INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

PHYSICS

Higher Level

Monday 8 November 1999 (morning)

Paper 3 — 1 hour 15 minutes

A

Candidate name:	Candidate category & number:

This examination paper consists of 5 options.
The maximum mark for each option is 30.
The maximum mark for this paper is 60.

INSTRUCTIONS TO CANDIDATES

Write your candidate name and number in the boxes above.

Do NOT open this examination paper until instructed to do so.

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
/30	/30
/30	/30
TOTAL /60	TOTAL /60

D

IBCA
/30
/30
TOTAL /60

EXAMINATION MATERIALS

Required:
Calculator
Physics HL Data Booklet

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

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]*

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

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D2. Poiseuille's equation is often used in calculations relating 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]*

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(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]*

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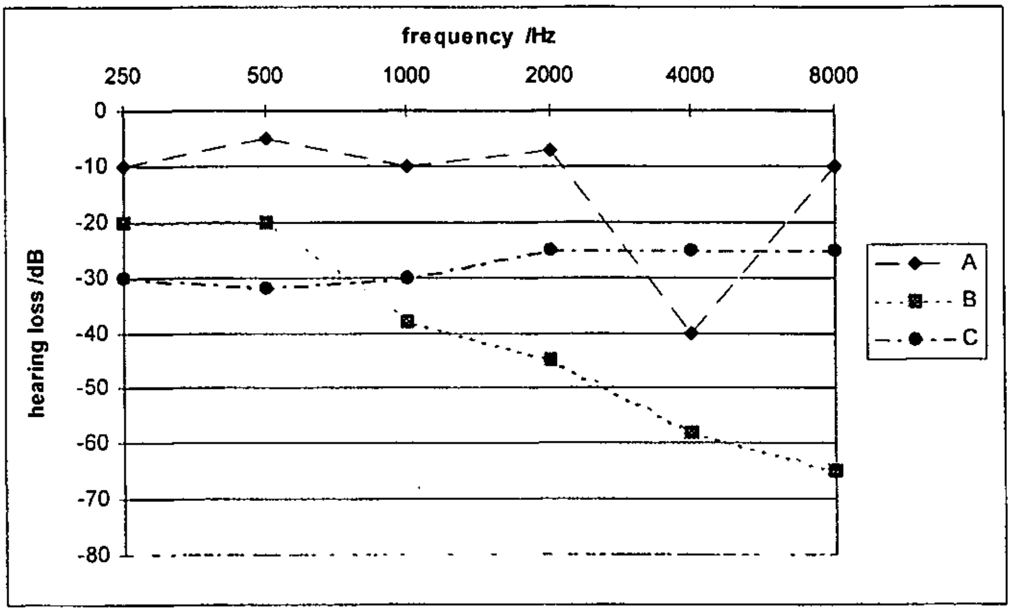
D3. Three air conduction audiograms, for three different patients, are shown below. Each patient shows some form of hearing loss.



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

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(b) State and **give reasons to explain** which of the above patients could be suffering from *[5]*

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

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

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(iii) hearing loss associated with noise exposure.

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D4. Radioactive tracers are used in medical research and many diagnostic procedures.

(a) Explain what is meant by a 'radioactive tracer' and why they are useful. *[2]*

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(b) In measurements of blood volume, a tracer substance is injected into the patient's blood. After about 15 minutes the tracer will have spread uniformly thoughout the circulatory system. A blood sample is then removed from a vein and the count rate is compared to that from a standard sample of the tracer.

The table below presents half-life and decay mode data for three nuclides. Assume that all can be safely used from a chemical stand point *i.e.* none are 'poisonous'.

^{99}Tc	6.0 hours	gamma
^{90}Sr	28.8 years	beta
^{223}Fr	21.8 minutes	alpha, beta, gamma

On the basis of the above data, select the most appropriate nuclide to act as a radioactive tracer for the blood volume measurements. State the reasons for your selection and why the others are rejected. *[3]*

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(Question D4 continued)

(c) When radioactive isotopes are used to study physiological processes that take many hours or days, the biological half-life must be considered as well as the physical half-life.

