INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

N01/430/S(3)

PHYSICS
STANDARD LEVEL
PAPER 3

Tuesday 20 November 2001 (morning)

1 hour

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
	/20	/20	/20
	/20	/20	/20
	TOTAL /40	TOTAL /40	TOTAL /40

OPTION A — MECHANICS EXTENSION

A1. In our Solar system, the Moon orbits the Earth while the Earth orbits the Sun. Both orbits are approximately circular.

The following diagram is not to scale.

The following tables give the masses of the Sun, Earth and Moon and their distances apart:

Body	**Mass / kg**
Sun	1.99×10^{30}
Earth	5.98×10^{24}
Moon	7.35×10^{22}

Measurement	**Radius of orbit / m**
Average distance from Sun to Earth (and Moon):	1.50×10^{11} m
Average distance from Earth to Moon:	3.84×10^{8} m

(a) State Newton's law of universal gravitation. *[2]*

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(This question continues on the following page)

(Question A1 continued)

(b) On the diagram opposite add **two** arrows to show the direction of the forces which act on the Moon. *[2]*

(c) Calculate the ratio:

$$\frac{\text{gravitational force on the Moon due to the EARTH}}{\text{gravitational force on the Moon due to the SUN}}$$ *[3]*

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(d) If the Earth was not present, what would be the motion of the Moon? Explain your answer. *[3]*

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A2. A white billiard ball moving at $0.5\ \text{m s}^{-1}$ strikes a stationary black billiard ball. See Diagram 1. As a result of the collision, the white ball changes its direction of motion by 30° and its speed becomes $0.2\ \text{m s}^{-1}$. See Diagram 2.

The mass of each billiard ball is 200 g.

Before:

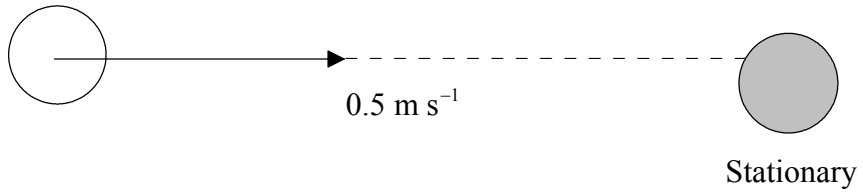

Diagram 1

After:

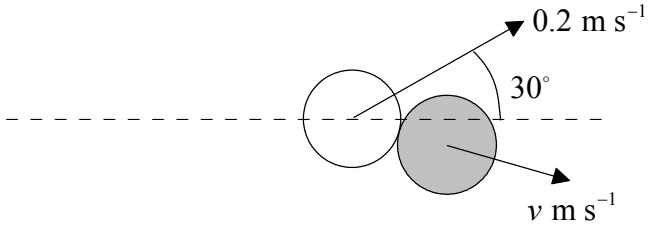

Diagram 2

(a) On Diagram 2, add an arrow to show the direction of the **total momentum** of the two billiard balls after the collision. *[1]*

(b) Calculate the *speed* **and** the *direction* of the black ball after collision. *[6]*

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(Question A2 continued)

(c) Calculate the energy lost in the collision. *[3]*

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OPTION B — ATOMIC AND NUCLEAR PHYSICS EXTENSION

B1. A **transmission electron microscope** uses the wave properties of electrons to study things too small to be observed using an optical microscope. A potential difference is used to accelerate the electrons into a beam.

If the de Broglie wavelength of the electrons in a particular beam is 1.0×10^{-10} m,

(a) calculate the momentum of an electron in the beam. *[2]*

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(b) calculate the kinetic energy of an electron in the beam. *[3]*

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(c) calculate the accelerating potential difference. *[2]*

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(d) On the axes below, sketch a qualitative graph to show how the wavelength of the beam varies with accelerating potential difference. The general shape is all that is required, without the values. *[3]*

B2. Carbon-15 and Nitrogen-15 both have the same mass number and in principle can transform into each other as shown below:

Reaction I: $^{15}_{6}\mathrm{C} \rightarrow ^{15}_{7}\mathrm{N} + ^{0}_{-1}\beta + \bar{\upsilon}$

Reaction II: $^{15}_{7}\mathrm{N} \rightarrow ^{15}_{6}\mathrm{C} + ^{0}_{+1}\beta + \upsilon$

Their nuclear masses are given in the table below:

