INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

PHYSICS
HIGHER LEVEL
PAPER 3

Tuesday 20 November 2001 (morning)

1 hour 15 minutes

Name

Number

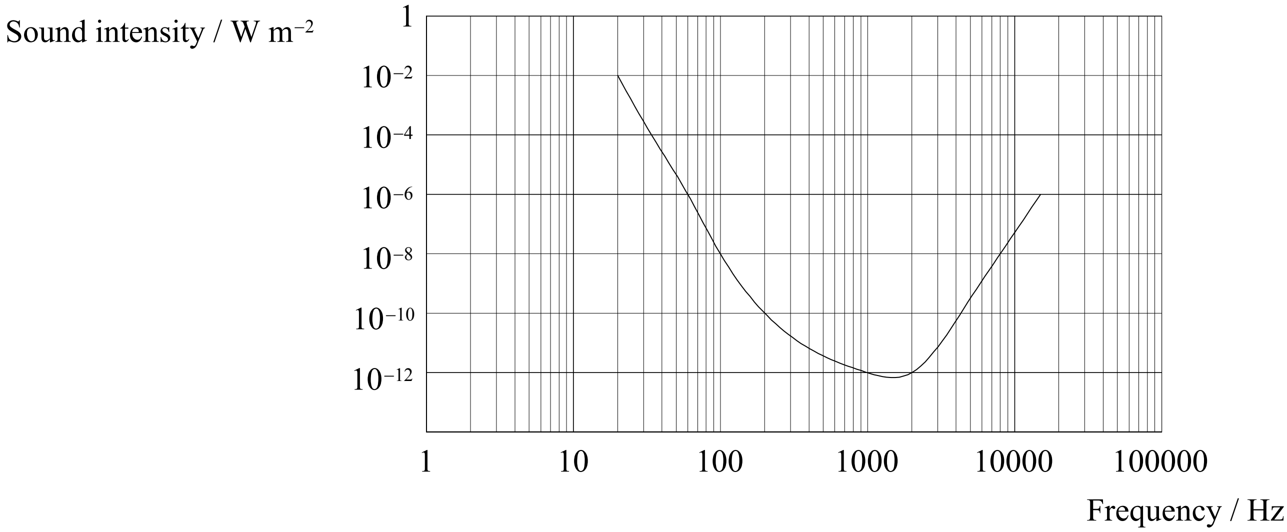
INSTRUCTIONS TO CANDIDATES

- 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, indicate the letters of the Options answered in the boxes below.

OPTIONS ANSWERED	EXAMINER	TEAM LEADER	IBCA
	/30	/30	/30
	/30	/30	/30
	TOTAL /60	TOTAL /60	TOTAL /60

OPTION D — BIOMEDICAL PHYSICS

D1. The diagram below shows how the typical threshold of hearing varies with frequency for a normal young person.



[Source: Martin Hollins, *Medical Physics*, Figure 3.4, page 44]

(a) Outline how the data for this graph could be obtained. *[3]*

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(b) To what approximate frequency of sound is the ear most sensitive? *[1]*

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(c) Over what range of frequencies is a sound of intensity 10^{-10} W m^{-2} audible? *[1]*

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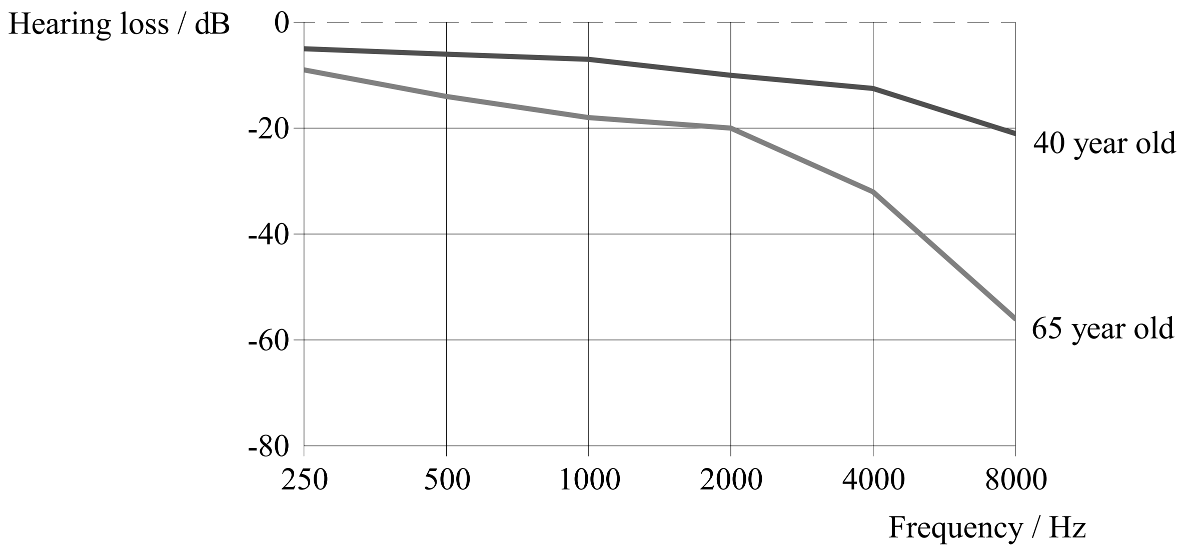
(Question D1 continued)

