NATIONAL JUNIOR COLLEGE
Preliminary Examination
Higher 1

CANDIDATE NAME	

SUBJECT CLASS		REGISTRATION NUMBER	

PHYSICS **8866/02**

Paper 2 Structured Questions
Candidate answers on the Question Paper.

31 August 2015
2 hours

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Answers **all** questions.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 8
2	/ 9
3	/ 9
4	/ 14
5	/ 10
6	/ 13
7	/ 17
Total (80m)	

This document contains 16 printed pages, including this cover page.

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ ms^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$
permittivity of free space,	$\varepsilon_0 = 8.85 \times 10^{-12}\ Fm^{-1} = (1/(36\pi)) \times 10^{-9}\ F\ m^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ C$
the Planck constant,	$h = 6.63 \times 10^{-34}\ Js$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ kg$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ kg$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ kg$
molar gas constant,	$R = 8.31\ JK^{-1}mol^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ mol^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ JK^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ Nm^2kg^{-2}$
acceleration of free fall,	$g = 9.81\ ms^{-2}$

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2\ ,\ v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure	$p = \rho g h$
gravitational potential,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ *and* $v = \pm\omega\sqrt{x_0{}^2 + x^2}$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
Transmission coefficient	$T = \exp(-2kd)$ *Where* $k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$0.693/t_{1/2}$

1 **(a)** Give a reasoned estimate for the kinetic energy of a bus travelling along an expressway [2]

kinetic energy = __________ J

(b) **(i)** A student is conducting an experiment involving an electric circuit.

Give an example of a possible systematic error in this experiment. [1]

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(ii) Give an example of a possible random error in this experiment. [1]

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1 (c) (i) In the experiment, the student attempts to determine the power of a light bulb. The student records the bulb's potential difference as 2.0 V $\pm$ 0.1 V, and the resistance of the light bulb as 1.0 $\pm$ 1.0 R [2]

Calculate the power of the light bulb and its percentage uncertainty.

Power of light bulb = __________________ W

Percentage uncertainty = __________________ %

(ii) The true power of the light bulb is 3.9W. Explain whether the experimental value of power determined by the student is accurate and precise. [2]

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2 **(a)** A baseball player throws a 2.0 kg ball upwards. The air resistance of the ball cannot be neglected. **Fig. 2.1** shows the velocity of the ball with respect to time.

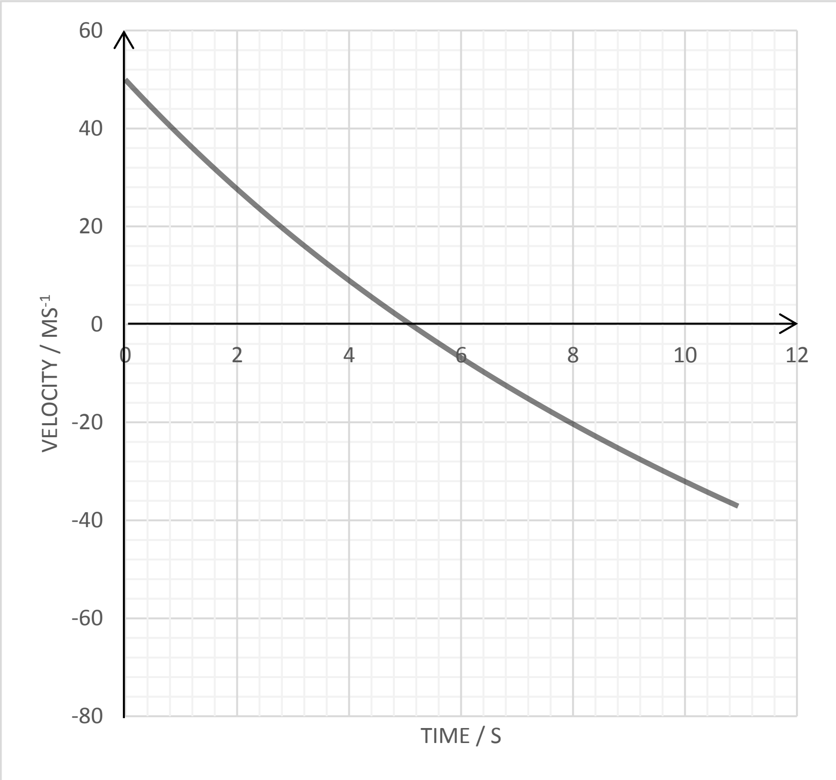

Fig. 2.1

(i) Determine the resultant force on the ball at t = 0 s. [1]