Isotope	**Nuclear mass / u**
Carbon-15, $^{15}_{6}\mathrm{C}$	15.007 306
Nitrogen-15, $^{15}_{7}\mathrm{N}$	14.996 265

(a) Explain, without doing any calculations, which reaction can take place spontaneously. *[2]*

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(b) Calculate the energy released in the spontaneous reaction. *[4]*

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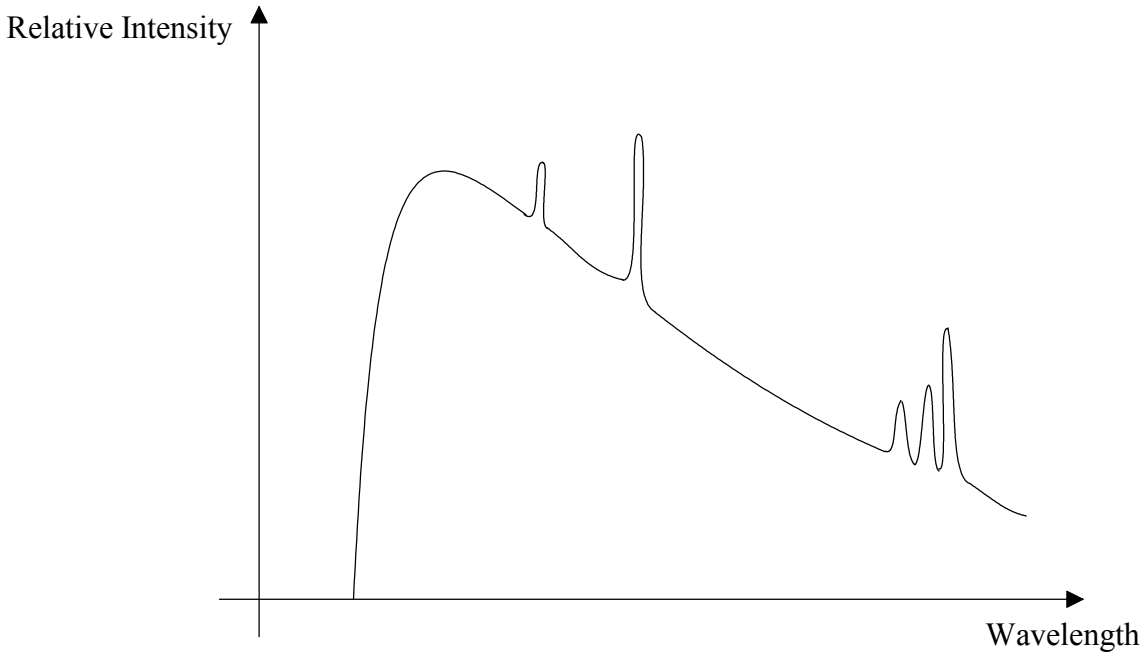
B3. When electrons are accelerated through a potential difference and strike a metal target, the following X-ray spectrum is produced.



(a) Label the **characteristic** part of the spectrum. *[1]*

(b) Explain the mechanism of how the **characteristic** part of the spectrum is produced. *[3]*

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OPTION C — ENERGY EXTENSION

C1. A wind generator converts wind energy into electric energy. The source of this wind energy can be traced back to solar energy arriving at the Earth's surface.

(a) Outline the energy transformations involved as solar energy converts into wind energy. *[2]*

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(b) List **one** advantage and **one** disadvantage of the use of wind generators. *[2]*

Advantage:

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Disadvantage:

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The expression for the maximum theoretical power, P, available from a wind generator is

$$P = \frac{1}{2} A \rho v^3$$

where A is the area swept out by the blades,
ρ is the density of air and
v is the wind speed.

(c) Calculate the maximum theoretical power, P, for a wind generator whose blades are 30 m long when a 20 m s^{-1} wind blows. The density of air is 1.3 kg m^{-3}. *[2]*

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(Question C1 continued)

(d) In practice, under these conditions, this generator only provides 3 MW of electrical power.

