Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 3

Monday 20 May 2019 (morning)

Candidate session number

1 hour

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[35 marks]**.

Section A	Questions
Answer all questions.	1 – 3

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Relativity	4 – 7
Option B — Engineering physics	8 – 10
Option C — Imaging	11 – 12
Option D — Astrophysics	13 – 15

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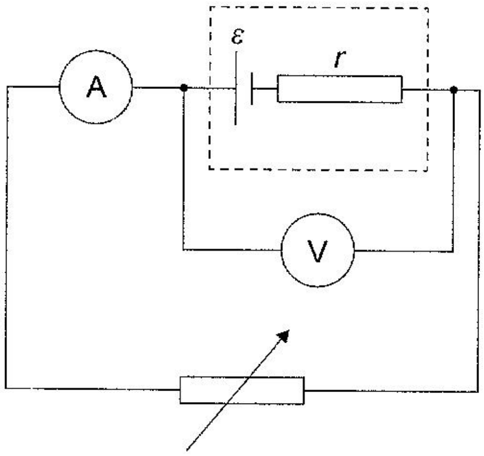
Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A student investigates the electromotive force (emf) ε and internal resistance r of a cell.



The current I and the terminal potential difference V are measured.

For this circuit $V = \varepsilon - Ir$.

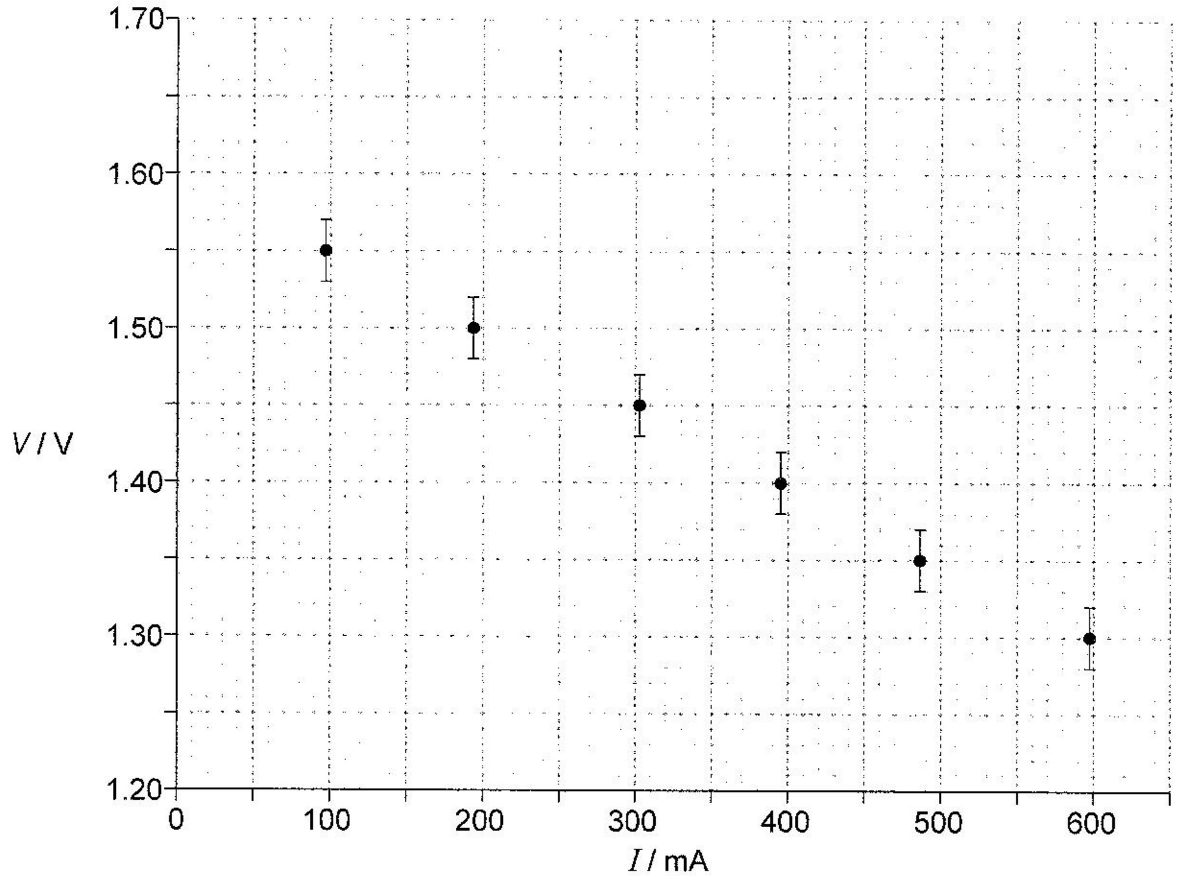
The table shows the data collected by the student. The uncertainties for each measurement are shown.