resultant force = ____________ N

(ii) The force of air resistance on the ball at t = 0 s is kv where k = 0.150 kg s^{-1} and v is the velocity.. Determine the force exerted by the baseball player on the ball at t = 0 s, assuming that the baseball player has not completely lost contact with the ball at t=0s. [2]

force = __________ N

2 **(b)** Explain why the time taken for the ball to travel upwards is faster than the time taken to travel downwards. [2]

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(c) Explain how you will use **Fig. 2.1** to determine the gravitational acceleration due to the Earth. [2]

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(d) On **Fig. 2.1**, draw in the velocity time graph if air resistance can be neglected. [2]

3 **(a)** State the principle of conservation of linear momentum. [1]

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(b) A 2.0 kg skateboard was initially travelling to the right at a constant speed of 1.50 ms^{-1}. A 60.0 kg skateboarder attempts a complex stunt as shown in **Fig. 3.1**.

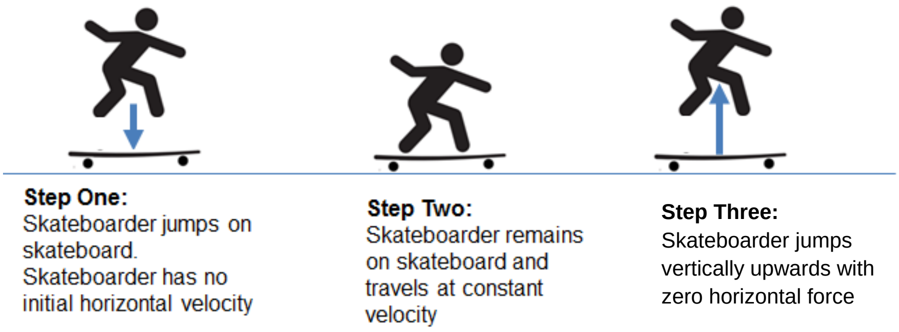

Fig. 3.1

3 **(b)** **(i)** Determine the new speed of the skateboard after the skateboarder has landed on it. State an assumption that you have made in your calculations. [3]

speed = _________ $m\ s^{-1}$

(ii) **1** Determine the kinetic energy of the skateboard at **step two**. [1]

kinetic energy = _________ J

2 The skateboarder does a vertical jump off the skateboard. Explain how the kinetic energy of the skateboard changes with time after the skateboarder has jumped off. [2]

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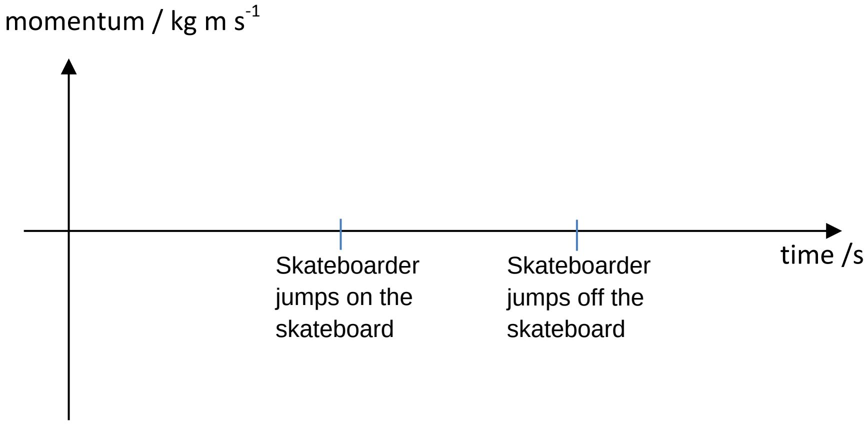
3 **(b)** **(iii)** Draw a graph of momentum versus time for the skateboard on **Fig. 2.2**. [2]



4 **(a)** **(i)** Using relevant diagrams, describe an experimental setup that will allow you to determine the absorption line spectrum of an atom. [2]

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(ii) Distinguish between the appearance of absorption and emission line spectra [2]