(i) Calculate the efficiency of this generator. *[2]*

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(ii) Give **two** reasons explaining why the actual power output is less than the maximum theoretical power output. *[2]*

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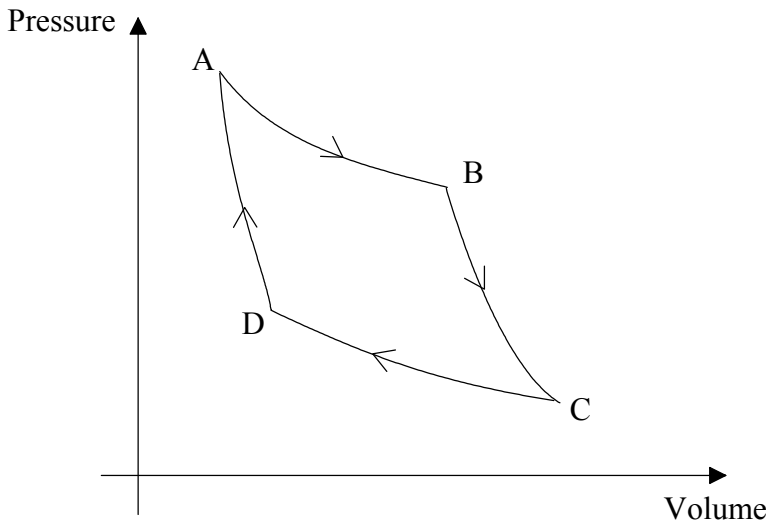
C2. The diagram below shows an ideal gas in a heat engine undergoing a Carnot cycle.



(a) Which labelled parts of the cycle are

(i) isothermal? *[1]*

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(ii) adiabatic? *[1]*

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(b) In which processes is work done **by** the gas? *[1]*

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(c) The isothermal processes take place at 200 °C and 400 °C. What is the theoretical maximum efficiency of this engine? *[2]*

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(Question C2 continued)

(d) In one of the processes, 1000 J of energy is absorbed from a hot reservoir.

(i) During which process does this absorption of energy take place? *[1]*

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(ii) Calculate the work output in the cycle. *[2]*

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(iii) Calculate the energy ejected into the cold reservoir during the cycle. *[2]*

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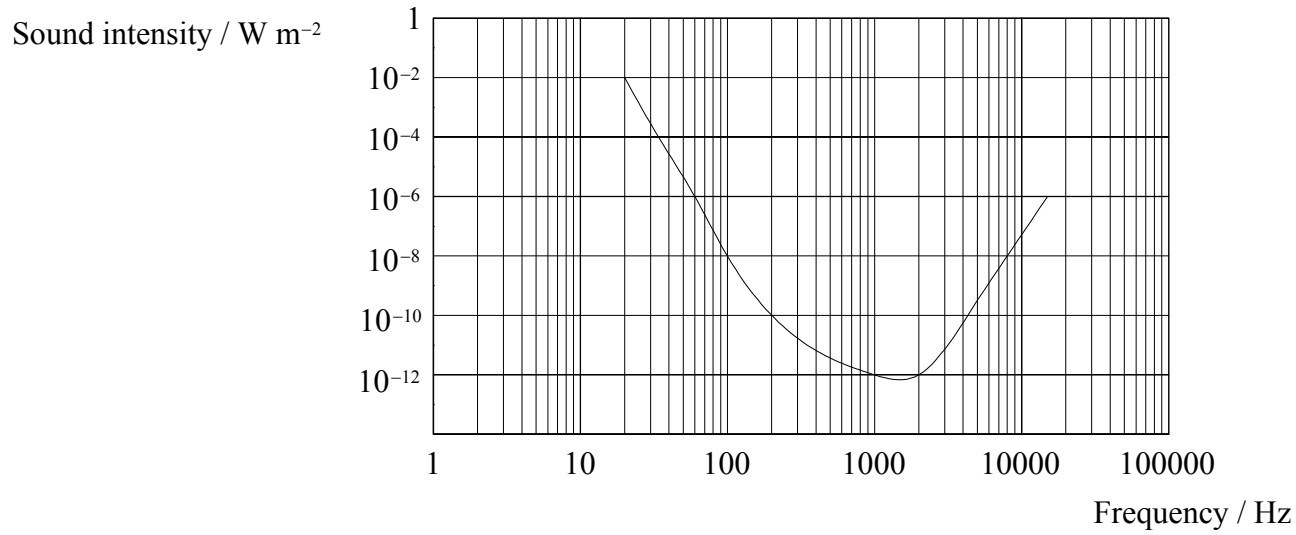
OPTION D — BIOMEDICAL PHYSICS