The diagram below shows typical audiograms for people aged 40 and 65, whose loss of hearing is due only to ageing.



(d) Use the information in the diagram to describe the changes in hearing that take place due to ageing. *[2]*

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(e) For a 65 year old person, what is the sound intensity in $W\ m^{-2}$ that is just audible at a frequency of 2000 Hz? *[3]*

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(f) Should a hearing aid for a 65 year old amplify all frequencies equally? Explain your answer. *[2]*

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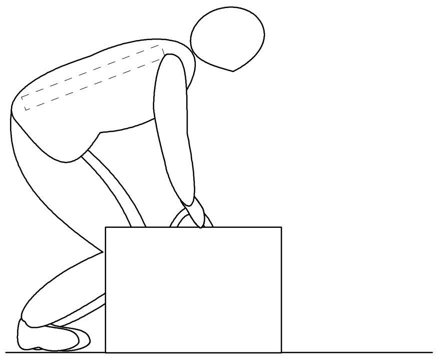
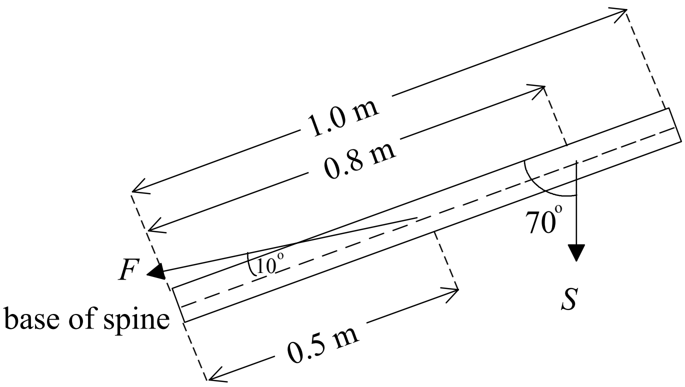
D2. When a person lifts a suitcase, the spine experiences large extra forces. In a simplified model of the situation, the spine can be treated as a rigid rod.



In this model, when the suitcase is lifted, three extra forces act on the spine which need to be in equilibrium.

- The additional force due to lifting the suitcase, *S*.
- The additional force from the muscles, *F*.
- The additional force on the base of the spine, *R*.

The diagram below shows the directions and points of action of *S* and *F*, but not *R*.



(a) State the **two** conditions for *S*, *F*, and *R* to be in equilibrium. *[2]*

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(b) Add an arrow to the diagram to show the approximate direction of *R*, the additional force on the base of the spine. *[2]*

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(Question D2 continued)

(c) Write down an expression for the torque about the base of the spine due to the force S. *[2]*

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(d) Show that the force F is approximately nine times the force S, *i.e.* the muscle force is nine times the weight of the suitcase being lifted. *[2]*

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D3. Radioisotopes can be introduced into the body for **imaging** or for **therapy**. One common radioisotope is Iodine-131.

(a) Explain the difference between **biological** half-life and **physical** half-life of a radioisotope. *[2]*

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(b) A sample of a compound of Iodine-131 is administered to a patient. The physical half-life of Iodine-131 is 8 days whereas the biological half-life of this compound is about 20 days. What percentage activity will remain after 40 days? *[3]*

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(c) If a patient receives the same **absorbed dose** from two different sources they would not necessarily receive the same **dose equivalent**. Explain what is meant by the terms **absorbed dose** and **dose equivalent**. Explain how they are related. *[3]*

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(d) Outline **two** precautions necessary when introducing radioisotopes into the body. *[2]*

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OPTION E — HISTORICAL PHYSICS

E1. Aristotle's and Galileo's theories of motion provide different ways of explaining some everyday observations. The different theories sometimes make different predictions.

In the following situations, outline how Aristotle's and Galileo's theories of motion would be applied in order to answer the question.

