INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

N99/430/S(3)

PHYSICS

Standard Level

Monday 8 November 1999 (morning)

Paper 3

1 hour

A

Candidate name:	Candidate category & number:

This examination paper consists of 8 options.
The maximum mark for each option is 20.
The maximum mark for this paper is 40.

INSTRUCTIONS TO CANDIDATES

Write your candidate name and number in the boxes above.

Answer all of the questions from TWO of the options in the spaces provided.

At the end of the examination, complete box B below with the letters of the options answered.

B

OPTIONS ANSWERED

C

EXAMINER	TEAM LEADER
/20	/20
/20	/20
TOTAL /40	TOTAL /40

D

IBCA
/20
/20
TOTAL /40

EXAMINATION MATERIALS

Required:
Calculator
Physics SL Data Booklet

Allowed:
A simple translating dictionary for candidates not working in their own language

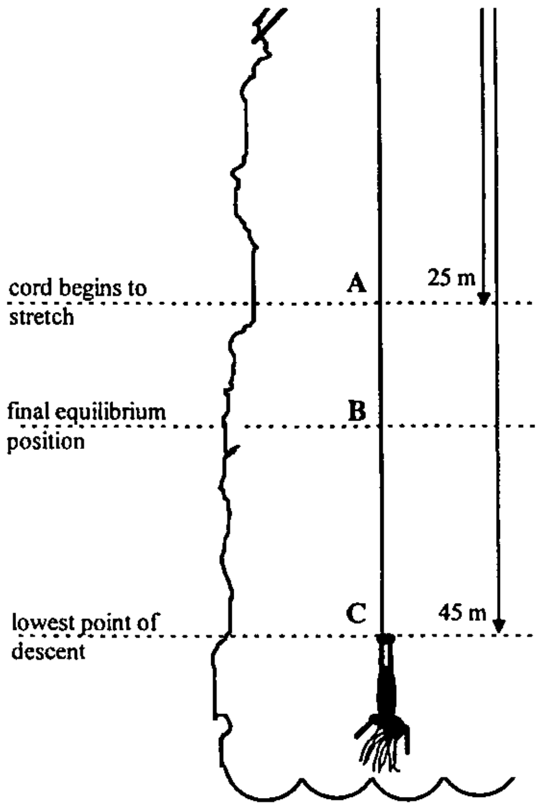
OPTION A—MECHANICS EXTENSION

Answer ALL questions in this option.

A1. In the sport of Bungee Jumping people stand on a high platform and allow themselves to fall while tied to the platform by an elastic cord attached to their ankles.

Johanna does a bungee jump. The unstretched length of the bungee cord is 25.0 m.

The figure shows three important positions during her motion. In her **initial drop**, the lowest point she reaches is with her feet 45.0 m below the platform (see figure).



(a) As Johanna drops, describe the energy changes taking place. Do this by completing the table below by writing ***increasing***, ***decreasing*** or ***constant*** under the headings gravitational potential energy, kinetic energy and elastic potential energy.

The top row refers to energy changes between her initial position on the platform and position **A** - the point where the bungee cord just starts to stretch; the middle row as she falls from **A** to position **B**, the final equilibrium position; and the bottom row as she falls from **B** to position **C**, the lowest point of her initial drop.

The top box for kinetic energy is filled in as an example. *[5]*

	gravitational potential energy	**kinetic energy**	**elastic potential energy**
From platform to **A**		increasing	
From **A** to **B**			
From **B** to **C**			

(This question continues on the following page)

(Question A1 continued)

Take Johanna's centre of mass to be about 1 m above her feet when she is standing and her mass to be 54.0 kg. Assume the bungee cord has an elastic constant of 75.0 Nm^{-1}.

(b) Estimate Johanna's vertical speed at point **A**, the point where the bungee cord just starts to stretch. *[3]*

. . . .

. . . .

. . . .

. . . .

. . . .

(c) Calculate the **resultant** force acting on Johanna when she is at **C**, the lowest point of her drop. *[3]*

. . . .

. . . .

. . . .

. . . .

. . . .

(d) After reaching the lowest point, the stretched bungee cord accelerates Johanna upwards. In this way she 'bounces' up and down a few times before stopping, hanging by her ankles at the end of the cord.

