \text{ m s}^{-1}$



Now we can use $v^2 = u^2 + 2as$

$0 = (16.46)^2 + 2(-9.8)s$

height = 13.82 m

OR you could have used: $\frac{1}{2}mv^2 = mgh$

2014 Question 7

(i) **What is meant by the terms (*i*) diffraction and (*ii*) interference?**

(i) the spreading of a wave into the space beyond a barrier/obstacle/gap

(ii) the addition/(meeting) of two or more waves (to form a new wave)

(ii) **Calculate the energy of each photon in the laser beam.**

E = hf

We don't know the frequency but we do know the wavelength, so we can use $c = f\lambda$

E = $h\frac{c}{\lambda}$

E = $\frac{(6.6\times10^{-34})(3\times10^{8})}{709\times10^{-9}}$

E = 2.8×10^{-19} J

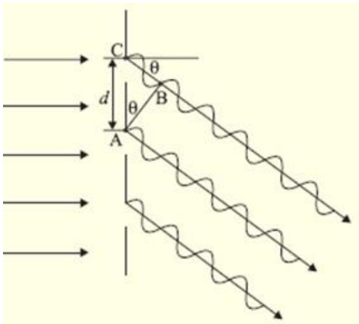
(iii) **Where in the eye are these sensors located?**

retina

(iv) **State two differences between . . .**

laser has one frequency/wavelength only / laser light is more powerful / laser light is coherent / laser light is collimated

(v) **Derive, with the aid of a labelled diagram, 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**

(vi) **Calculate the number of lines per millimetre on the grating used in the experiment.**

nλ = d Sinθ

$\Rightarrow\ d = \frac{n\lambda}{\sin\theta}$

$$d = \frac{(2)(709 \times 10^{-9})}{\sin 34.6}$$

d = 0.000002497 m

Now if a grating has n lines per m $\Rightarrow$ **d =** $\boldsymbol{\frac{1}{n}}$ **metres**

$\Rightarrow$ n = $\boldsymbol{\frac{1}{d}}$

$\Rightarrow$ n = $\frac{1}{0.000002497}$

$\Rightarrow$ 400000 lines per m

$\Rightarrow$ 400 lines per mm

(vii) **What would be observed on the screen if the laser was replaced by a ray of white light?**

Spectra

2014 Question 8

(i) **Explain the underlined terms.**

A chain reaction is a self-sustaining reaction where fission neutrons go on to produce further fission (giving more neutrons) etc.

Fission is the splitting of a large nucleus into two (smaller) nuclei with the release of energy and neutrons.

(ii) **Give an example of a moderator.**

graphite / heavy water

(iii) **Explain why a moderator is needed in a nuclear reactor**

To slow down neutrons so as to increase the probability of fission.

(iv) **Explain how the control rods affect the rate of the reaction.**

By absorbing neutrons

(v) **Explain how the heat exchanger operates.**

Heat/energy from reactor transfers to a coolant which has a very high boiling point. Heat from the hot radioactive coolant passes to another series of pipes containing water without having to mix together. This turns the water into steam which then goes on to power a turbine.

(vi) **Why is it necessary to use a heat exchanger?**

So that the radioactive coolant can be contained, and it also allows very high temperatures to be obtained.

(vii) Write an equation for this nuclear reaction.

$$U_{92}^{238} + n_0^1 \rightarrow Pu_{94}^{239} + 2\beta_{-1}^0$$

(viii) **How many uranium–235 nuclei are required to undergo fission to generate a constant electric power of 1 GW for a day?**

Each nucleus that underdoes fission produces (202×10^6) eV of energy, or

$(202 \times 10^6)(1.6 \times 10^{-19}) = 3.23 \times 10^{-11}$ *Joules* of energy. {1 eV = 1.6×10^{-19} J}

Efficiency is 35%, so 35% of 3.23×10^{-11} J = 1.13×10^{-11} J

1GW = 1×10^9 W = 1×10^9 Joules per second {1 Watt = 1 Joule per second}

1 GW for a day = $(1\times 10^9)(60)(60)(24)$ Joules

= 8.64×10^{13} J

So we need 8.64×10^{13}J, and each nucleus produces 1.13×10^{-11} J of useable energy.