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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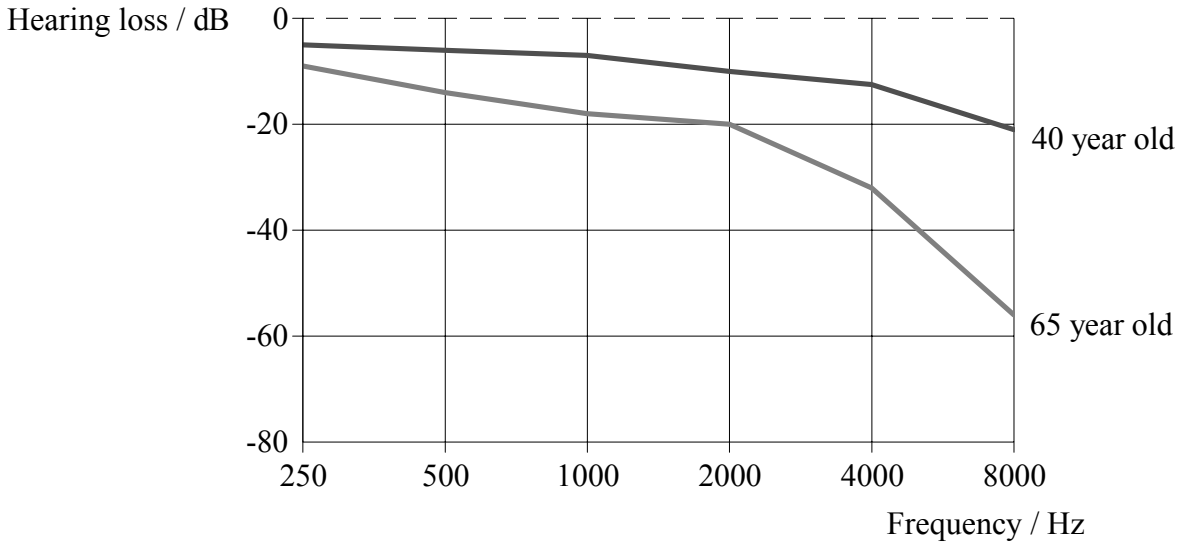
(Question D1 continued)

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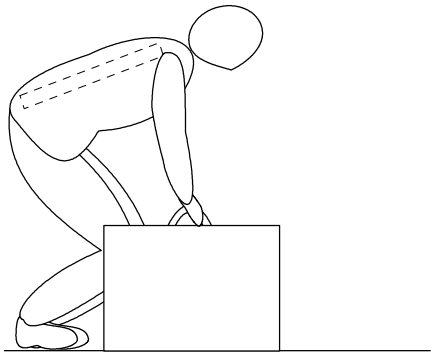
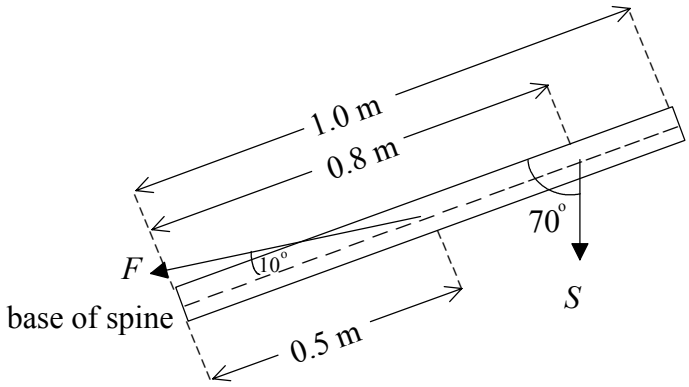
D2. When a person lifts a suitcase, the spine experiences large extra forces. In a simplified model of the situation, the spine can be treated as a rigid rod.



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]*

(This question continues on the following page)

(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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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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(This question continues on the following page)

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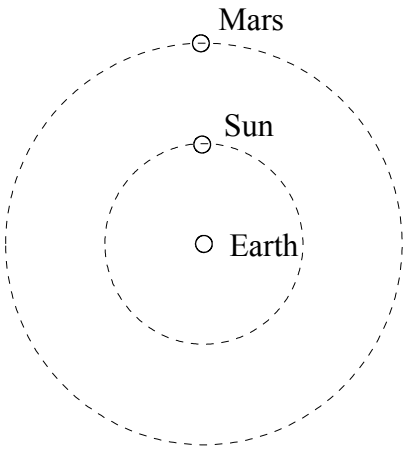
E2. Different models of the Universe have been able to explain the observed motions of the Sun, stars and planets. The diagram below represents, part of a simple Geocentric model as proposed by Ptolemy.