(i) Explain what is meant by *biological half-life*. *[2]*

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(ii) A radioactive tracer with a 12 hour physical half-life is injected into a patient. The substance involved has a 24 hour biological half-life. What proportion of the radioactive nuclide will still be present in the patient's body after 24 hours? *[2]*

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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]*

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(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]*

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(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]*

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(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
Moon's period	=	27.3 days

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

(i) 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. *[2]*

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(ii) Calculate the centripetal acceleration required for the Moon to maintain its orbit. *[3]*

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(iii) In order for Newton to arrive at the conclusion he did, what must be true about the two accelerations calculated in (i) and (ii) above? *[1]*

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E2. The first quantitative determination of what is known as 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]*

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(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]*

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(ii) Sketch and label a piece of apparatus that would be appropriate for investigating the mechanical equivalent of heat. State the **two** quantities that Joule needed to measure in this experiment. *[4]*

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(Question E2 continued)

(iii) Give **two** sources of experimental uncertainty that Joule needed to minimise. Explain how these uncertainties would have affected the quantities he needed to measure. *[4]*

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E3. The following two tables summarise some of the properties of the neutron, proton, electron and antineutrino and of two quarks.

(You may find some of the data useful in answering this question.)

particle name	**charge**	**baryon number**	**lepton number**
neutron (n)	0	1	0
proton (p^+)	1	1	0
electron (e^-)	–1	0	1
antineutrino ($\bar{\nu}$)	0	0	–1

quark name ('flavour')	**charge**	**baryon number**	**lepton number**
up (u)	2/3	1/3	0
down (d)	–1/3	1/3	0

(a) What are the quarks making up a neutron? *[2]*

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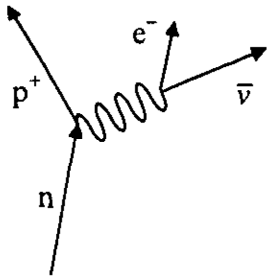
(Question E3 continued)

(b) The diagram below shows the decay of a free neutron as mediated by the intermediate, short-lived W particle, which is represented by the wavy line.



(i) What fundamental interaction is involved in this decay process? *[1]*

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(ii) What must be the charge, baryon number and lepton number of the W particle? *[3]*

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(iii) In terms of the current quark model of nucleon structure, what changes have taken place in the internal make up of the neutron to change it into a proton? *[2]*

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OPTION F—ASTROPHYSICS

Answer ALL questions in this option.

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

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

(b) (i) What property of a star determines whether it ultimately becomes a black hole, a neutron star or a white dwarf? *[1]*

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(ii) Describe the last stages of our sun's evolution **after** it has entered the red giant stage and explain which **one** of the three objects above it is expected to form. *i.e.* will it end up as a black hole, a neutron star or a white dwarf? *[4]*

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

When light from a star is passed through a spectrometer and recorded, a continuous spectrum is observed with a number of dark lines across it.

(a) Explain the origin of the dark lines. What can we learn about the stars from these? *[3]*

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(b) (i) 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. What is the reason for this apparent shift in wavelength? *[2]*

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(ii) If the wavelength of such a dark line was measured to be 3.0 % greater than the wavelength **measured on Earth**, what can be deduced from this measurement? *[4]*

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

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F3. This question is about Wien's displacement law and the 3 K 'background' radiation.

(a) Wien's displacement law states that $\lambda_p = \frac{2.90 \times 10^{-3}}{T}$ metres.