I / mA **± 1 mA**	**V / V** **± 0.02 V**
97	1.55
193	1.50
304	1.45
395	1.40
487	1.35
598	1.30

(This question continues on the following page)

(Question 1 continued)

The graph shows the data plotted.



(a) The student has plotted error bars for the potential difference. Outline why no error bars are shown for the current. [1]

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(This question continues on page 5)

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Answers written on this page
will not be marked.

(Question 1 continued)

(b) Determine, using the graph, the emf of the cell including the uncertainty for this value. Give your answer to the correct number of significant figures. [3]

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(c) Outline, **without** calculation, how the internal resistance can be determined from this graph. [2]

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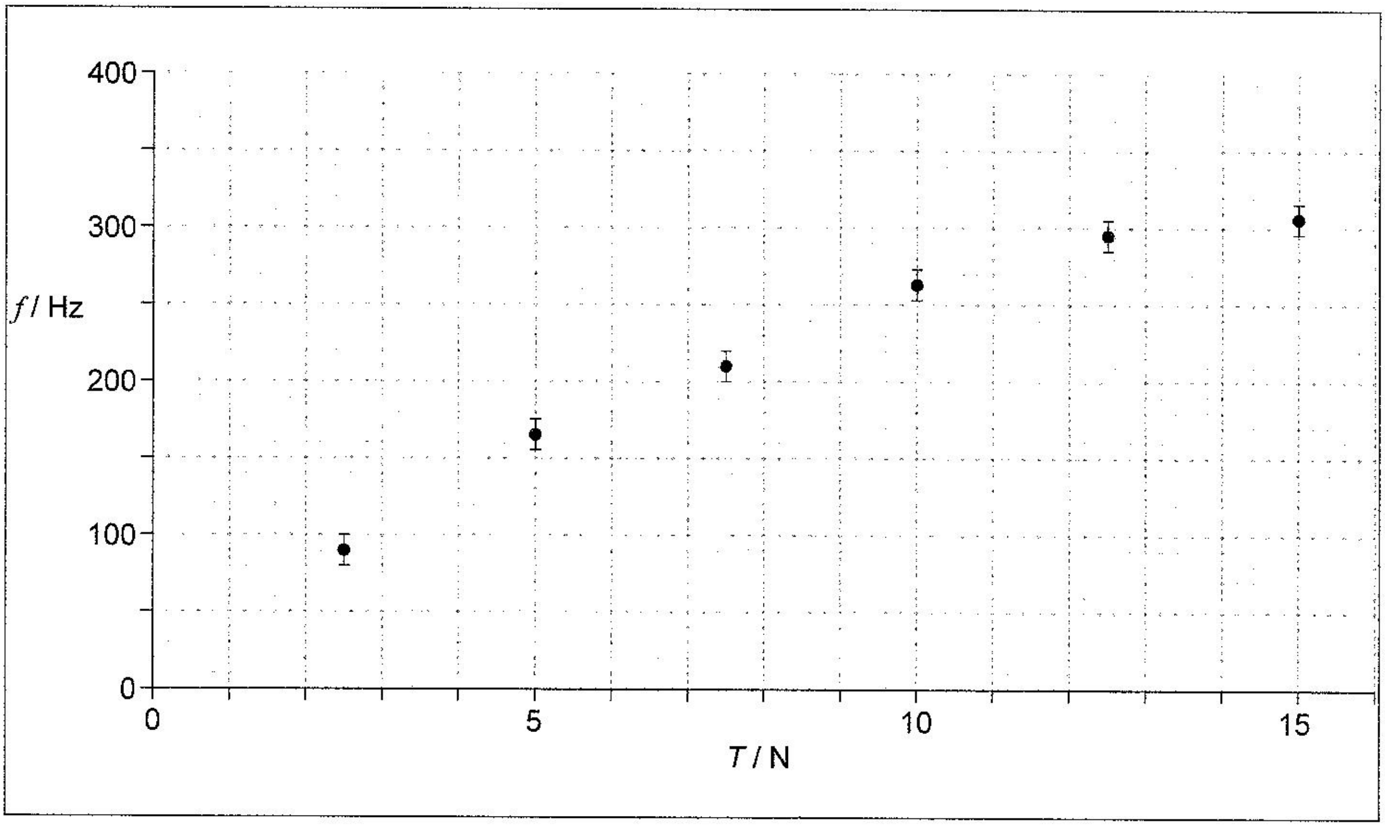
2. An experiment is conducted to determine how the fundamental frequency f of a vibrating wire varies with the tension T in the wire.