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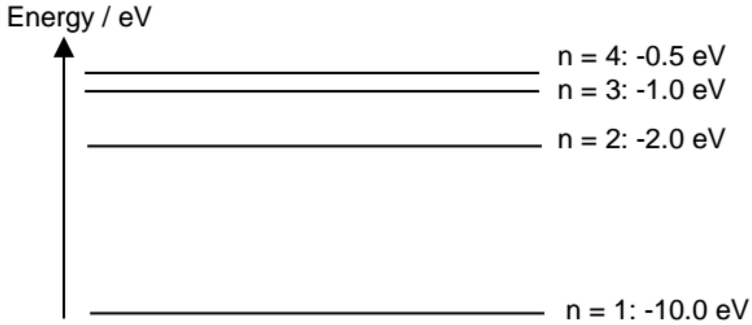
4 **(b)** The first 4 levels of a **cool** sample of a hypothetical atom are shown below:



(i) State the ionization energy of this atom [1]

Ionization energy = _______________ J

(ii) State all possible excited states when this atom is bombarded with

Photons of energy = 0.5eV [1]

Excited state(s) = ____________________

Photons of energy = 9.5 eV [1]

Excited state(s) = ____________________

Photons of energy = 8.5 eV [1]

Excited state(s) = ____________________

Electrons of energy = 7.5 eV [1]

Excited state(s) = ____________________

Electrons of energy = 9.5 eV [1]

Excited state(s) = ____________________

4 (b) (iii) Determine the wavelength of the light produced when an electron falls from the n = 2 level to the n = 1 level. [2]

wavelength = ____________________

(iv) State the region of the electromagnetic spectrum in which the radiation lies. [1]

region = ____________________

(v) State one useful purpose of the concept of the emission line spectra [1]

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5 **(a)** The equation $hf = \Phi + \frac{1}{2}mv^2$ is commonly used in photoelectric theory. Explain the meaning of each of the three energy terms in the equation. [3]

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(b) Explain how the results of photoelectric experiments contradict the evidence that electromagnetic radiation behaves purely as a wave. [3]

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(c) **(i)** Suggest some practical difficulties in measuring the kinetic energy term $\frac{1}{2}mv^2$ from the equation in **5 (a)**. [2]

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5 **(c)** **(ii)** Suggest strategies for how these difficulties can be overcome. [2]

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6 **a)** A neutron of mass 1.00 u is travelling with velocity 3.0×10^4 ms^{-1} directly toward a stationary carbon atom of mass 13.0 u. It collides elastically with the carbon atom. After collision, the carbon atom has velocity V and the neutron has velocity U.

(i) Calculate the De Broglie wavelength of the neutron before the collision [1]

wavelength = ____________________ m

(ii) Estimate the De Broglie wavelength of an electron travelling at 500 ms^{-1} [1]

wavelength = ____________________ m

(iii) Estimate the De Broglie wavelength of a basketball travelling at 1.0 ms^{-1} [1]

wavelength = ____________________ m

6 (a) (iv) Rank these three objects, an electron, a neutron and a basketball, in terms of the difficulty in demonstrating the wave nature for each of them. Explain the rationale for your choice. [2]

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(b) (i) Calculate the value of V and U [3]

V = ____________________ ms^{-1}
U = ____________________ ms^{-1}

(ii) Calculate the kinetic energy of the carbon atom and the neutron after the collision. [2]

kinetic energy of carbon atom = ___________________________ J
kinetic energy of neutron = ___________________________ J

(iii) Determine the percentage loss of the kinetic energy of the neutron during the collision. [1]

percentage loss = ___________________________ %

(iv) Suggest what happens to the percentage loss of the kinetic energy of the neutron during the collision if

1 the initial speed of the neutron is halved. [1]

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2 it collides with a gold particle instead of a carbon atom [1]

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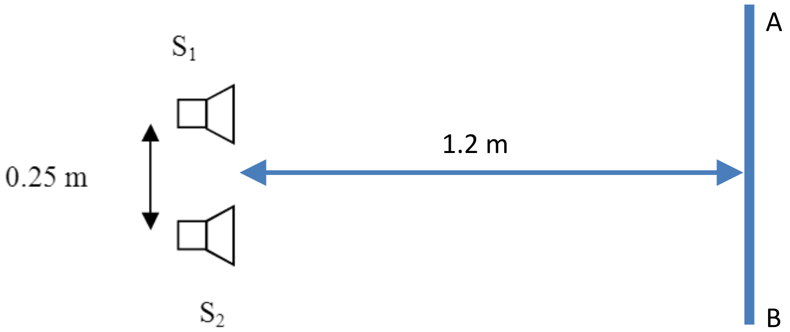
7 **(a)** Two identical, coherent loudspeakers are in phase with each other