What is λ_p and what does this law tell us when applied to the study of stellar spectra? Explain, using one or more sketches. *[3]*

(b) Using Wien's displacement law, calculate the dominant wavelength for the 3 K 'background' radiation. Name the spectral region in which this radiation occurs and state what type of telescope is used for its observation. *[3]*

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

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(Question F3 continued)

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

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

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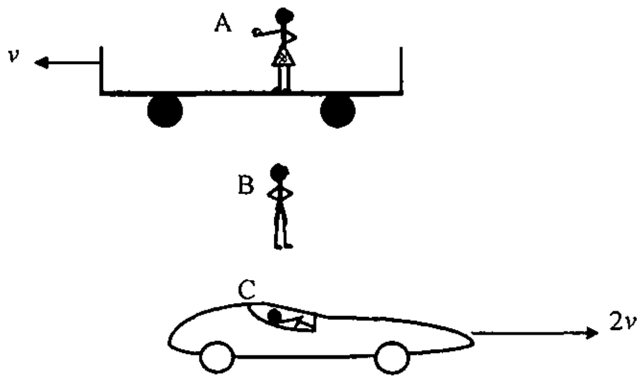
OPTION G—SPECIAL AND GENERAL RELATIVITY

Answer ALL questions in this option.

G1. Consider three observers A, B and C as shown in the figure below. Observer A is in an open rail carriage moving smoothly at a constant velocity $-v$ relative to observer B. Observer C is 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 a ball.

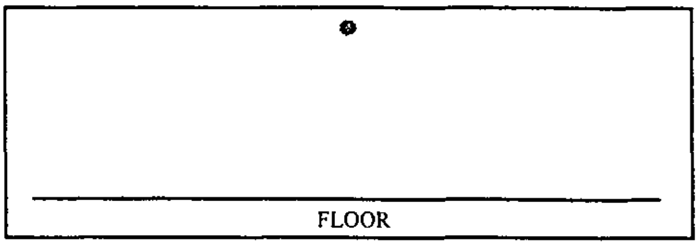
Observer A measures the time taken for the ball to fall to the floor to be 0.50 s.



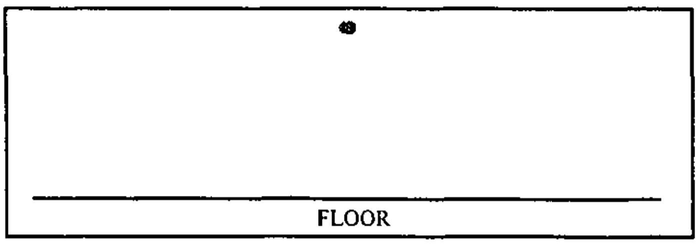
(a) Suppose v and $2v$ to be 'everyday' low speeds, say 2 and 4 m s^{-1} respectively. Complete the figures below by sketching the trajectory of the ball until the time it hits the carriage floor, as measured with respect to all **three** observers. Neglect air drag.

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

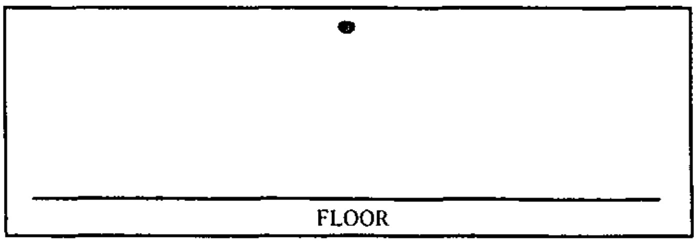
with respect to observer A



with respect to observer B



with respect to observer C



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(Question G1 continued)

(b) Suppose that the speeds of A and C relative to observer B were relativistic, say 0.40c and 0.80c respectively. Calculate the velocity of B and the velocity of C relative to A. *[4]*

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(c) For the relativistic case in (b) above, what time interval would observer B measure for the ball to fall to the floor? *[3]*

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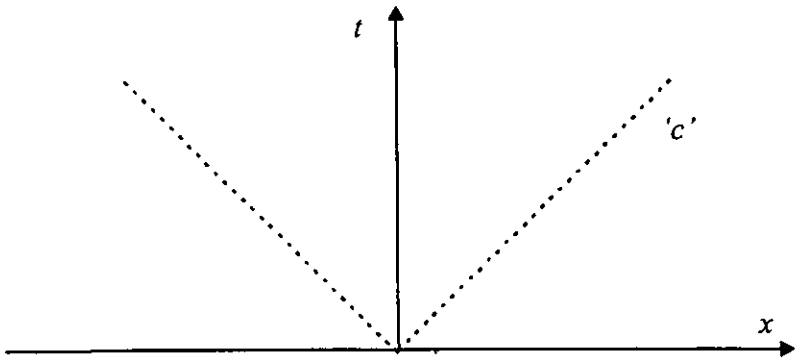
(d) For the relativistic case in (b) above, on the axes below, sketch the spacetime paths of observers B and C from the **point of view of observer A**. The dashed lines marked '*c*' represent the speed of light. *[3]*