(a) Why does a stone fall to the ground if released, whereas smoke rises up in the air? *[3]*

Aristotle

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Galileo

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(b) What would happen if a 10 kg object and a 100 kg object were dropped from the same height above the ground at the same time? *[2]*

Aristotle

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Galileo

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(Question E1 continued)

(c) What are the forces that act on a cannon ball after the cannon has been fired and the cannon ball is moving through the air? *[2]*

Aristotle

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Galileo

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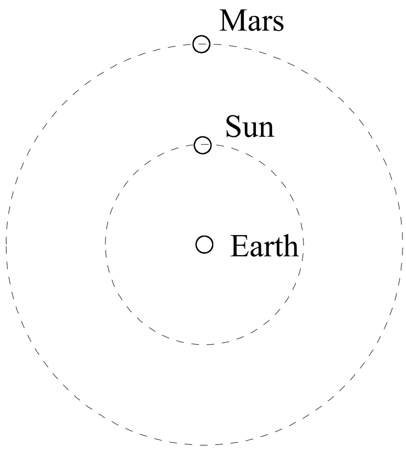
E2. Different models of the Universe have been able to explain the observed motions of the Sun, stars and planets. The diagram below represents part of a simple Geocentric model as proposed by Ptolemy.



(a) Show on the diagram the position of Venus **and** the stars according to this model. *[3]*

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(b) The planet Mars is observed to show retrograde motion. Explain, with the aid of the above diagram, how Ptolemy accounted for this retrograde motion. *[2]*

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E3. At the beginning of the eighteenth century, scientists thought of heat as a fluid.

(a) What was the name given to this fluid? *[1]*

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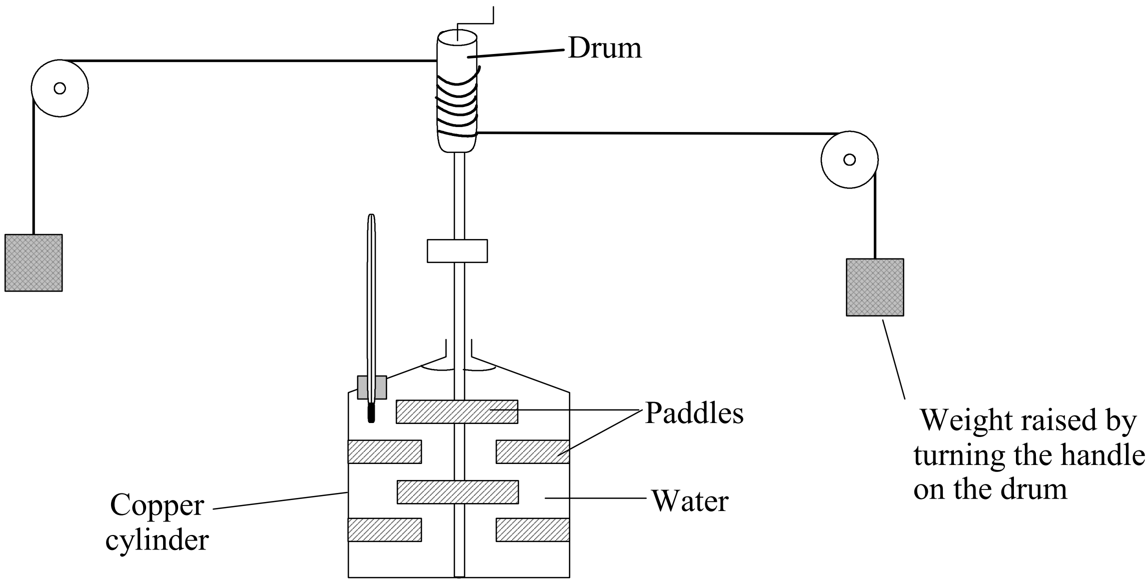
(b) The diagram below represents the apparatus used by Joule in an experiment that helped to change the way in which scientists thought about heat. The experiment was repeated many times before a conclusion was reached.



(i) What was the aim of the experiment? *[1]*

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(ii) List all the measurements that were recorded. *[4]*

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(iii) In what way did the results of this experiment change scientists' views about the nature of heat? *[2]*

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E4. Over the years, the **second law of thermodynamics** has been stated in many different forms. In 1865 Clausius published a famous paper on the thermodynamics of bodies in which he identified an important quantity, *S*, which was linked to the quantity of heat, *Q*, and the absolute temperature, *T*. He proposed a name for this quantity based on a word that meant 'transformation'. His paper concluded with a simple statement of the second law of thermodynamics.