(i) State the principle of superposition [2]

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7 **(a)** **(ii)** Describe what will be observed if a microphone is moved along the line AB. [2]

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(iii) Describe the changes that will be observed if the distance between the loudspeakers and the screen is doubled. [1]

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(iv) Describe the changes that will be observed if loudspeaker S_1 is now in anti-phase with loudspeaker S_2. [1]

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(v) Describe and explain what will be observed if loudspeakers S_1 and S_2 are replaced with two light bulbs [2]

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(b) **(i)** State the conditions required to form a stationary wave [2]

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7 **(b)** **(ii)** The speed of waves in a guitar string is 400 ms^{-1}. Determine the fundamental frequency of the string if its length is 100.0 cm. [2]

frequency = _________________ Hz

(iii) On **Fig 6.1,** draw a diagram showing the 1^{st} mode of vibration of the guitar string. [2]

On the same diagram, draw a diagram showing the 5^{th} mode of vibration of the guitar string.

Fig. 6.1

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(iv) Calculate the frequency for the 5^{th} mode of vibration of the string. [1]

frequency = _________________ Hz

(v) **1** Identify two points in **Fig 6.1** that are in phase with each other. Label these two points as A_1 and A_2. [1]

2 Identify two points in **Fig 6.1** that are in antiphase with each other. Label these two points as B_1 and B_2 [1]

Solutions for H1 Prelim

Question 1

(a) Estimate for speed of bus approximately 60kmh^{-1} = 60 x 1000 / 3600 ms^{-1}
Estimate for mass of bus = 500kg (for a mini bus) to about 3 tonnes (for a big bus)

(b)(i) Zero error in the reading of the ammeter

(b)(ii) Fluctuations in the environment such as temperature will affect the voltage and current readings.

(c)(i) Power = $2^2/1$ = 4 W

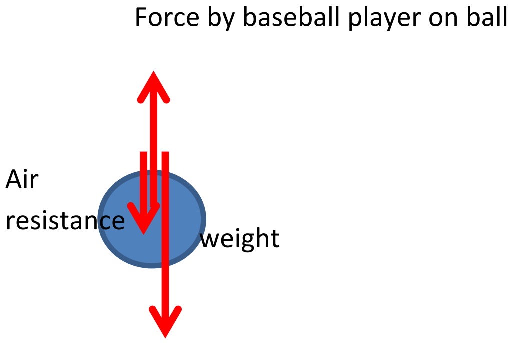
Percentage Uncertainty $100\frac{\Delta P}{P} = 100\left(2\frac{\Delta V}{V}+\frac{\Delta R}{R}\right) = 100\left(2\frac{0.1}{2}+\frac{1}{1}\right) = 110\%$

(c)(ii) It is accurate as 4W is close to the true value of 3.9 W. It is not precise as the percentage uncertainty is very large (110%)

Question 2

(a)(i) F= ma= 2 x gradient = 2 x 12.25 = - 24.5 N **(negative sign indicates downwards)**

(a)(ii)



Resultant Force = Weight + air resistance – Force by baseball player
Weight + air resistance – Force by baseball player
24.5 = 2 x 9.81 + 0.150 x 49 – Force by baseball player
Force by baseball player = 2.47N

(b)

- Average upward velocity is larger than average downward velocity.
  Time = Distance / Average Velocity. Same distance in both cases
- Lower average downward velocity due to continual loss of Kinetic energy due to work done against air resistance

(c)

- Find the gradient of the graph
- At v = 0 at t=5s on the graph, because the only force on ball is gravity at that point

(d)

- Straight line graph
- Gradient of approximately $9.81ms^{-2}$

Question 3

(a)

- no resultant external force
- total linear momentum of the system in any direction always remain constant.

b)i)

Assumption: There is no external resultant force acting on the skateboard and the skateboarder. Examples are air resistance or friction.