The data are shown in the graph, the uncertainty in the tension is not shown.



(a) Draw the line of best fit for the data. [1]

(This question continues on the following page)

(Question 2 continued)

(b) It is proposed that the frequency of oscillation is given by $f^2 = kT$ where k is a constant.

(i) Determine the fundamental SI unit for k. [1]

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(ii) Write down a pair of quantities that, when plotted, enable the relationship $f^2 = kT$ to be verified. [1]

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(iii) Describe the key features of the graph in (b)(ii) if it is to support this relationship. [2]

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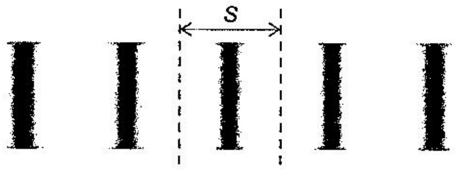
3. A student uses a Young's double-slit arrangement to determine the wavelength of light emitted by a monochromatic source. A portion of the interference pattern is observed on a screen.



The distance D from the double slits to the screen is measured using a ruler with a smallest scale division of 1 mm.

The fringe separation s is measured with uncertainty $\pm$ 0.1 mm.

The slit separation d has negligible uncertainty.

The wavelength is calculated using the relationship $\lambda = \frac{sd}{D}$.

(a) When $d = 0.200$ mm, $s = 0.9$ mm and $D = 280$ mm, determine the percentage uncertainty in the wavelength. [2]

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(b) Explain how the student could use this apparatus to obtain a more reliable value for λ. [2]

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Section B

Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

Option A — Relativity

4. (a) The speed of a spaceship is measured to be 0.50c by an observer at rest in the Earth's reference frame.

(i) Define an *inertial reference frame.* [1]

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(ii) As the spaceship passes the Earth it emits a flash of light that travels in the same direction as the spaceship with speed c as measured by an observer on the spaceship. Calculate, according to the Galilean transformation, the speed of the light in the Earth's reference frame. [1]

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(b) Use your answer to (a)(ii) to describe the paradigm shift that Einstein's theory of special relativity produced. [2]

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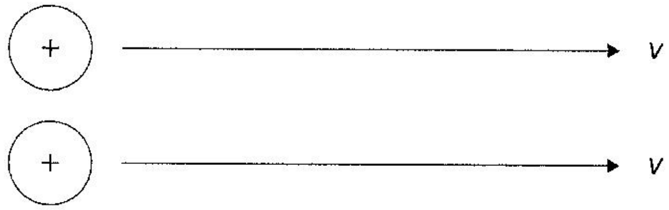
(Option A continues on the following page)

(Option A continued)

5. Two protons are moving to the right with the same speed v with respect to an observer at rest in the laboratory frame.



(a) Outline why there is an attractive magnetic force on each proton in the laboratory frame. [1]

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(b) Explain why there is no magnetic force on each proton in its own rest frame. [1]

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(c) Explain why the net repulsive force on the proton is the same in all reference frames. [2]

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(Option A continues on the following page)

(Option A continued)

6. A train of proper length 85 m moves with speed 0.60c relative to a stationary observer on a platform.

(a) Define *proper length.* [1]

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(b) In the reference frame of the train a ball travels with speed 0.50c from the back to the front of the train, as the train passes the platform. Calculate the time taken for the ball to reach the front of the train in

(i) the reference frame of the train. [1]

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(ii) the reference frame of the platform. [3]