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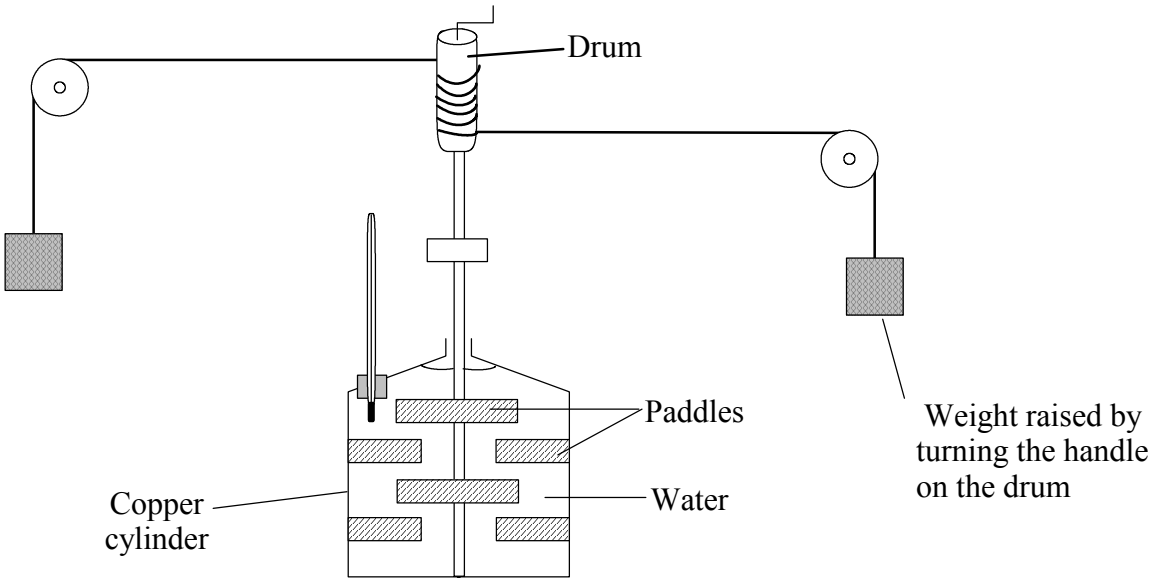
(b) The diagram below represents the apparatus used by Joule in an experiment that helped to change the way in which scientists thought about heat. The experiment was repeated many times before a conclusion was reached.



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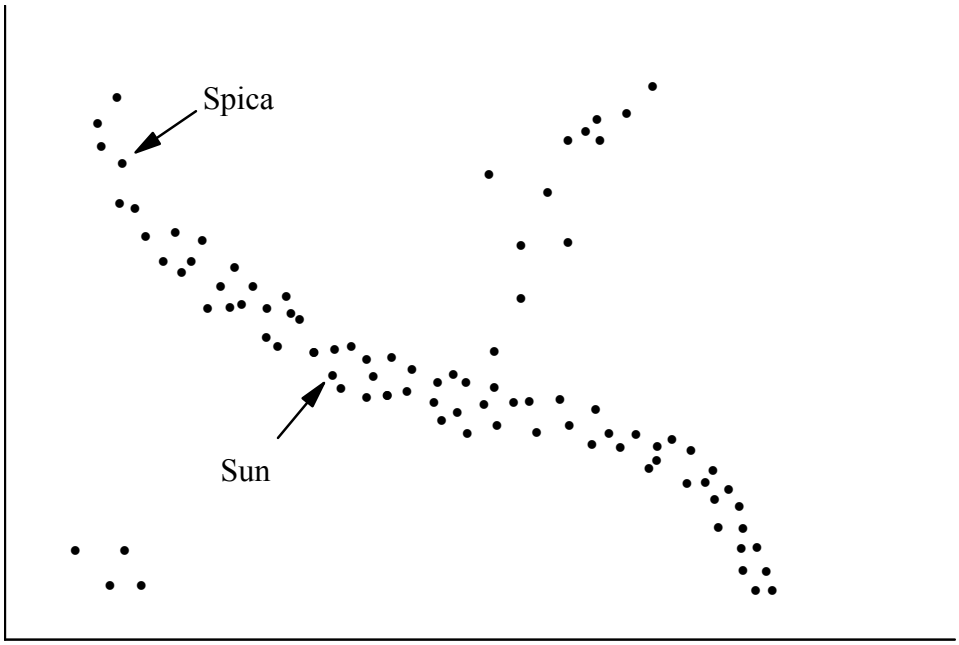
F2. The diagram below represents a simplified Hertzsprung-Russell diagram with a particular star (Spica) and the Sun identified.