By how much has the cord stretched when she is in this final position? *[2]*

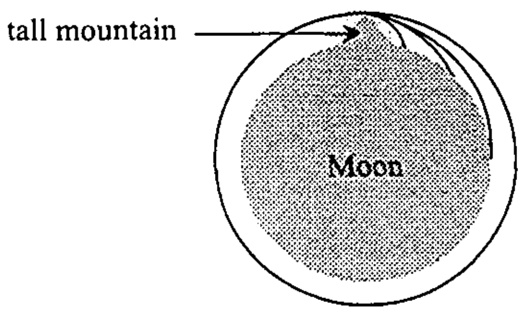
. . . .

. . . .

. . . .

A2. Imagine launching projectiles horizontally with increasing initial speeds, from a tall mountain on the Moon.

The radius of the Moon is 1.74×10^6 m, and the mass of the moon is 7.35×10^{22} kg.



(a) Show that 'g_m', the acceleration due to gravity near the surface of the moon is 1.62 ms^{-2}. *[2]*

. . . .

. . . .

. . . .

. . . .

(b) Take the mountain to be 5.0 km high and in the shape of a cone with a base **diameter** of 20 km. With what minimum horizontal speed would a projectile have to be launched in order to miss hitting the side of the mountain? Note that g_m at the top of the mountain is very nearly equal to that at the surface. *[3]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(c) Calculate the horizontal speed required for the projectile to go into a circular orbit. *[2]*

. . . .

. . . .

. . . .

. . . .

. . . .

OPTION B—ATOMIC AND NUCLEAR PHYSICS EXTENSION

Answer ALL questions in this option.

B1. In the current model of the atom the nucleus is held together by the strong nuclear force while the electrons exist outside this region.

(a) Describe **two** ways in which the neutrons in a nucleus enhance nuclear stability. *[2]*

. . . .

. . . .

. . . .

. . . .

(b) (i) Define *nuclear binding energy.* *[1]*

. . . .

. . . .

. . . .

(ii) On the axes below sketch the variation of nuclear binding energy per nucleon as a function of mass number, for the stable isotopes. Indicate on your sketch approximate scales for each axis. *[4]*

(iii) In terms of the binding energy per nucleon curve sketched in (ii) above, explain why both fusion and fission are permissible natural processes. *[3]*

. . . .

. . . .

. . . .

. . . .

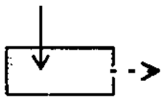
. . . .

B2. Doubly ionised Helium atoms, He^{++}, are required to form the particle beam in a linear particle accelerator. When neutral Helium is ionised a mixture of both He^{+} and He^{++} is produced.

(a) Describe a method of separating the He^{+} from the He^{++} ions before the latter are injected into the accelerator. Include

- the physical principles on which your method is based.
- an explanation of how the separation takes place.
- any equations or conditions relevant to your method.

As an aid in your description complete the following diagram to show finally a single beam of He^{++} ions. *[6]*



. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question B2 continued)

(b) The He^{++} particle beam is used to study the nuclear reaction

$$ {}^{4}_{2}He + {}^{9}_{4}Be \rightarrow {}^{12}_{6}C + n $$

This is a very well known reaction that has been studied since 1930, well before the invention of particle accelerators. How might a beam of high speed He^{++} have been obtained in the early 1930s? *[2]*

. . . .

. . . .

. . . .

. . . .

. . . .

(c) In the ionisation of Helium atoms, the Bohr model of the atom accurately predicts the energy required to ionise He^{+} to He^{++}. However, it fails to give the correct result for the ionisation of He to He^{+}. Explain why the model works in the former but not in the latter case. *[2]*

. . . .

. . . .

. . . .

. . . .

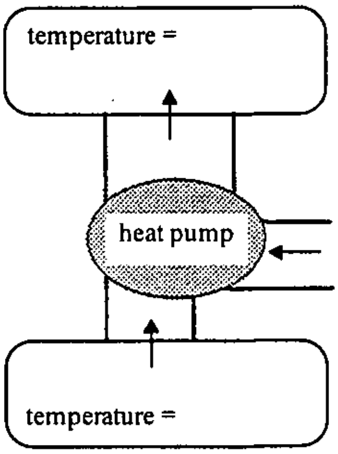
. . . .

OPTION C—ENERGY EXTENSION

Answer ALL questions in this option.

C1. This question is about the use of a heat pump for domestic heating in a cold environment.