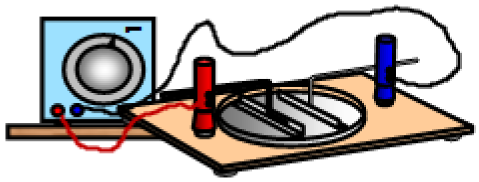
So total number of nuclei required = $\frac{8.64 \times 10^{13}}{1.13 \times 10^{-11}}$ = 7.65×10^{24} nuclei

2014 Question 9

(i) **Explain the underlined terms.**

Capacitance is the ratio of charge (on a capacitor) to the potential difference across it.
An electric field is a region (of space) where electrostatic forces are experienced / forces experienced by charged particles

(ii) **Describe an experiment to demonstrate an electric field pattern.**



1. Place two electrodes in a petri-dish.
2. Pour some oil into the petri-dish and sprinkle on some semolina powder.
3. Connect a high voltage source (about 2,000 volts) to the metal electrodes.
4. Result: The semolina lines up in the direction of the field, showing the electric field.

(iii) **Calculate the charge on each plate**

$C = \frac{Q}{V}$

$Q = CV = (12\times10^{-6})(6) = 72 \times10^{-6}$ C

(iv) **Calculate the energy stored in the capacitor.**

$E = \frac{1}{2}CV^2 = \frac{1}{2}(12\times10^{-6})(6)^2 = 216 \times10^{-6}$ J

(v) **Calculate the new capacitance.**

$C \propto \frac{1}{d}$

So if the distance increases by a factor of 3 then the capacitance decreases by a factor of 3.
So new capacitance is 3 times smaller = 4 μF

(vi) **State two differences between a capacitor and a battery.**

Capacitor discharges faster than a battery / capacitor stores (electrostatic) potential energy while a battery stores chemical energy / battery gives a constant current / battery stores more energy
{I would have struggled to give anything beyond the first one}

(vii) **Touchscreens also contain two polarising filters. What is meant by polarisation of light?**

Vibration of a wave is in one plane only.

(viii) **Give one application of capacitors, other than in touchscreens.**

e.g. flash of a camera / tuning circuits / defibrillator

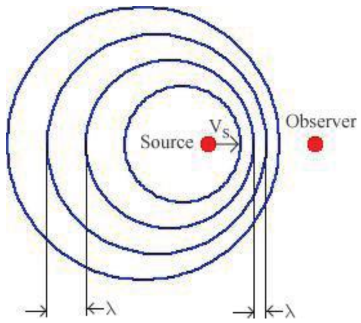
2014 Question 10

(i) **What is the Doppler effect?**

The (apparent) change in the frequency (of a wave) due to the relative motion between the source (of the wave) and the observer

(ii) **Explain, with the aid of labelled diagrams, how the Doppler effect occurs.**

The circles represent the crests of sound waves emitted from the source.
In this case the source is moving to the right while emitting the waves.



The result is that:

1. Ahead of the moving source, the crests are closer together than crests from a stationary source would be. This means that the wavelength is smaller and the frequency is greater.
2. Behind the moving source, the crests are further apart than crests from the stationery source would be.
3. This means the wavelengths are greater and therefore the frequency is less.