(a) What name did he propose for the new quantity? *[1]*

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(b) State the second law of thermodynamics in terms of this quantity. *[1]*

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(c) Outline the contribution made by Boltzmann, eleven years later, to the interpretation of this quantity. *[2]*

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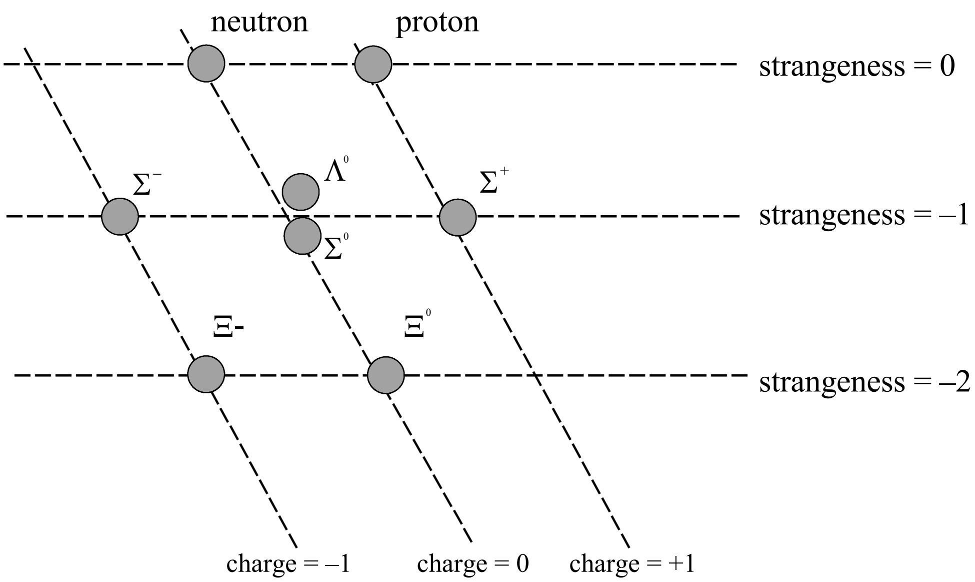
E5. One example of the success of organisational principles in science is Gell-Mann's 'eight fold way' which led to the development of quark theory.

The diagram below shows how eight baryons (each of **baryon number = +1**) can be grouped together according to **charge** and **strangeness**.



According to quark theory, each of these baryons are made up of **three** quarks. The properties of some quarks are given in the table below. Other types of quarks are known to exist.

Type of quark	Charge	Strangeness	Baryon number
u	$+\frac{2}{3}$	0	$+\frac{1}{3}$
d	$-\frac{1}{3}$	0	$+\frac{1}{3}$
s	$-\frac{1}{3}$	–1	$+\frac{1}{3}$
$\bar{u}$	$-\frac{2}{3}$	0	$-\frac{1}{3}$
$\bar{d}$	$+\frac{1}{3}$	0	$-\frac{1}{3}$
$\bar{s}$	$+\frac{1}{3}$	+1	$-\frac{1}{3}$

(a) What is the quark composition of the Σ^+ particle? Explain your answer. *[3]*

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(Question E5 continued)

(b) Name the interaction **and** the associated exchange particle that binds these quarks together in the Σ^+ particle. *[2]*

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(c) Name the **three** other types of quark that are known to exist. *[1]*

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OPTION F — ASTROPHYSICS

F1. The table below gives information about two nearby stars.

Star	**Apparent magnitude**	**Distance away / ly**
Fomalhaut (α-Piscis Austrini)	1.2	22
Aldebaran (α-Tauri)	0.9	68

(a) To an observer on Earth which star would appear brighter? Justify your answer. *[2]*

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(b) Explain the difference between **apparent** and **absolute** magnitudes. *[2]*

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(c) Which star would have the lowest numerical value for **absolute** magnitude? Explain your answer. *[2]*

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(d) The parallax angle for Fomalhaut is 0.148 arcseconds. Confirm that its distance away is 22 ly. *[2]*

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(e) Would you expect Aldebaran to have a greater or smaller parallax angle than Fomalhaut? Explain your answer. *[2]*