(a) The figure below depicts the operation of a heat pump. Adjacent to the figure are a number of symbols and their definitions. Use these symbols to label the respective aspects of the figure. Arrows on the figure show the direction of energy flow. *[2]*



Q_C = heat extracted from the cooler reservoir
Q_H = heat delivered to the hotter reservoir
T_C = temperature of the cooler reservoir
T_H = temperature of the hotter reservoir
W = work done on the heat pump

(b) Q_C, Q_H and W are related through the First Law of Thermodynamics. What is this relationship? *[1]*

. . . .

. . . .

. . . .

. . . .

(c) One statement of the Second Law of Thermodynamics is that

"It is impossible to construct a cyclic engine which would transfer thermal energy from one body to another body at a higher temperature with ***no other change*** *taking place".*

What ***other change*** takes place in the case of the heat pump depicted above? *[2]*

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question C1 continued)

(d) The *coefficient of performance* (COP), is used as a measure of the effectiveness of a heat pump. For an **ideal** heat pump this is defined as

$$\text{COP} = T_H/(T_H - T_C).$$

(i) Suppose an **ideal** heat pump is used to maintain the interior of a house at 24 °C while the temperature outside was at –5 °C. In order to achieve this the temperature of the hot reservoir of the heat pump must be about 45 °C (this is the heat source within the house). Show that the COP for such a heat pump must be 6.4. *[2]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(ii) If heat energy escaped from the house at a rate of 1.5 kW what would be the work input required for this ideal heat pump? *[3]*

. . . .

. . . .

. . . .

. . . .

. . . .

(iii) How would you expect this to change in the case of a **real** heat pump? *[1]*

. . . .

. . . .

. . . .

. . . .

C2. Solar panels are to be used to provide energy for a house whose requirements are a modest 12 kWh per day. The panels charge batteries which can be used to provide energy during the day and night. A solar panel in direct, bright sunlight produces 70 W of electrical power per square metre of solar panel area. Estimate the total area of solar panels required. State clearly any assumptions or estimates that you need to make. *[5]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

C3. The table below is an 'energy conversion matrix'. Each 'box' at the intersection of a particular row and column should contain an **energy conversion process** or **device**. A number of examples are given to show how the matrix works. *e.g.* **electrical** energy is converted to **mechanical** by an **electric motor**. Complete the table. *[4]*

Convert FROM ⇓ / TO ⇒	**electrical**	**mechanical**	**thermal**
electrical	transformer	electric motor	
mechanical			heating by friction
thermal	thermoelectricity		———

OPTION D—BIOMEDICAL PHYSICS

Answer ALL questions in this option.

D1. A physics teacher and his child, Youlie are out walking when the weather turns cold. Youlie is only 70 % as tall as her father. By considering how various quantities scale, explain the following.

(i) Why does Youlie lose body heat at about half the rate of her father? *[2]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(ii) Despite this Youlie can not survive exposure to the cold weather for as long as her father. *[4]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

D2. Poiseuille's equation is often used in calculations related to blood flow in the human circulatory system.

(a) State **two** assumptions that need to be made about the properties of blood and its flow in blood vessels, in order that Poiseuille's equation can be applied? *[2]*

. . . .

. . . .

. . . .

. . . .

. . . .

(b) Arteriosclerosis involves both thickening and hardening of the arteries. With reference to the Poiseuille equation explain what consequences these **two** aspects of arteriosclerosis have for

- blood flow rates
- blood pressure
- the control of blood flow rates (*e.g.* during exercise). *[5]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

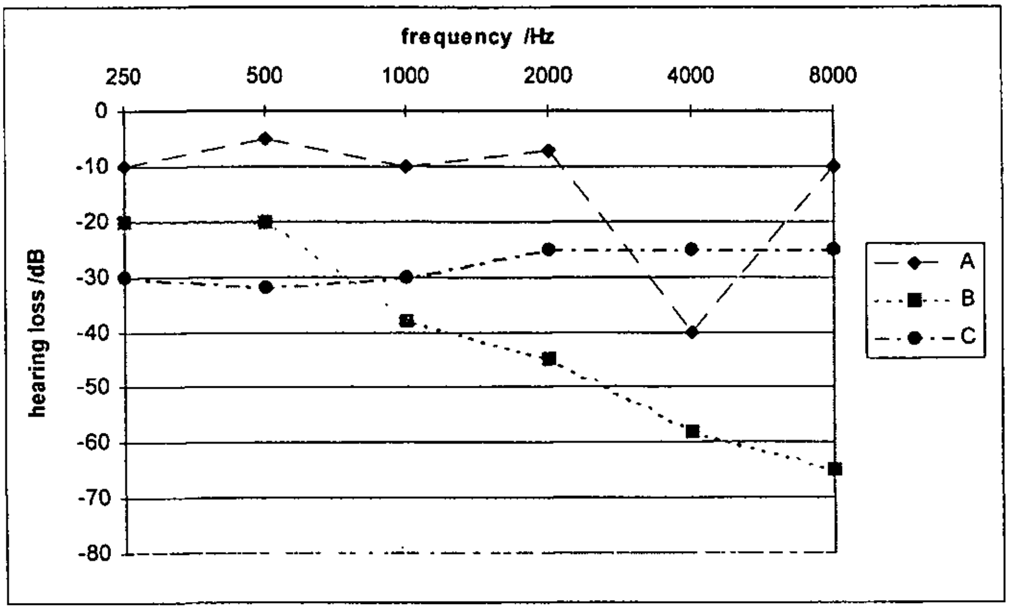
. . . .