(iii) **What is the speed of the ambulance?**

f' = 820 Hz
f = 750 Hz
c = 340 m s^{-1}
The ambulance is travelling towards an observer, therefore we use the 'minus' in the formula.

$$f' = \frac{fc}{c-u}$$

$$820 = \frac{(750)(340)}{340-u}$$

$$820(340-u) = 255000$$

$$278800 - 820u = 255000$$

$$278800 - 255000 = 820u$$

$$23800 = 820u$$

u = 29 m s^{-1}

(iv) **State two other practical applications of the Doppler effect.**

e.g. police "speed guns" / measuring velocities of stars / ultrasound (scan) / landing aircraft / weather forecasting

(v) **How would an observer know that a Wheatstone bridge is balanced?**

zero reading on / no deflection of / no current flowing through galvanometer

(vi) **What is the resistance of the unknown resistor?**

The formula for a balanced Wheatstone bridge is as follows:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

$$\frac{5.1}{R_2} = \frac{11.9}{40.5}$$

$R_2 = \frac{(5.1)(40.5)}{11.9}$
$R_2 = 17.36\ \Omega$

(vii) **Write an expression for the resistance of a wire in terms of its resistivity, length and diameter.**

$R = \frac{\rho l}{A}$

$A = \pi r^2$ or in terms of diameter $A = \pi\frac{d^2}{4}$

$\Rightarrow R = \frac{4\rho l}{\pi d^2}$

(viii) **The radius of a wire is doubled. What is the effect of this on the resistance of the wire?**

$R \propto \frac{1}{d^2}$

$\Rightarrow$ if the radius (or the diameter) goes up by a factor of 2, then the resistance goes down by a factor of 4.

2014 Question 11 (*a*)

(i) **List the three fundamental forces that electrons experience in increasing order of strength.**
gravitational, weak (nuclear) and electromagnetic

(ii) **Write an equation to represent the pair annihilation described in the text.**

$$e^- + e^+ \rightarrow 2hf$$

OR

$${}^{0}_{-1}e + {}^{0}_{+1}e \rightarrow 2\gamma$$

(iii) **Calculate the frequency of each photon produced in this pair annihilation.**
Mass of electron = $9.1093826 \times 10^{-31}$ kg
Energy 'released' when one electron is annihilated = mc^2
We only need to look at one electron because two electrons are annihilated to produce two photons, so it's as if one electron is responsible for producing one photon.
E = $(9.1093826 \times 10^{-31})(3 \times 10^{8})^2$
E = 8.198444×10^{-14} J

This energy now goes on to create a photon
Energy associated with a photon = hf

$$f = \frac{E}{h} = \frac{8.198444 \times 10^{-14}}{6.6260692 \times 10^{-24}}$$

f = 1.237×10^{20} Hz

(iv) **Why do the photons produced in pair annihilation travel in opposite directions?**
momentum is conserved

(v) A carbon–11 nucleus, which has a half-life of twenty minutes, decays with the emission of a positron.
Write a nuclear equation to represent the decay of carbon–11.
{This is the first time we have come across what is known as *beta-positive decay*, where instead of a neutron decaying into a proton plus electron (beta-minus decay), we have a proton decaying into a neutron plus a positron. Physicists must have done some serious head-scratching the day that baby was born}

$$c_6^{11} \rightarrow B_5^{11} + e_1^0$$

(vi) **What is the value of the decay constant of carbon–11?**

$T_{1/2} = \frac{\ln 2}{\lambda}$

$\lambda = \frac{\ln 2}{T_{1/2}}$

Half-life is 20 minutes = (20)(60) = 1200 seconds

$\lambda = \frac{\ln 2 0.693}{1200}$

$\lambda = 0.000578\ s^{-1}$

(vii) **Explain why . . .**
Because of their short half-life - too many would have decayed before they could be used.

(viii) **Give an expression . . .**
The word 'radius' is the clue that tells us we're talking about a centripetal force, the term 'magnetic flux density' is the clue that tells us that we're talking about a magnetic force.
Equate the expression for both and rearrange so that we get *mv* (momentum) on one side:

Centripetal force = magnetic force

$$\frac{mv^2}{r} = Bqv$$

Cancel one v on both sides and multiply both sides by r to get rid of the r on the left hand side.