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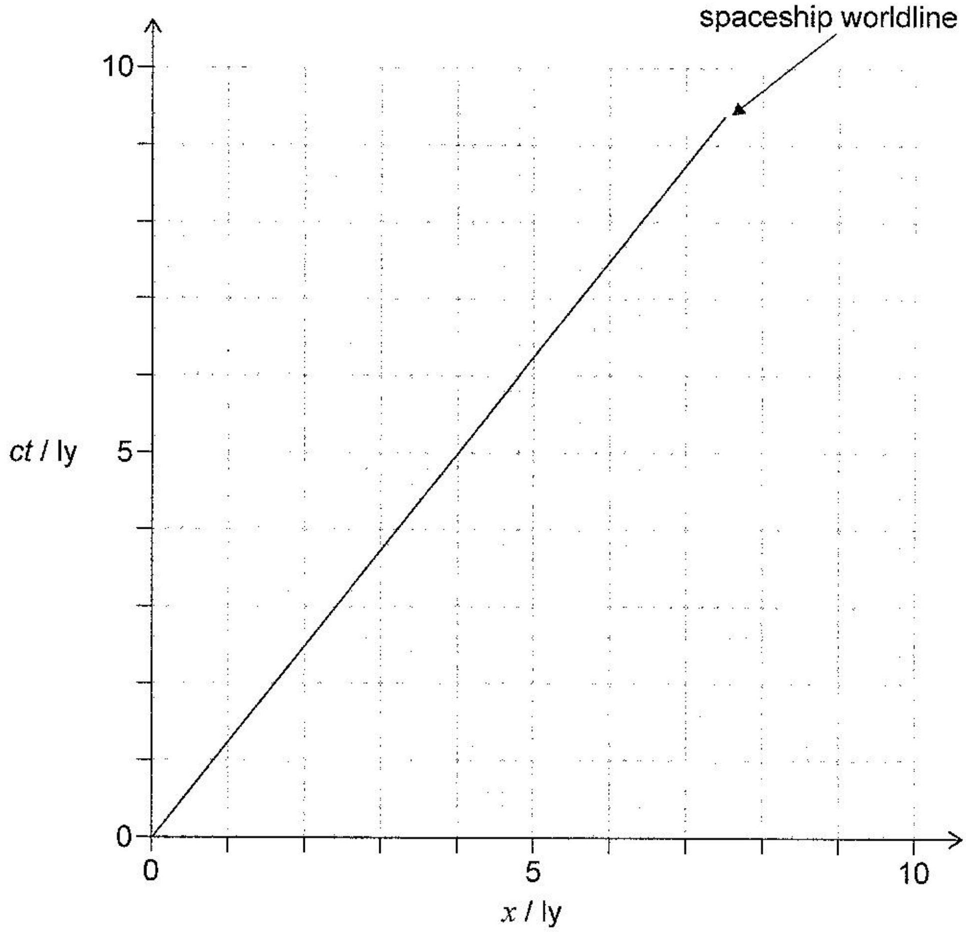
(Option A continues on the following page)

(Option A continued)

7. A spaceship moves away from the Earth in the direction of a nearby planet. An observer on the Earth determines the planet is 4 ly from the Earth. The spacetime diagram for the Earth's reference frame shows the worldline of the spaceship. Assume the clock on the Earth, the clock on the planet, and the clock on the spaceship were all synchronized when $ct = 0$.



(a) Show, using the spacetime diagram, that the speed of the spaceship relative to the Earth is $0.80c$. [1]

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(b) Label, with the letter E, the event of the spaceship going past the planet. [1]

(Option A continues on the following page)

(Option A, question 7 continued)

(c) Determine, according to an observer on the spaceship as the spaceship passes the planet,

(i) the time shown by the clock on the spaceship. [2]

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(ii) the time shown by the clock on the planet. [1]

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(d) On passing the planet a probe containing the spaceship's clock and an astronaut is sent back to Earth at a speed of 0.80c relative to Earth. Suggest, for this situation, how the twin paradox arises and how it is resolved. [2]

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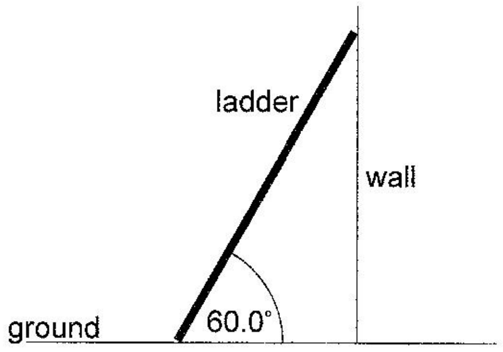
End of Option A

Option B — Engineering physics

8. A uniform ladder of weight 50.0 N and length 4.00 m is placed against a smooth wall making an angle of 60.0° with the ground.



(a) Outline why the normal force acting on the ladder at the point of contact with the wall is equal to the frictional force *F* between the ladder and the ground. [1]

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(b) Calculate *F*. [2]

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(c) The coefficient of friction between the ladder and the ground is 0.400. Determine whether the ladder will slip. [2]

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(Option B continues on the following page)

(Option B continued)

9. The moment of inertia of a solid sphere is $I = \frac{2}{5}mr^2$ where m is the mass of the sphere and r is the radius.