(e) For the relativistic case in (b) above, describe how you would expect the **three** trajectories determined in (a) to change, if at all. *[2]*

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G2. (a) The $^{14}_{6}$ carbon nucleus is radioactive and decays according to

$$^{14}C \rightarrow \ ^{14}N + \beta^- + \bar{\nu}$$

Show that the energy released in this disintegration process is 0.157 MeV. This energy is shared between the ^{14}N, the β^- and the $\bar{\nu}$.

The **atomic** mass of ^{14}C is 14.003242 u and that for ^{14}N is 14.003074 u. *[3]*

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(b) (i) Suppose that half of the energy released in the above decay goes to the emitted β^-. What is the ratio of the kinetic energy of the β^- to its rest mass energy? *[2]*

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(ii) What is the speed of the beta particle? *[3]*

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G3. 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]*

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

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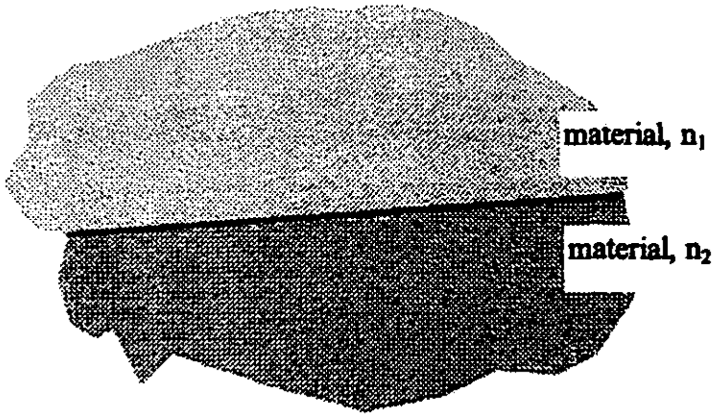
OPTION H—OPTICS

Answer ALL questions in this option.

H1. (a) The figure below shows two materials in contact. Their refractive indices are n_1 and n_2, with $n_2 > n_1$. Use this figure to help explain the phenomenon of *total internal reflection*. (Draw the paths of light rays incident at different angles upon the boundary). *[3]*



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(b) In high quality optical instruments, total internal reflection is often used to reflect a beam or ray of light rather than simple reflection off a mirror. Why is total internal reflection preferable? *[1]*

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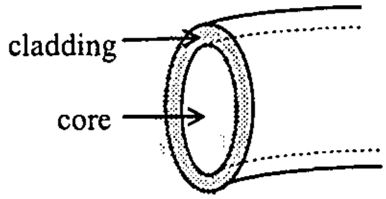
(Question H1 continued)

(c) In the fabrication of an optic fibre the central core material is covered by a thin layer of similar material, the cladding, of slightly lesser refractive index, as shown in the figure below.



Why is a cladding used and why is the refractive index of the cladding only **slightly** less than that of the core? *[3]*

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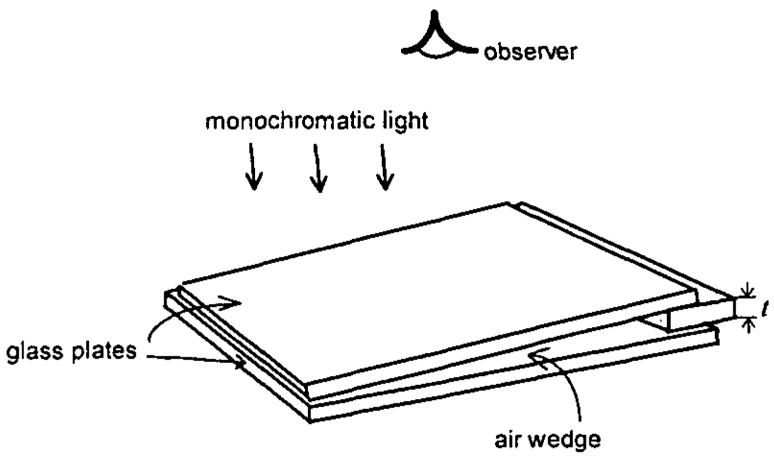
H2. (a) When monochromatic light illuminates a thin wedge of air formed between two very flat glass plates a series of bright and dark bands are observed.