$\Rightarrow \quad mv = Bqr$

2014 Question 11 *(b)*

(i) **Draw a labelled diagram to show the basic structure of a transistor.**
npn / pnp layers (4)
collector, base and emitter all shown correctly

(ii) **State the relationship between the three currents flowing in a transistor.**
$I_e = I_b + I_c$

(iii) **Draw a circuit diagram for a voltage amplifier.**
transistor and resistor in series
complete circuit with input and output voltages indicated

(iv) **Draw the symbol and truth table for an AND gate.**
correct symbol
correct table

(v) **Give two ways in which the operation of a photodiode differs from that of an LED.**
Photodiode requires light to allow current to flow, LED produces light when a current flows / photodiode is in reverse bias, LED is in forward bias / photodiode does not need a protective resistor, LED does

(vi) **What event inside an LED causes the release of a photon?**
electron drops to a lower energy level (combines with a hole)

(vii) **Explain, with the aid of a labelled diagram, how a ray of light is guided along an optical fibre.**
angle of incidence greater than critical angle / total internal reflection more than once on diagram

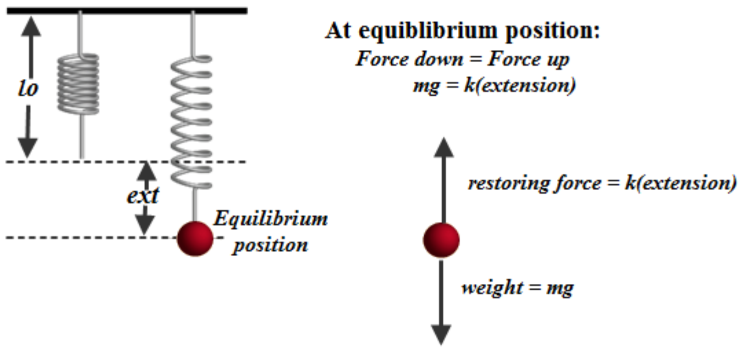
(viii) **Give an expression . . .**
$\text{Sin } C = c_{glass}/c_{air}$
$C = \text{Sin}^{-1}(c_{glass}/c_{air})$

2014 Question 12 (a)

(i) **State Hooke's law.**

Hooke's Law states that when an object is stretched the restoring force is directly proportional to the displacement, provided the elastic limit is not exceeded.

(ii) **What is the new length of the spring?**



$k = 12\ \mathrm{N\ m^{-1}}$

$l_0 = 25\ \mathrm{mm} = 0.025\ \mathrm{m}$

$m = 0.02\ \mathrm{kg}$

After the mass has been attached it will come to rest at a new equilibrium position (E.P.) where
force down = force up
force down = mg = 0.02g
force up = k(extension)

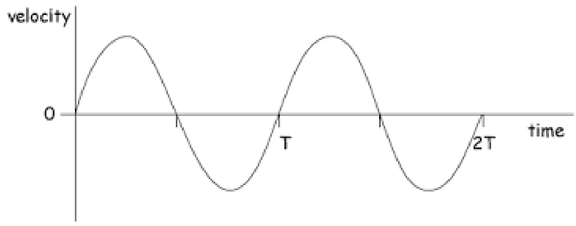
force down = force up

$0.02g = 12(ext)$

$ext = 0.0163\ \mathrm{m}$

New length = 0.025 + 0.0163 = 0.0413 m

(iii) **Sketch a velocity-time graph of the motion of the object.**



(iv) **Calculate the period of oscillation of the object.**

$T = \frac{2\pi}{\omega}$, so first we need to calculate ω.