. . . .

. . . .

. . . .

D3. Three air conduction audiograms, for three different patients are shown below. Each patient shows some form of hearing loss.



(a) Describe the procedure for obtaining the data displayed. *[3]*

. . . .

. . . .

. . . .

. . . .

(b) State and **give reasons to explain** which of the above patients could be suffering from *[4]*

(i) presbycusis (hearing loss due to old age).

. . . .

. . . .

. . . .

. . . .

(ii) otosclerosis (a form of conductive hearing loss).

. . . .

. . . .

. . . .

. . . .

OPTION E—HISTORICAL PHYSICS

Answer ALL questions in this option.

E1. This question is about Newton's contribution to the understanding of Gravitation.

(a) In order to solve many problems in mechanics, Newton invented the branch of mathematics we now call *Calculus*. However, in the *Principia* he did not use this new mathematics. What was the predominant form of mathematics that he used? *[1]*

. . . .

. . . .

. . . .

(b) One of Newton's important contributions in the field of mechanics was to realise that the force of gravity was *universal*.

What is meant by the phrase 'the force of gravity is universal'? *[2]*

. . . .

. . . .

. . . .

. . . .

. . . .

(c) Newton concluded that the same force was responsible for the acceleration of a falling object on the Earth's surface and for the acceleration **of the Moon in its orbit**. This he showed would be true as long as that force was a 'central force' and followed an 'inverse square law'.

In this context, explain what is meant by a 'central force' and by 'an inverse square law'. *[2]*

. . . .

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question E1 continued)

(d) The following data was well known in Newton's time (although not so precisely):

acceleration due to gravity at the Earth's surface	=	$9.81\ \text{m s}^{-2}$
Earth's radius	=	6.37×10^{6} m
Earth—Moon distance	=	3.84×10^{8} m

We can repeat a part of Newton's work using the above data, and **only this data**.

Assuming the force of gravity is universal and obeys an inverse square law, calculate the acceleration expected at the Moon's orbit, due to this force. *[3]*

. . . .

. . . .

. . . .

. . . .

. . . .

E2. The first quantitative determination of what we now call the *mechanical equivalent of heat* was made by Julius Mayer. He deduced that the potential energy released when a mass of 1.00 kg falls through a height of 365 m was equivalent to the heat energy required to raise the temperature of 1.00 kg of water by 1.00 °C.

(a) Given that the modern value for the specific heat of water is 4186 J kg^{-1} K^{-1}, by what percentage was Mayer's result for the mechanical equivalent of heat in error? *[2]*

. . . .

. . . .

. . . .

(b) Soon after Mayer's estimate, James Joule published the results of many experiments on the mechanical equivalent of heat.

(i) What physical principle did Joule help establish through this work? *[1]*

. . . .

. . . .

(ii) Sketch and label a piece of apparatus that would be appropriate for investigating the mechanical equivalent of heat. *[3]*

E3. The photoelectric effect.

(a) It has been said that Einstein's explanation of the photoelectric effect seemed to violate everything that was known at that time about light.

What was Einstein's explanation for the photoelectric effect and why was it so controversial? *[3]*

....

....

....

....

....

....

....

(b) Describe **one** aspect of the photoelectric effect that the model of light prevailing at the time failed to explain. Give an explanation for this aspect in terms of Einstein's model. *[3]*

....

....

....

....

....

....

....

OPTION F—ASTROPHYSICS

Answer ALL questions in this option.