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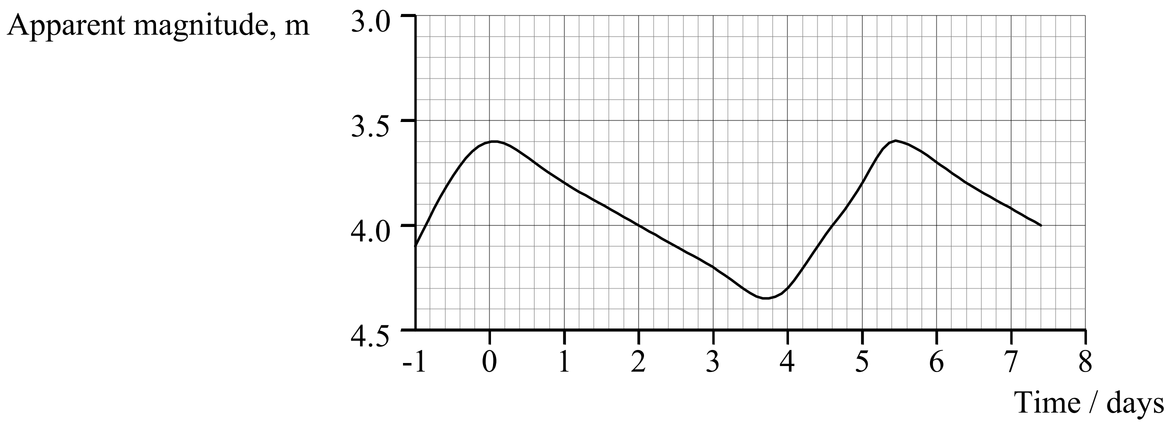
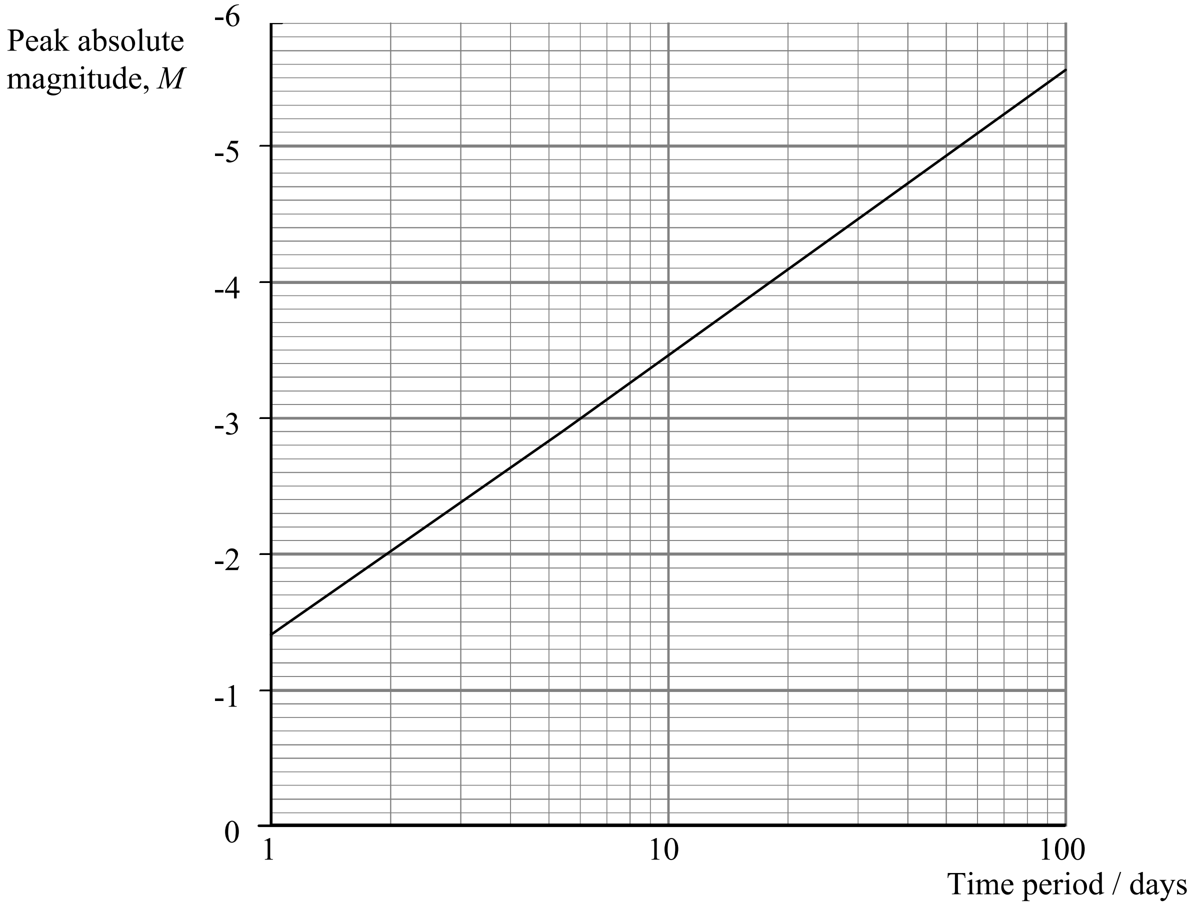
(Question F1 continued)

Another method of determining stellar distances involves a class of variable stars called *Cepheid variables*. One of the first Cepheid variable stars to be studied is δ-Cephei. Its apparent magnitude varies over time as shown below:



