**2006 Leaving Cert Physics Solutions (Higher Level)**

1

In investigating the relationship between the period and the length of a simple pendulum, a pendulum was set up so that it could swing freely about a fixed point.

The length l of the pendulum and the time t taken for 25 oscillations were recorded.

This procedure was repeated for different values of the length.

The table shows the recorded data.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| l/cm | 40.0 | 50.0 | 60.0 | 70.0 | 80.0 | 90.0 | 100.0 |
| t/s | 31.3 | 35.4 | 39.1 | 43.0 | 45.5 | 48.2 | 50.1 |

The pendulum used consisted of a small heavy bob attached to a length of inextensible string.

1. **Explain why a small heavy bob was used.**

To reduce air resistance and to keep the string taut

1. **Explain why the string was inextensible.**

So that length remains constant because length would be another variable.

1. **Describe how the pendulum was set up so that it swung freely about a fixed point.**

The string was placed between two coins (or a split cork).

1. **Give one other precaution taken when allowing the pendulum to swing.**

Make sure that there are no draughts / make sure it oscillates in one plane only.

1. **Draw a suitable graph to investigate the relationship between the period of the simple pendulum and its length.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Time for 25 swings* /s | 31.3 | 35.4 | 39.1 | 43.0 | 45.5 | 48.2 |
| *T*/s | 1.25 | 1.42 | 1.56 | 1.72 | 1.82 | 1.93 |
| *T2/*s*2* | 1.57 | 2.01 | 2.45 | 2.96 | 3.31 | 3.72 |
| *l*/m | .40 | .50 | .60 | .70 | .80 | .90 |

Values of *t* divided by 25 to get *T*

Axes correctly labelled *T2*vs. *l*

At least six points plotted correctly

Straight line drawn

Good distribution (about straight line)

1. **What is this relationship?**

T2 is proportional to l

1. **Justify your answer.**

The graph resulted in a straight line through the origin

2

In an experiment to measure the wavelength of monochromatic light, a narrow beam of the light fell normally on a diffraction grating. The grating had 300 lines per millimetre. A diffraction pattern was produced. The angle between the second order image to the left and the second order image to the right of the central bright image in the pattern was measured.

The angle measured was 40.60.

1. **Describe, with the aid of a labelled diagram, how the data was obtained.**

The apparatus was set up as shown.

To get a value for θ the distance x was measured between the centre image and the second order image, then the distance D between grating and screen was measured.

θ = Tan-1 (x/D)

We did the same for the other side and got an average value for θ.

1. **How was a narrow beam of light produced?**

Use a laser.

1. **Use the data to calculate the wavelength of the monochromatic light.**

nλ = d sin θ

n = 2

d = 1/(3.00 x105) m = 3.33 x 10-6 m = 3.33 x 10-3 cm = 1/300 mm

θ = 20.30

λ = 5.78 x 10-7 m (= 578 ≈ 580 nm)

1. **Explain how using a diffraction grating of 500 lines per mm leads to a more accurate result.**

This would result in a greater angle for each order image and therefore a smaller percentage error in measuring the angle.

1. **Give another way of improving the accuracy of this experiment.**

Repeat and get average value for the wavelength , repeat for higher orders.

3

A cylindrical column of air closed at one end and three different tuning forks were used in an experiment to measure the speed of sound in air. A tuning fork of frequency f was set vibrating and held over the column of air.

The length of the column of air was adjusted until it was vibrating at its first harmonic and its length l was then measured. This procedure was repeated for each tuning fork.

Finally, the diameter of the column of air was measured.

|  |  |  |  |
| --- | --- | --- | --- |
| f/Hz | 512 | 480 | 426 |
| l/cm | 16.0 | 17.2 | 19.4 |

The following data was recorded.

Diameter of column of air = 2.05 cm

1. **Describe how the length of the column of air was adjusted.**

The inner pipe was raised while immersed in water.

1. **Describe how the frequency of the column of air was measured.**

The frequency was read from the tuning fork which caused the vibration.