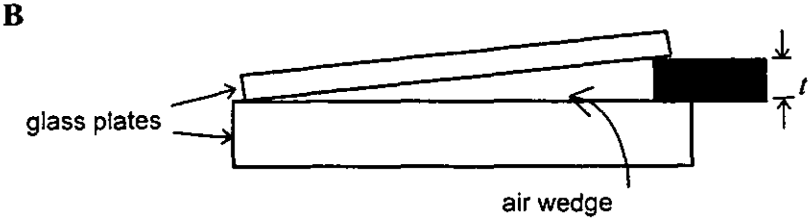
(i) Use **Diagram A** below to show some bright and dark bands as they would appear to the observer. *[1]*

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



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(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]*

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(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]*

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

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H3. **Figure A** below shows a simple camera. It has a single, thin lens, fixed in position so as to produce a clear image of a distant object on the film as shown in **Figure B**. The lens to film distance is 35.0 mm.

Figure A

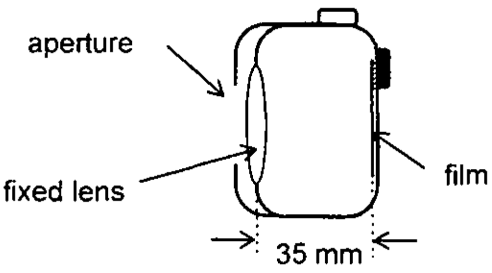
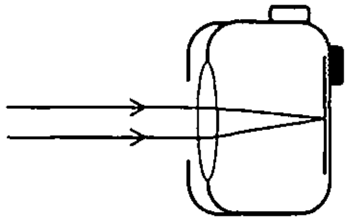


Figure B



(a) If the aperture is reduced the image of a distant object becomes even sharper. Using a diagram explain why this is so. *[3]*

(b) What is the focal length of the lens? *[1]*

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(c) If a 'close up' photograph was taken the image would not be focused on the film. In a camera where the lens is adjustable, the lens would be moved to bring the image into focus. Suppose an object is at a distance of 1.20 m from the lens, calculate by how much the lens would need to be moved. *[3]*

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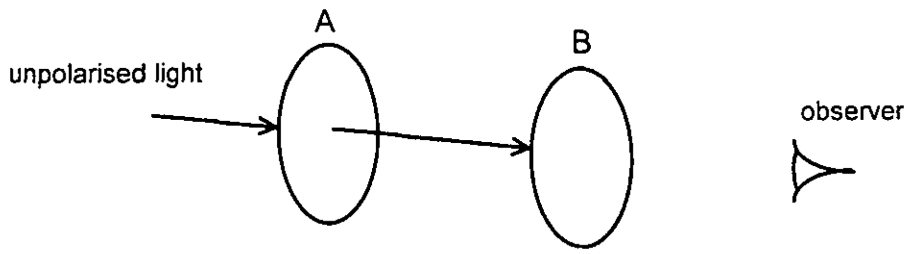
H4. (a) The figure below shows two sheets of Polaroid. A ray of unpolarised light is shown incident on sheet A but an observer viewing the sheets from behind sheet B, as shown below, cannot see any light.

Explain this observation. *[3]*



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(b) Polaroid A is held stationary while Polaroid B is rotated about its axis through 360°. On the axes below sketch a graph to show the variation of light intensity, I, as seen by the 'observer', with the angle of rotation, θ, of sheet B. *[3]*

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