[Source: Collins Gem, *Night Sky*, page 83]

There is a relationship between peak absolute magnitude, M, and the time period of the variation in magnitude as shown below:



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(Question F1 continued)

(f) Use the data above to estimate the peak **absolute** magnitude M for δ-Cephei. *[2]*

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(g) The relationship between peak absolute magnitude M, apparent magnitude m and distance d is given by the following equation:

$$m - M = 5\log_{10}\left(\frac{d}{10\,pc}\right)$$

Use this equation to calculate the distance to δ-Cephei. *[3]*

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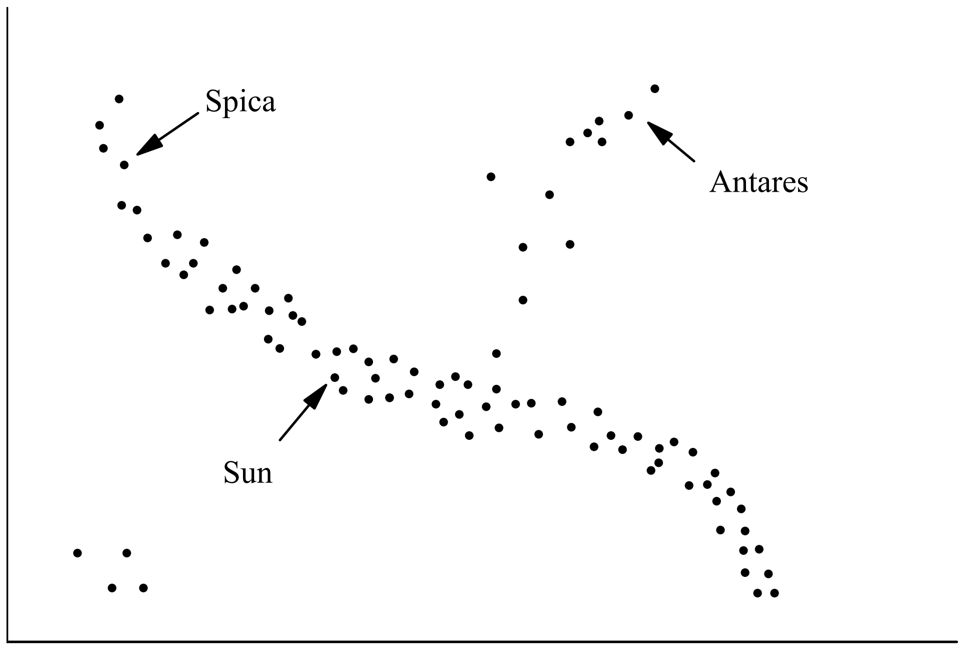
F2. The diagram below represents a simplified Hertzsprung-Russell diagram with two particular stars (Spica and Antares) and the Sun identified.



(a) Label the axes. *[2]*

(b) How does Spica compare with our Sun in the following respects? Explain your reasoning.

(i) Surface temperature. *[1]*

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(ii) Mass. *[1]*

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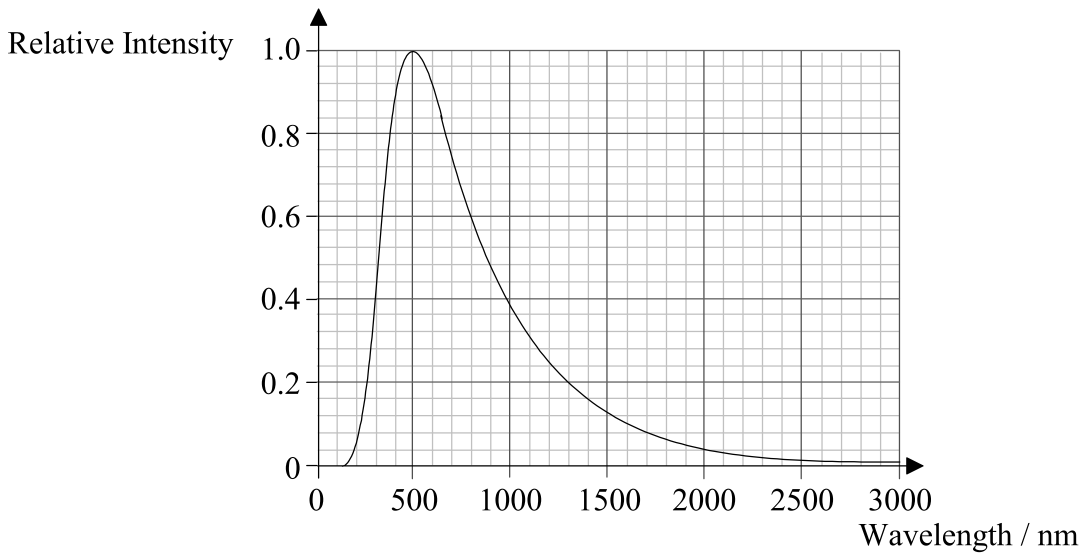
(Question F2 continued)

(c) The spectrum of light from the Sun is shown below.