1. **Describe how the diameter of the column of air was measured.**

Using a digital calipers

1. **How was it known that the air column was vibrating at its first harmonic?**

The inner tube was raised until a loud sound could be heard.

1. **Using all of the data, calculate the speed of sound in air.**

*v* = *f λ*

*λ* = 4( *l* +0.3 *d*)

*v1* = 340(.3) m s-1; *v2* = 342(.0) m s-1 ; *v3* = 341(.1) m s-1  
*v*ave = 341(.13) ms-1

 4

In an experiment to verify Joule’s law a student passed a current through a heating coil in a calorimeter containing a fixed mass of water and measured the rise in temperature Δθ for a series of different values of the current I. The student allowed the current to flow for three minutes in each case.

1. **Describe, with the aid of a labelled diagram, how the student arranged the apparatus.**

****See diagram.

1. **Why was a fixed mass of water used throughout the experiment?**

The mass of water would be a third variable and you can only investigate the relationship between two variables at a time.

1. **The student drew a graph, as shown. Explain how this graph verifies Joule’s law.**

Straight line graph through origin  Δθ α I2   P α I2

1. **Given that the mass of water in the calorimeter was 90 g in each case, and assuming that all of the electrical energy supplied was absorbed by the water, use the graph to determine the resistance of the heating coil.**

**The specific heat capacity of water is 4200 J kg–1 K–1.**

Electrical energy in = Heat energy out

RI2 t = mcΔθ

Rt = mc(Δθ/ I2)  Rt = mc(slope)  R = mc(slope)/t = (.09)(4200)(3.8)/180

*R* = (7.8 ↔ 8.2) Ω

**2006 Question 5**

1. **State Newton’s third law of motion.**

Newton’s third law of motion states that if object A exerts a force on object B, B exerts a force on A which is equal in magnitude but opposite in direction.

1. **Why is it easier to turn a nut using a longer spanner than a shorter one?**

The distance from the fulcrum is greater therefore there is a greater turning effect.

1. **The average value for the solar constant in Ireland is 1.2 × 102 W m–2.   
   What is the average energy falling normally on an area of 5 m2 of ground in Ireland in 1 minute?**

Energy per minute on 5 m2 = energy *per second* on *1 m2* multiplied by the number of seconds, multiplied by the number of m2.

= (1.2 x 102)(60)(5) = 36,000 J

1. **A sound wave is diffracted as it passes through a doorway but a light wave is not. Explain why.**

For diffraction to occur the gap needs to be approximately the same width as the wavelength.

The width of a doorway is approximately the same as the wavelength of sound, but the wavelength of light is much, much smaller.

1. **What is the Doppler effect?**

The Doppler effectis the apparent change in the frequency of a wave due to the relative motion between the source of the wave and the observer.

1. **An RCD is rated 30 mA. Explain the significance of this current.**

The RCD trips the circuit at 30 mA or greater .

1. **Why is Coulomb’s law an example of the inverse square law?**

Because force is inversely proportional to distance squared.

1. **Sketch a graph to show the variation of current with potential difference for a semiconductor diode in forward bias.**

See diagram

1. **Describe the Bohr model of the atom.**

A dense positively-charged nucleus with the negatively-charged electrons in orbit at discrete levels around it.

1. **Name the three negatively charged leptons.**

*{See page 48 of the log tables}* Electron (*e*) , muon (*μ*), tau (*τ* )

**2006 Question 6**

1. **Define velocity.**

Velocity is the rate of change of displacement with respect to time.

1. **Define angular velocity.**

Angular velocity is the rate of change of angle with respect to time.