By the Principle of Conservation of Linear Momentum,

$2 (1.5) + 60(0) = 62(v)$

$v = 0.0484ms^{-1}$

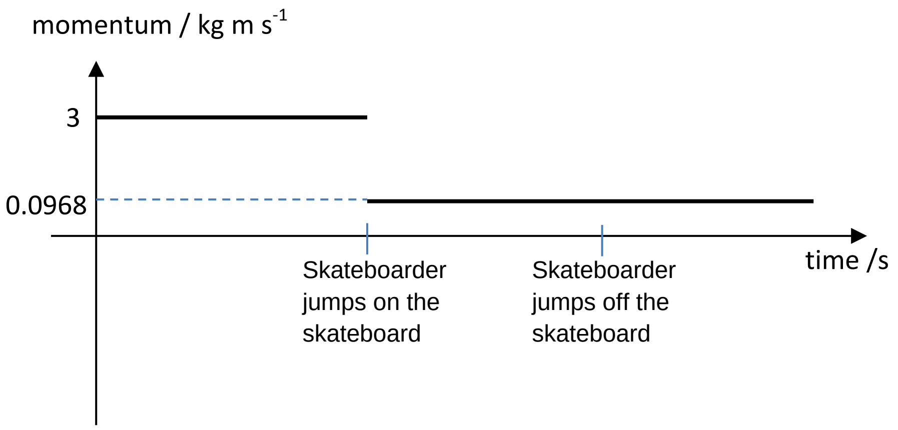
b) ii)

1. $E_k = 0.5 \times \mathbf{2} \times (0.0484)^2 = 2.34 \times 10^{-3}$ J

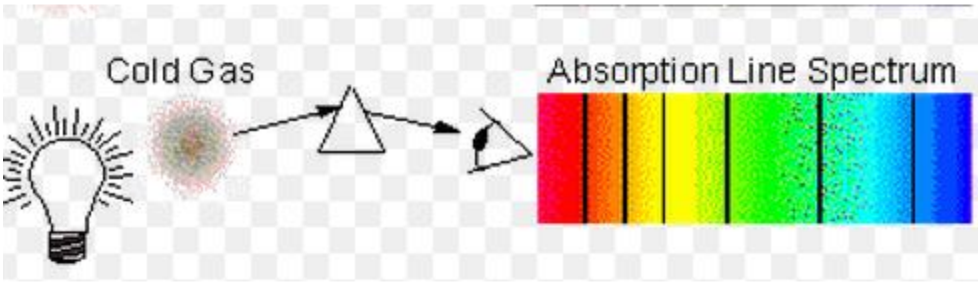
2. - The kinetic energy of the skateboard remains constant before and after the skateboarder has jumped off.

   - This is because the vertical motion of the skateboarder has no impact on the horizontal velocity (and hence the kinetic energy) of the skateboard.

b) iii)

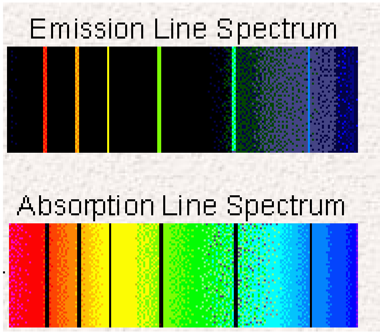


Question 4(a)(i)



Photons of energy matching the energy difference in the energy level diagram of the cold gas are absorbed. These show up as dark lines on a continuous spectrum.

(ii)



From the diagram above, an emission spectrum consists of coloured bands of light on a black background, while the absorption line spectrum consists of dark bands of light on a coloured background.

(b) (i) -10eV

(ii) Nil, n=4, Nil, Nil, n=2 to 4

(b)(i) Using $\frac{hc}{\lambda}$ = 8eV

Wavelength = 1.55 x 10^{-7} nm

(iv) Ultraviolet

(v) As each atom will have it's own unique emission line spectra, this can be used to distinguish and identify specific atoms.

Question 5

(a) hf = energy of incoming photon

Φ = work function of the metal, which is the energy required to extract an electron from the metal surface

$\frac{1}{2}mv^2$: kinetic energy of the emitted electron.

(b)

- Existence of minimum frequency below which there will be no photoelectric effect, regardless of the intensity and time of exposure. Following the wave model, there should be no minimum frequency.
- No time delay in the emission of photo-electrons even when light intensity is very low. For wave model, it should take time for the energy transfer to take place.
- Maximum kinetic energy of photoelectrons is independent of light intensity but dependent on the frequency of light. According to wave model, the higher the intensity, the higher the max KE (not observed in experiments).