[Source: Dobson, Grace and Lovett, *Physics*, page 623]

Use this spectrum to estimate the surface temperature of the Sun. *[2]*

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(d) Outline how the following quantities can, in principle, be determined from the spectrum of a star.

(i) The elements present in its outer layers. *[2]*

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(ii) Its speed relative to the Earth. *[2]*

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(Question F2 continued)

(e) Describe the likely differences between the nuclear processes taking place in Spica and Antares. *[2]*

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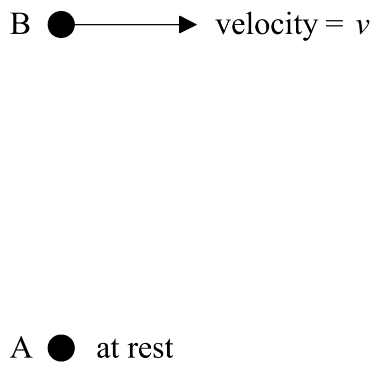
(f) Show on the Hertzsprung-Russell diagram the path taken by Spica as it ‘evolves’ from a main sequence star to its final state. Name and label the separate evolutionary stages. *[3]*

OPTION G — SPECIAL AND GENERAL RELATIVITY

G1. Two inertial observers, A and B, agree to compare their measurements of time. They each carry an accurate clock. During the experiment, A observes B to be moving at a constant velocity, *v*, as shown below.



A and B observe two events. For the first event B measured a **proper time** of 6 seconds while A measured 10 seconds.

(a) What is meant by **proper time**? *[1]*

(b) Calculate the time dilation factor, γ, for B's clock as observed by A. *[1]*

(c) According to A, how fast is B moving in order to give this time dilation factor? *[2]*

(d) According to B, how fast is A moving? *[1]*

(This question continues on the following page)

(Question G1 continued)

(e) The second event is at rest with respect to observer A. Observer B measures 6 seconds for this event. What time interval does A measure? *[3]*

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(f) Which version of time is ‘correct’? Explain your answer. *[2]*

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G2. In a laboratory experiment two identical particles (P and Q), each of rest mass m_0, collide. In the **laboratory frame of reference**, they are both moving at a velocity of 2/3 c. The situation before the collision is shown in the diagram below.

Before:

(a) In the laboratory frame of reference,

(i) what is the **total momentum** of P and Q? *[1]*

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(ii) what is the **total energy** of P and Q? *[3]*

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(Question G2 continued)

The same collision can be viewed according to **P’s frame of reference** as shown in the diagrams below.

Before:

(b) In P’s frame of reference,

(i) what is Q’s velocity, v? *[3]*

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(ii) what is the **total momentum** of P and Q? *[3]*

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(iii) what is the **total energy** of P and Q? *[3]*

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(c) As a result of the collision, many particles and photons are formed, but the total energy of the particles depends on the frame of reference. Do the observers in each frame of reference agree or disagree on the number of particles and photons formed in the collision? Explain your answer. *[2]*

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G3. One prediction of the General Theory of Relativity is **gravitational redshift**. Explain what is meant by the term gravitational redshift **and** outline an experiment that demonstrates the effect. *[5]*

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OPTION H — OPTICS

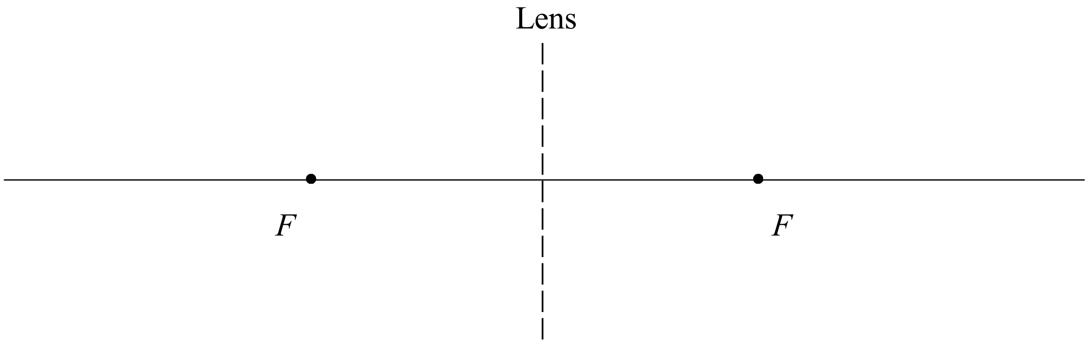
H1. A student uses a single **converging** lens of focal length 12 cm to produce a magnified **virtual** image.