1. **Derive the relationship between the velocity of a particle travelling in uniform circular motion and its angular velocity.**

{divide both sides by *t*}

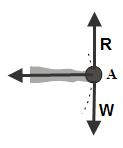
but = ω and = *v*

ω =  *v = rω*

1. **What is the velocity of the ball?**

v = rω = (0.70)(10) = 7.0 m s-1

1. **How long does the ball take to complete one revolution?**

   
*{the distance corresponds to the circumference of the circle = 2πr}*

time = 0.63 s

1. **Draw a diagram to show the forces acting on the ball when it is at position A.**

Weight (W) downwards; reaction (R) upwards; force to left (due to friction or curled fingers)

1. **Calculate the maximum height, above the ground, the ball will reach.**

*v*2 = *u*2+ 2*as*  0 = (7)2 + 2(-9.8)*s*  *s* = 2.50 m max. height = 2.5 + 1.30 = 3.8 m

1. **Calculate the time taken for the ball to hit the ground after its release from A.**

Time to go from point A to max. height: {Use *v* = *u* + *at}*  0 = 7-(9.8)*t*  *t* =0.71 s

Time to go from max. height to ground: {Use *s* = *ut* + 1/2 *at2* } 3.8 = 0(*t*) + 4.9*t*2  *t* = 0.88 s

Total time = 0.71 + 0.88 = 1.59 s

*Alternative method*:

*{When it hits the ground it has ended up 1.3 m below where it started, so s =* ***-****1.3m}*

s = ut + ½ at2-1.30 = 7t – ½ (9.8)t2  4.9t2-7t -1.3 = 0

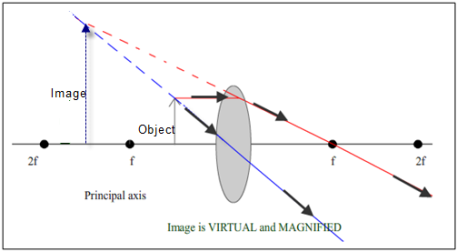
Use where a=4.9, b=-7, c=-1.3t = 1.59 s

**2006 Question 7**

1. **What is meant by the refraction of light?**

Refraction is the bending of light as it passes from one medium to another.

1. **Draw a ray diagram to show how an erect image is formed by a magnifying glass.**

See diagram

1. **Explain why.**

The image is always diminished.

1. **Determine the two positions that an object can be placed to produce an image that is four times the size of the object?**

The image is 4 times the size of the object  M =4 *v*=4*u*

   4*u* = 40   
*u* =10 cm

*{The other way an image could be formed is if the object is inside the focus.*

*This would result in a* ***virtual*** *image, and we represent this mathematically by making v* ***negative****.}*

   4*u* = 24   
*u* =6 cm

*{Note that our value for u is less than the value for f, implying that the object is inside the focus, as we would expect.}*

1. **Calculate the focal length of the lens required to correct this defect.**

PTotal = P1 + P2  PCorrected lens = Pdefective lens + Pcorrective lens

60 = 64 + P2  P2 = -4 m-1

*f* = 0.25 m

1. **What type of lens is used?**

Diverging / concave lens

1. **Name the defect.**

Short sight / myopia

**2006 Question 8**

1. **Distinguish between fission and fusion.**

Nuclear fission is the break-up of a large nucleus into two smaller nuclei with the release of energy and neutrons.

Nuclear fusion is the combining of two small nuclei to form one large nucleus with the release of energy.

1. **The core of our sun is extremely hot and acts as a fusion reactor.**

**Why are large temperatures required for fusion to occur?**

Nuclei are positively charged so enormous energy is required to overcome the very large repulsion.

1. **Write an equation for this nuclear reaction.**

→

1. **What condition is necessary for this reaction to take place on earth?**

Very large energy/temperature is necessary.

1. **Calculate the energy released during this reaction.**

Mass beforehand = mass of hydrogen-2 nucleus + mass of hydrogen-3 nucleus

= 3.342 × 10–27 kg + 5.004 × 10–27 kg

= 8.346 x 10-27 kg

Mass after = mass of helium nucleus + mass of neutron

= 6.644 × 10–27 kg + 1.674 × 10–27 kg

= 8.318 × 10-27 kg

Loss in mass /defect mass = (8.346 x 10-27) – (8.318 × 10-27) = 2.8 × 10-29 kg

*E* = *mc*2 E = (2.8 × 10-29)( 2.998 × 108)2 E = 2.52 × 10-12 J

1. **Give one benefit of a terrestrial fusion reactor under each of the following headings:**
   1. fuel; (b) energy; (c) pollution.