(c)(i) Electrons have very small mass and very high speeds, so it is difficult to observe an electron and measure its speed directly using standard laboratory equipment.

(c)(ii) They can be overcome by measuring the kinetic energy indirectly by measuring the electric potential energy of the most energetic electron. A negatively charged metal plate is used to repel the electrons, so that their kinetic energy can be converted to electric potential energy (eV). e, the electronic charge for an electron is a known value, and the potential can be measured using a digital voltmeter.

<u>Question 6</u>

a) i) $\lambda = \frac{h}{p} = \frac{6.63x10^{-34}}{(1u)(3x10^{4})}$ =1.33 x 10^{-11} m

aii) $\lambda = \frac{h}{p} = \frac{6.63x10^{-34}}{(9.11x10^{-31})(500)}$ =1.45x10^{-6} m

aiii) $\lambda = \frac{h}{p} = \frac{6.63x10^{-34}}{(0.5)(1)}$ =1.33x10^{-33} m

aiv) For these objects to demonstrate their wave nature, they must be confined to dimensions that are comparable to their De Broglie wavelength.
For a basketball to undergo diffraction with dimensions around 10^{-33} m is virtually impossible. For both neutrons and electrons, it is possible to demonstrate diffraction by passing them through small apertures such as the distance between crystal spacing like graphite. So, in terms of order of difficulty (highest to lowest): Basketball > electron = neutron

b)(i) For elastic collision, we can apply the conservation of linear momentum and also the relative speed relation.

Conservation of Linear momentum:

$(1u)(3x10^4) + 0 = (1u)(v_n) + 13u(v_c)$

Relative speed relation

$3x10^4 = v_c - v_n$

Combining the equations, we have:

$(1)(3x10^4) + 0 = (1)(v_n) + 13\,(3x10^4 + v_n)$

V_n = -25714 ms^{-1}

V_c = -25714 + 3 x 10^4 = 4285.7 ms^{-1}

V, velocity of carbon atom = 4285.7 ms^{-1}

U, velocity of neutron = -25714 ms^{-1}

bii) KE of carbon = $\frac{1}{2}(13u)(4285.7)^2$ =1.98 x 10^{-19} J

KE of neutron = $\frac{1}{2}(u)(-25714)^2 = 5.4880x10^{-19} J$

biii) Initial KE of neutron= $\frac{1}{2}(u)(3x10^4)^2 = 7.47x10^{-19} J$

% loss in KE = $\frac{7.47-5.49}{7.47} x100$ = 26.5%

(iv)(1) No change

(iv)(2) % loss in KE for the neutron is smaller

7aWhen two or more waves meet at point, the resultant displacement at that point is the vector sum of the displacement due to each individual wave.

7a(ii) An alternating pattern of loud and soft sounds will be heard, with the loudest sound to be found at the midpoint of AB

7a(iii) The distance between the loud and soft sounds along the line AB will increase

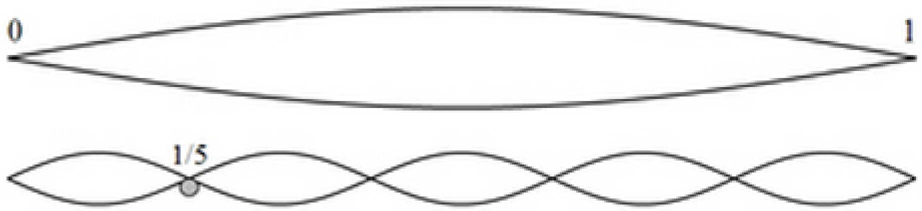
7a(iv) The loud sounds will become soft sounds, and the soft sounds will become loud sounds.

7a(v) As the two light bulbs are not coherent sources and because they emit a range of wavelengths, no interference pattern will be observed. Instead, we will only see white light along the line AB

bi) Two waves with the same speed, frequency and amplitude travelling in opposite directions

bii) 400 = (Fundamental frequency)(2 x 1)

f = 200Hz



Amplitude of first mode must be higher than that of the 5th mode.

iv) $f_5 = f_1 \times 5 = 200 \times 5 = 1000$Hz

v1) A_1 and A_2 in blue below, B_1 and B_2 in red below.