(a) Show the approximate arrangement of object, lens and eye in order to produce this type of image. Add rays to the diagram, and label the

(i) object.

(ii) image.

(iii) eye. *[4]*



(b) If the object height is 1.5 cm and linear magnification is +2.0, calculate

(i) the height of the image. *[1]*

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(ii) the distance from the lens to the object. *[2]*

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(Question H1 continued)

(c) If the lens was slowly moved **away** from the object, would the magnification increase or decrease initially? Explain. *[2]*

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(d) Where would the image be formed if the object were placed at the focal length? Explain. *[2]*

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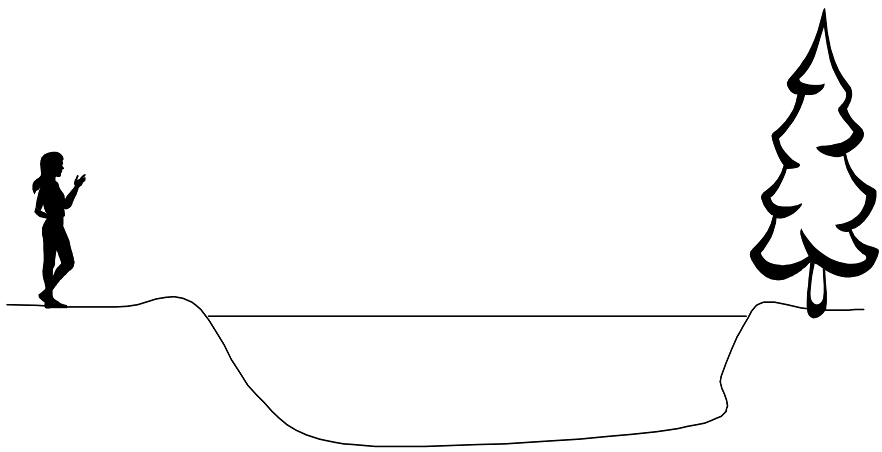
H2. Caroline is looking into a pond as shown below. A tree is located on the far side of the pond. When she looks in **one particular direction**, she can see the bottom of the pond as well as the reflection of the top of a tree on the far side of the pond.



(a) Add rays to the diagram to show how light arrives at her eyes from

(i) the tree top.

(ii) the bottom of the pond. *[2]*

She notices that the bottom of the pond becomes clearer when she puts on **Polaroid sunglasses**.

(b) Explain why. *[3]*

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H3. Light can behave both as a particle and as a wave. Outline an experiment that demonstrates

(a) the particle nature of light. *[2]*

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(b) the wave nature of light. *[2]*

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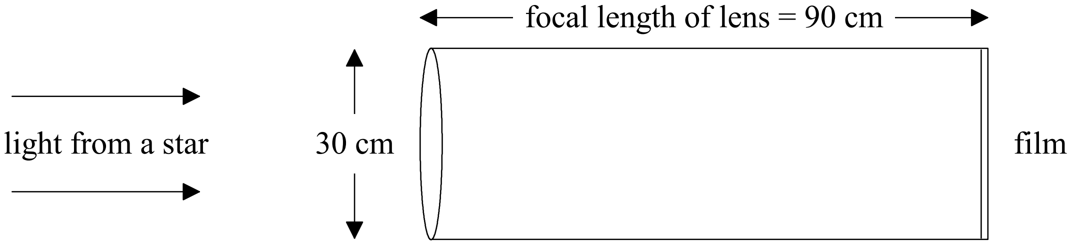
H4. A telescope is used to produce a photographic image of a star in the night sky. Light from a single star enters the lens aperture and is focussed by the lens on to the film as shown below.



The light from the star is brought to a focus by the circular lens.

(a) Sketch and describe the appearance of the image of the star on the film as a result of diffraction at the lens aperture. Assume that the star is effectively a point source of light. *[3]*

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(Question H4 continued)

(b) If the wavelength of light received from the star is 450 nm, calculate the angle at which the first minimum of the diffraction pattern is found. *[2]*

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(c) Calculate the diameter in μm of the central maximum on the photographic film. *[2]*

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(d) The telescope is used to view a binary star (*i.e.* two separate stars that orbit each other). The two stars are just resolved as separate images by the telescope.

(i) State the Rayleigh criterion for the stars to be just resolved. *[1]*

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(ii) If the stars are 10^{20} m from the Earth, what is the separation of the stars? *[2]*

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