F1. Number the following objects in order of increasing size, 1 (smallest) to 5 (largest). *[3]*

red giant	[ ]	galaxy	[ ]
Jupiter	[ ]	neutron star	[ ]
solar system	[ ]		

F2. This question is about the analysis of light emitted by stars.

When light from a star is analysed using a diffraction grating, a continuous spectrum is observed with a number of dark lines across it.

(a) What can we learn about the stars from these? *[2]*

. . . .

. . . .

. . . .

. . . .

(b) If the spectrum from a star is compared to laboratory measurements of spectra, it is often found that similar patterns of dark lines are not at the wavelengths they would normally be. Explain why this occurs and what can we learn about the stars from a measurement of this apparent shift in wavelength? *[2]*

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question F2 continued)

(c) The light from many stars can have features other than the dark lines. What features might you expect to observe in the light from a binary system that was not visual? *[2]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(d) Our sun is expected to evolve through the 'red giant' stage in its future development. In what way(s) will the light it emits then differ from what it is now? *[2]*

. . . .

. . . .

. . . .

. . . .

F3. This question concerns the 3 K 'background' radiation.

(a) (i) Using Wien's displacement law, calculate the dominant wavelength for the 3 K 'background' radiation. *[2]*

. . . .

. . . .

. . . .

. . . .

(ii) Name the spectral region in which this radiation occurs and state what type of telescope is used for its observation? *[2]*

Spectral region . . . .

Telescope . . . .

(b) Why has the discovery of this radiation been important for astrophysics? (Indeed, so much so that a Nobel Prize was awarded to its discoverers). *[2]*

. . . .

. . . .

. . . .

. . . .

(c) Why was it important to make measurements of the relative intensity of the 3 K radiation at more than one wavelength? *[2]*

. . . .

. . . .

. . . .

. . . .

(d) What changes to this background radiation might be expected to take place with time if the universe is 'open'? *[1]*

. . . .

. . . .

OPTION G—SPECIAL AND GENERAL RELATIVITY

Answer ALL questions in this option.

G1. One of the effects of gravity on light predicted by General Relativity is the deflection of light as it passes close to a massive object such as the sun.

(a) How is this explained on the basis of the General Theory of Relativity? *[3]*

. . . .

. . . .

. . . .

. . . .

. . . .

. . . .

(b) Arthur Eddington made the first measurements of this effect in 1919. Describe the experiment and how it was conducted. *[3]*

. . . .

. . . .

. . . .

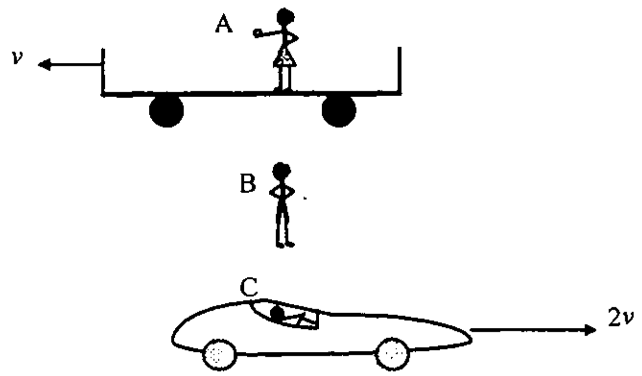
. . . .

. . . .

G2. Three observers, A, B and C, visit a market and buy a melon of mass 2.3 kg. Observer A then takes the melon on a journey in an open rail car as shown in the figure below. The rail carriage moves smoothly at a constant velocity $-v$ relative to observer B. Observer C drives by in a car moving in the opposite direction to A at a constant velocity of $2v$ relative to B.

At some instant of time all three observers are aligned as shown in the figure below and at that time observer A, in the railway carriage, drops the melon.

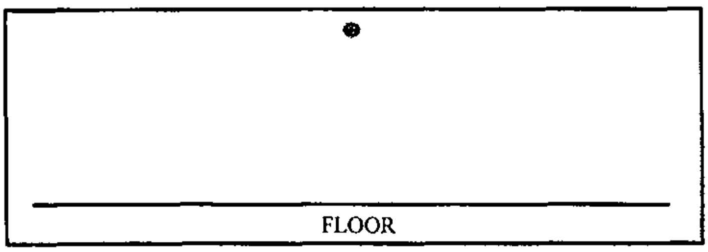
Observer A measures the time taken for the melon to fall to the floor to be 0.50 s.