$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{12}{0.02}}$$

$\omega = 24.5$

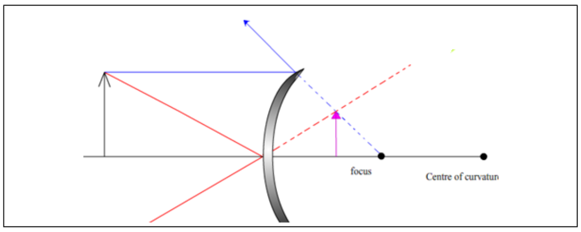
$$T = \frac{2\pi}{\omega} = \frac{2\pi}{24.5}$$

T = 0.256 s

2014 Question 12 (b)

(i) **What is reflection?**
Reflection is the bouncing of light off a surface.

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



(iii) **Find the position of the image.**

Note that the focus is half-way between the centre of curvature and the mirror.
The diameter of the decoration is 20 cm. Therefore the radius is 10 cm. Therefore the centre of curvature is 10 cm from the mirror. Therefore f = 5 cm.

Note also that we make $\frac{1}{f}$ negative to represent the fact that we are dealing with a *convex* mirror.

$$-\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$-\frac{1}{5} = \frac{1}{30} + \frac{1}{v}$$

$$-\frac{1}{5} - \frac{1}{30} = \frac{1}{v}$$

$$-\frac{7}{30} = \frac{1}{v}$$

$v = -\frac{30}{7}$ = - 4.3 cm (the negative sign indicates that the image is virtual and is formed behind the mirror)

(iv) **Concave mirrors, rather than convex mirrors, are used by dentists to examine teeth. Explain why.**
To give a magnified image

2014 Question 12 (c)

(i) **Define specific latent heat.**
This is the heat needed to change the state of 1 kg of a substance without a change in temperature.

(i) **Calculate the mass of the ice.**
$Density = \frac{mass}{volume}$
Mass of one cube of ice = (density)(volume)
Mass of one cube of ice = (0.92 g cm^{-3})(2.5×2.5×2.5) cm^3
Mass of one cube of ice = 14.375 g
Mass of *three* cubes of ice = 43.125 g

(ii) **Calculate the minimum temperature of the water when the ice has melted.**
Heat gained by the ice = heat lost by the water

The ice gains heat in three stages
Ice heating from –20 °C to 0 °C
Ice changing state (to water)
Melted ice (which is now water – obviously) heating up from 0 °C to some final temperature of the system T.

Heat lost by the water = mcΔθ, where Δθ is the difference between the initial temperature of the water (which was 24 °C) and the final temperature of the system T.
So Δθ = (24 – T)

$$m_{ice}c_{ice}\Delta\theta_1 + m_{ice}l_{ice} + m_{ice}c_{water}\Delta\theta_2 = m_{water}c_{water}\Delta\theta_3$$

$$(0.043125)(2100)(20) + (0.043125)(3.3\times10^5) + (0.043125)(4200)(T) = (0.5 \times 4200 \times (24 - T))$$

$$1811.25 + 14231.25 + 181.125T = 50400 - 2100T$$

$$2281.125T = 34357.5$$

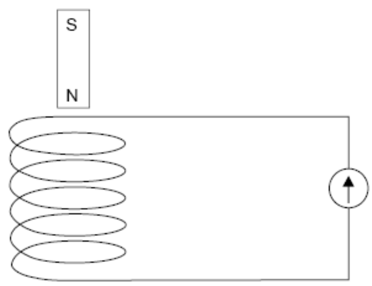
$$T = 15.06\ °C$$

2014 Question 12 (d)

(i) **State Faraday's law of electromagnetic induction.**
The size of the induced emf is proportional to the rate of change of flux.

(ii) **Describe an experiment to demonstrate Faraday's law.**

- Move the magnet in and out of the coil slowly and note a slight deflection.
- Move the magnet quickly and note a greater deflection.



(iii) **Explain why.**
The falling magnet creates a changing magnetic flux in both tubes.
An emf is therefore induced in both tubes.
But current flows in only the copper tube because this is the only material that is a conductor.
This induced current generates a magnetic field which opposes the motion of the falling magnet.