Fuel: plentiful / cheap

Energy: vast energy released

Pollution: little (radioactive) waste / few greenhouse gases

1. **Question 9**
2. **What is an electric current?**

An electric current is a flow of charge.

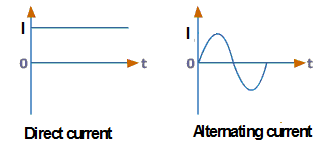
1. **Define the ampere, the SI unit of current.**

The ampere is the amount of charge which, if flowing in two very long parallel wires one metre apart in a vacuum will experience a force of 2 × 10-7 N ***per metre length***.

1. **Describe an experiment to demonstrate the principle on which the definition of the ampere is based.**
2. Connect two parallel conductors (aluminium strips will do nicely) in a circuit as shown.
3. Complete the circuit to switch on the current.

Result: The strips will either move towards each other or repel each other, depending on the direction of the currents.

1. **Sketch a graph to show the relationship between current and time for  
   (i) direct current (ii) alternating current.**



1. **The peak voltage of the mains electricity is 325 V. Calculate the rms voltage of the mains.**

1. **What is the resistance of the filament of a light bulb, rated 40 W, when it is connected to the mains?**

R = 1320 Ω

1. **Explain why the resistance of the bulb is different when it is not connected to the mains.**

Resistance for a metal increases with temperature. When the filament is not connected to the mains it is colder and so has a lower resistance

**2006 Question 10 (a)**

1. **What is a photon?**

A photon is a discrete amount of electromagnetic radiation.

1. **Calculate the frequency of a photon produced during the interaction.**

The equation for pair annihilation is as follows:

To calculate the frequency we first need to establish how much mass gets ‘annihilated’ and then calculate how much energy that releases.Mass of particles beforehand = mass of proton + mass of antiproton

= 2(1.673 × 10-27) = 3.346 × 10-27 kg

The energy released is calculated from *E = mc2*

*E* = (3.346 × 10-27 )(2.998 × 108)2 = 3.0074 × 10-10 J

This is the energy that now becomes associated with two photons.

So energy associated with *one* photon = 1.5037 × 10-10 J

We then use *E = hf*  *f* = 2.2694 × 1023 Hz

1. **Why are two photons produced?**

So that momentum is conserved.

1. **Describe the motion of the photons after the interaction.**

They move in opposite directions.

1. **How is charge conserved during this interaction?**

Total charge before = +1-1 = 0

Total charge after = 0 since photons have zero charge

1. **After the annihilation, pairs of negative and positive pions are produced. Explain why.**

The energy of the photons is converted into matter .

1. **Give the quark composition of (i) a positive pion, (ii) a negative pion.**

π+ = up and anti-down

π- = down and anti-up

1. **List the fundamental forces of nature that pions experience.**

Electromagnetic, strong, weak , gravitational

1. **A neutral pion is unstable with a decay constant of 2.5 × 1012 s–1. What is the half-life of a neutral pion?**

T1/2 = 2.8 ×10-13 seconds

**2006 Question 11**

* 1. **How does resonance occur in an acoustic guitar?**

Energy is transferred from the strings to the hollow body and both vibrate at the same frequency.

* 1. **What is the relationship between frequency and tension for a stretched string?**

Frequency is proportional to the square root of tension.

* 1. **A stretched string of length 80 cm has a fundamental frequency of vibration of 400 Hz.**

**What is the speed of the sound wave in the stretched string?**

For a standing wave the length of the wave from node to node corresponds to half the wavelength. *λ* = 2*l* *λ*=2(0.8) *λ* =1.6 m

*v = f λ*  **** *v* = 400(1.6) *v* = 640 m s-1

* 1. **Why must the strings in the electric guitar be made of steel?**

*{The permanent magnet under the guitar string causes the guitar string itself to become a low strength magnet. When the string is plucked it now acts like a moving magnet and it is this moving magnet that induces the emf in the coil underneath.*

*Because only metal strings can be magnitised, it follows that the strings in an electric guitar must be made of steel.}*  
Answer: Only metal strings can be magnetised

* 1. **Define magnetic flux.**

Magnetic flux is the product of magnetic flux density and area. *Φ = BA*

* 1. **Why does the current produced in a coil of the electric guitar vary?**

Because the size of the induced emf is proportional to the rate of change of flux, and this in turn is determined by the speed at which the guitar string is moving. *{The speed varies with the amplitude of the string (plucking it harder pulls the string back more).}*

* 1. **What is the effect on the sound produced when the number of turns in a coil is increased?**

A louder sound is produced.