(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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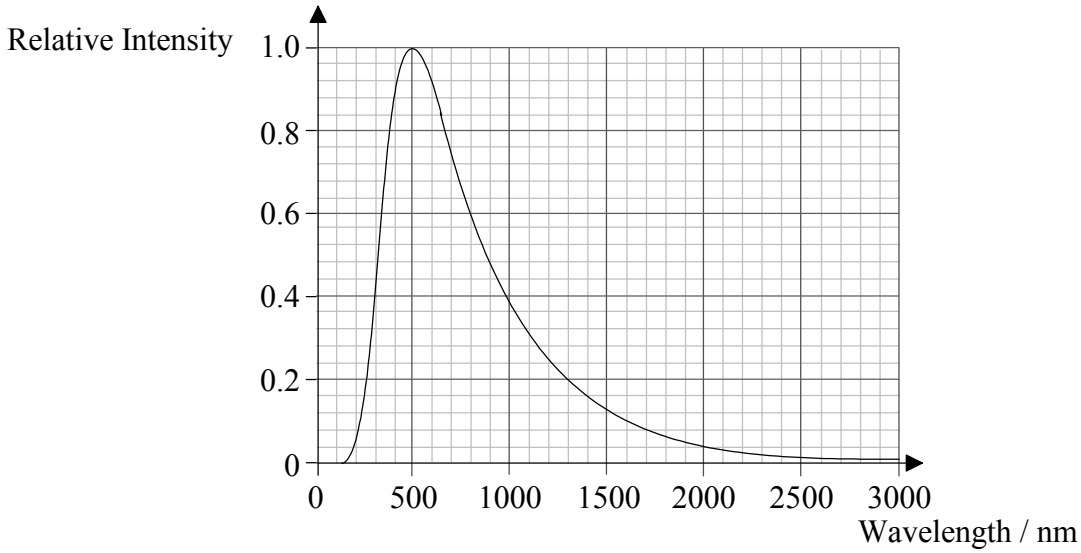
(Question F2 continued)

(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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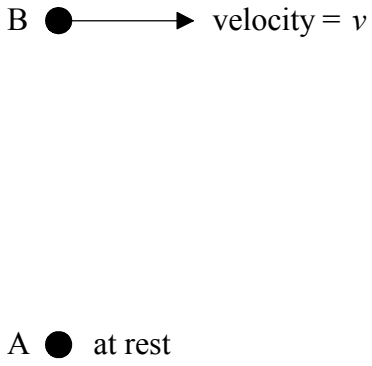
OPTION G — SPECIAL AND GENERAL RELATIVITY

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]*

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

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

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

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(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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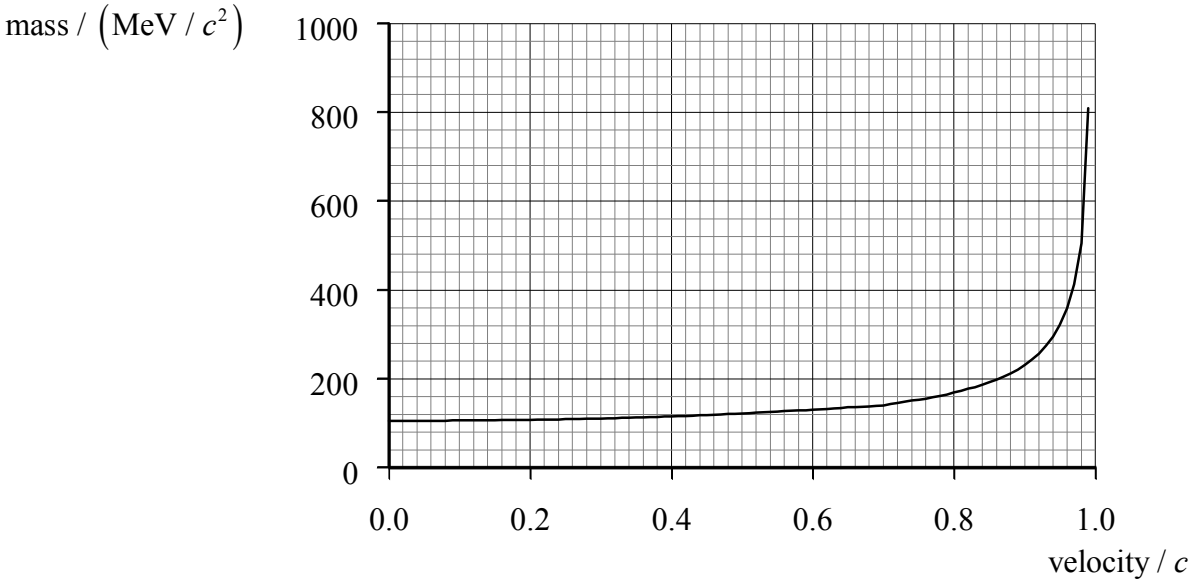
G2. The mass of a particle called a *muon* as a function of its speed is shown in the graph below.