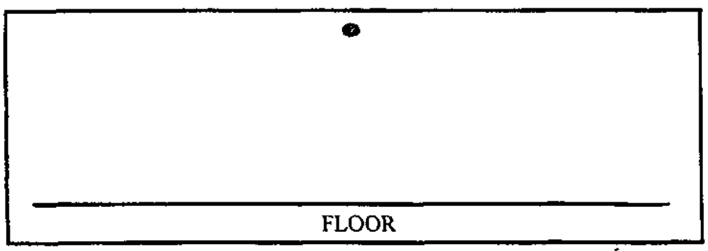
(a) Suppose v and $2v$ to be 'everyday' low speeds, say 2 and 4 m s^{-1} respectively. Complete the figures below by sketching the trajectory of the melon till the time it hits the carriage floor, as measured with respect to all **three** observers. Neglect air drag.

Indicate a scale for **horizontal** displacements. *[4]*

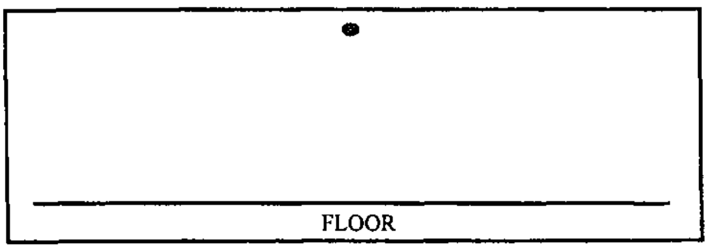
with respect to observer A



with respect to observer B



with respect to observer C



(This question continues on the following page)

(Question G2 continued)

(b) Suppose that the speeds v and $2v$ were relativistic, say 0.40c and 0.80c respectively. What time interval would observer B measure for the melon to fall to the floor? *[3]*

. . . .

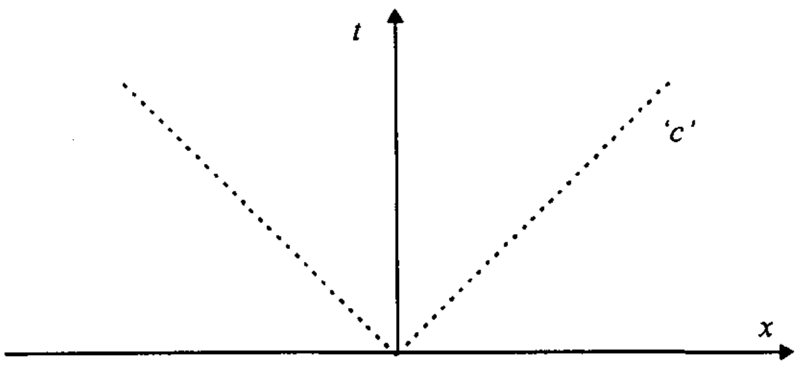
. . . .

. . . .

. . . .

. . . .

(c) For the velocities given in (b) above, on the axes below, sketch the spacetime paths of observers B and C from the **point of view of observer A**. The dashed lines marked 'c' represent the speed of light. *[4]*



(d) Consider the mass of the melon.

(i) What does observer A measure the mass of the melon to be?

. . . .

. . . .

. . . .

(ii) What does observer B measure the mass of the melon to be? *[3]*

. . . .

. . . .

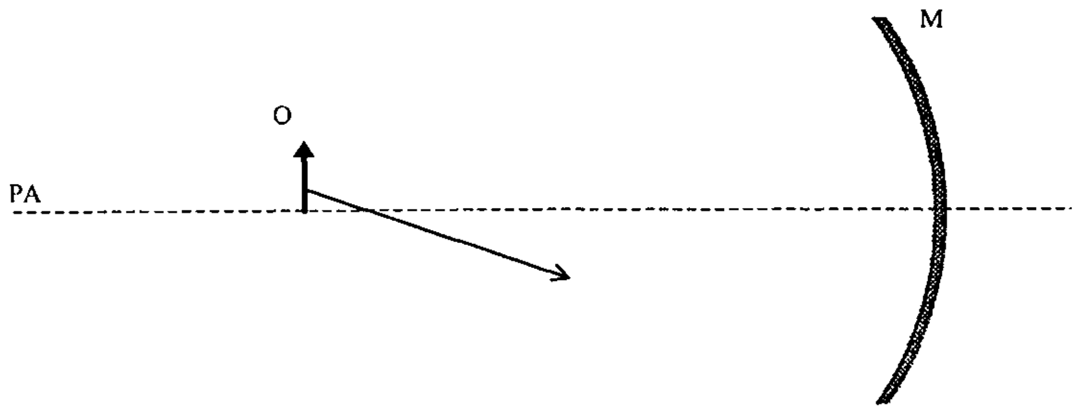
. . . .