* 1. **What is the emf induced in the coil when the magnetic flux cutting the coil changes by 8 × 10–4 Wb in 0.1 s?**

Induced emf = - Induced emf = - = 40 V

**2006 Question 12 (a)**

1. **Define pressure.**

Pressure = Force divided by area.

1. **Is pressure a vector quantity or a scalar quantity? Justify your answer.**

It is a scalar because it has no direction.

1. **State Boyle’s law.**

Boyle’s Law states that for a fixed mass of gas pressure is inversely proportional to volume if temperature is constant.

1. **Calculate the pressure at the bottom of the lake.**

P

*{So if the volume increases by a factor of 3 (threefold) then the pressure decreases by a factor of 3.*

*So the pressure at the top of the lake is 3 times smaller than the pressure at the bottom of the lake.*

*So the pressure at the bottom of the lake is 3 times greater than the pressure at the top of the lake.}*

Answer: Pressure at bottom = 3 × (1.01 × 105) =3.03 × 105 Pa

*{Why were you told that the temperature is 4 oC? - presumably just to note that the temperature was constant}*

1. **Calculate the depth of the lake.**

ΔP = ρgΔh

Answer: Depth of lake = 20.61 m

**2006 Question 12 (b)**

1. **List the factors that affect the capacitance of a parallel plate capacitor.**

Common area of plates, distance apart, permittivity of dielectric between plates.

1. **Calculate the capacitance of the capacitor.**

*{There are 10,000 (1×104) cm2 in a m2. Therefore 1 cm2 =1×10-4 m2 40 cm2 =40×10-4 m2}*

C = 3.54 × 10-12 F

1. **Calculate the magnitude of the charge on each plate.**

Q = CV Q = (3.54 x 10-12)(12) = 4.25 × 10-11 C

1. **What is the net charge on the capacitor?**

*{this seems like a trick question, but is actually testing whether or not you understand how a capacitor works. When charged, there will be equal amounts of positive charge on one plate and negative charge on the second plate. So total net charge is zero.}*

Answer: Zero

1. **Give a use for a capacitor.**

Flash guns for cameras / locks d.c. /smoothing /tuning circuits / timing circuits /

**2006 Question 12 (c)**

1. **Define power.**

Power is defined as energy divided by time.

1. **Define specific heat capacity.**

The specific heat capacity of a substance is the heat energy needed to change one kilogram of the substance by one Kelvin.

1. **Calculate the energy required to raise the temperature of the water to 100 oC.**

E = mcΔθ

E = (0.40)(4200)(85) = 1.428 x 105 J

1. **Calculate the energy supplied by the kettle per second.**

3000 J per second = 3000 W

1. **Calculate the least amount of time it would take to heat the water to 100 oC.**

time = 47.6 seconds

1. **In reality, the time taken to heat the water will be greater. Explain why.**

Energy will be lost to the surroundings.

**2006 Question 12 (d)**

1. **What are X-rays?**

High frequency electromagnetic radiation.

1. **Who discovered them?**

Rontgen

1. **How are the electrons emitted from the cathode?**

By thermionic emission.

1. **How are the electrons accelerated?**

By the high voltage between the anode and cathode.

1. **Calculate the kinetic energy gained by an electron when it is accelerated through a potential difference of 50 kV in an X-ray tube.**

Kinetic energy at the end = Potential energy at the beginning

= (1.6 × 10-19)(50 × 103)

= 8.0 × 10-15 J

1. **Calculate the minimum wavelength of an X-ray emitted from the anode.**

*E = hf* λ = 2.475 × 10-11 m