Use the information in the graph to answer the following questions.

(a) What is the rest mass of the muon? *[1]*

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(b) At what speed would the muon need to be moving in order to have a mass of **twice** its rest mass? *[2]*

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(c) If a constant force is applied to the muon, could this force ever accelerate it to a speed greater than the speed of light? Explain. *[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

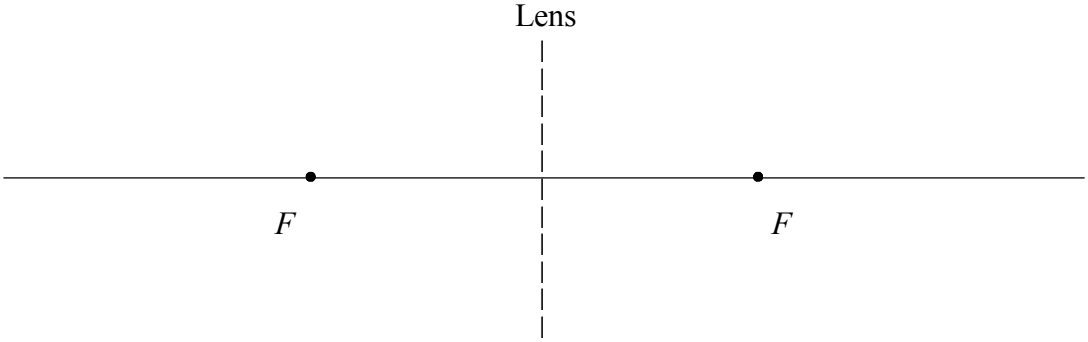
H1. A student uses a single **converging** lens of focal length 12 cm to produce a magnified **virtual** image.

(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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(This question continues on the following page)

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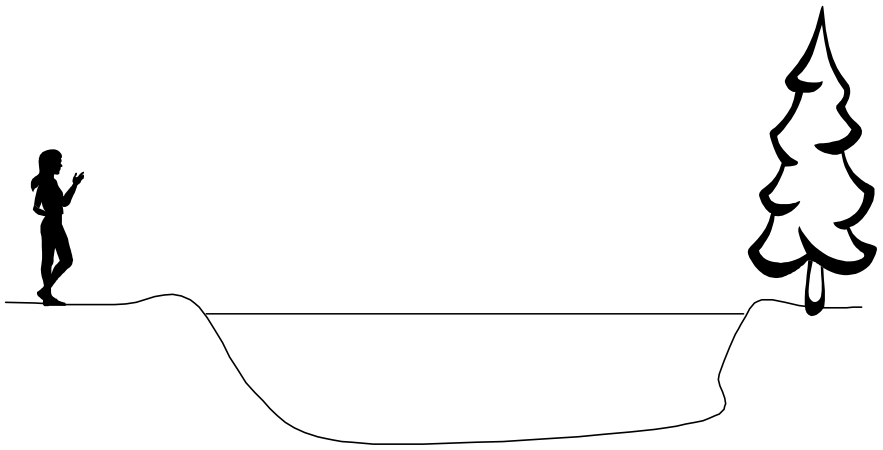
H2. Caroline is looking into a pond as shown below. A tree is located on the far side of the pond. When she looks in **one particular direction**, she can see the bottom of the pond as well as the reflection of the top of a tree on the far side of the pond.



(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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