OPTION H—OPTICS

Answer ALL questions in this option.

H1. (a) The figure below is drawn to scale and shows an object positioned on the principal axis, 30.0 cm away from a concave mirror of focal length 10.0 cm. The object is oriented at right angles to the principal axis. Also shown is a ray of light leaving from an arbitrary point on the object.

PA - the principal axis. O - the object. M - the mirror.



(i) By drawing in appropriate rays leaving the top of the object and reflecting off the mirror, locate the image of the object. *[3]*

(ii) Extend the given ray of light and show its path after reflection off the mirror. *[1]*

(iii) How far from the mirror will the image be located? *[3]*

. . . .

. . . .

. . . .

. . . .

(iv) What type of image of this object does the mirror produce? *[1]*

. . . .

. . . .

(This question continues on the following page)

(Question H1 continued)

(b) If you wanted to produce a 'beam' of light using a candle and the mirror above, where would be the best position for the candle flame relative to the mirror? *[1]*

. . . .

. . . .

(c) In good quality torches (flashlights) the reflector used is not spherical. What shape is the reflector? *[1]*

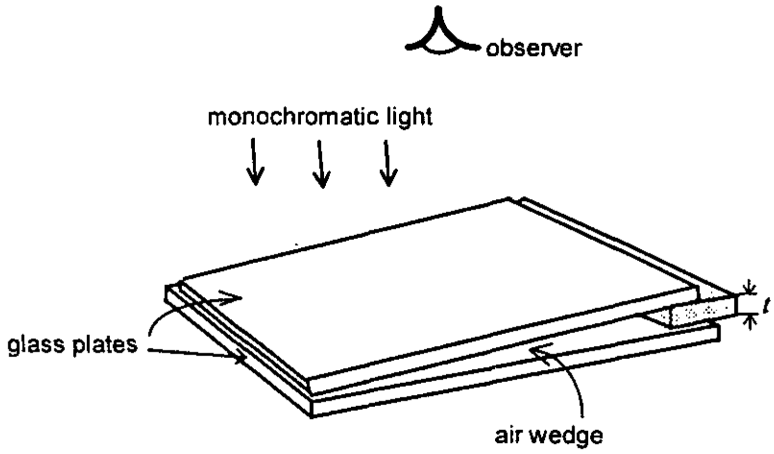
. . . .

. . . .

H2. (a) When monochromatic light illuminates a thin wedge of air formed between two very flat glass plates a series of bright and dark bands are observed.

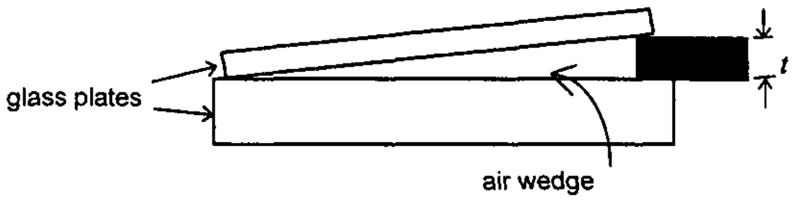
(i) Use **Diagram A** below to show some bright and dark bands as they would appear to the observer. *[1]*

Diagram A



(ii) **Diagram B** below shows a cross-sectional view of the air wedge. Use this to explain how the bands are formed. *[3]*

Diagram B



. . . .

. . . .

. . . .

. . . .

. . . .

(b) This arrangement can be used to measure small distances, much less than the thickness of a sheet of paper. A sample whose thickness, t, is to be measured is shown in the figures above. Explain how t can be determined. *[2]*

. . . .

. . . .

. . . .

. . . .

(This question continues on the following page)

(Question H2 continued)

(c) How would the appearance of the bright and dark fringes change if a white light source was used? Explain why this change occurs. *[3]*

. . . .

. . . .

. . . .

. . . .

(d) Which model of light is most appropriate to understanding the phenomenon described in (a)? *[1]*

. . . .

. . . .

. . . .

. . . .