(a) Show that the total kinetic energy E_k of the sphere when it rolls, without slipping, at speed v is

$$E_K = \frac{7}{10}mv^2.$$

[2]

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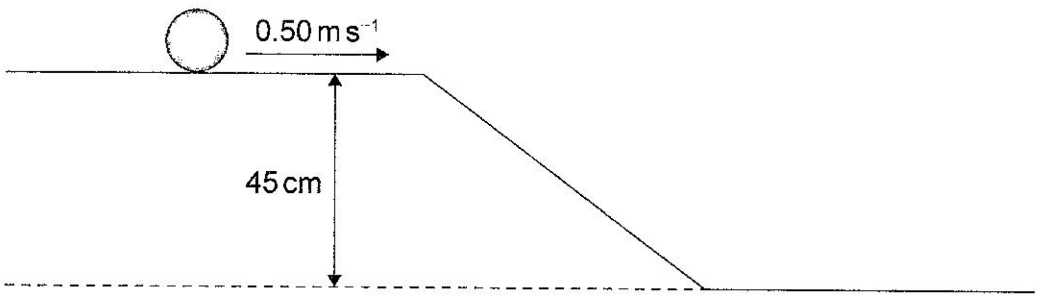
(b) A solid sphere of mass 1.5 kg is rolling, without slipping, on a horizontal surface with a speed of $0.50\,m\,s^{-1}$. The sphere then rolls, without slipping, down a ramp to reach a horizontal surface that is 45 cm lower.



Calculate the speed of the sphere at the bottom of the ramp.

[3]

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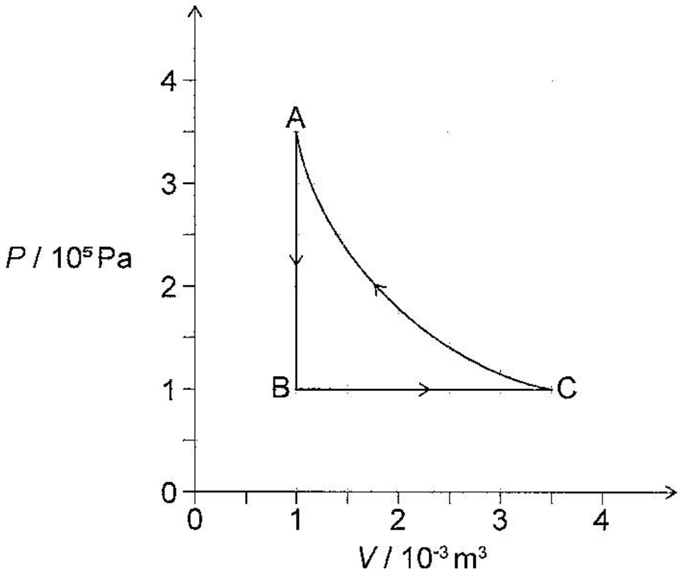
(Option B continues on the following page)

(Option B continued)

10. A heat pump is modelled by the cycle A→B→C→A.



The heat pump transfers thermal energy to the interior of a building during processes C→A and A→B and absorbs thermal energy from the environment during process B→C. The working substance is an ideal gas.

(a) Show that the work done on the gas for the isothermal process C→A is approximately 440 J. [2]

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(b) Calculate the

(i) change in internal energy of the gas for the process A→B. [2]

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(Option B continues on the following page)

(Option B, question 10 continued)

(ii) temperature at A if the temperature at B is −40°C. [1]

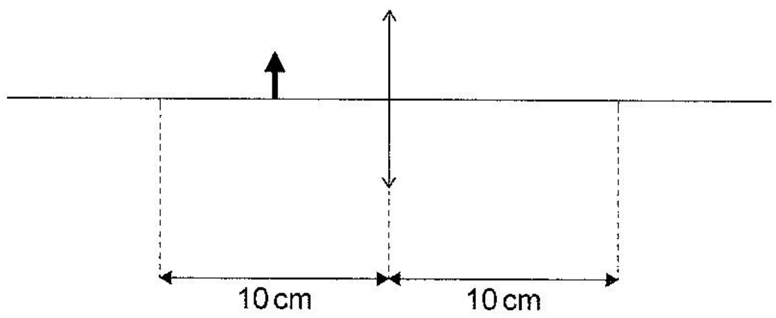
(c) Determine, using the first law of thermodynamics, the total thermal energy transferred to the building during the processes C→A and A→B. [3]

(d) Suggest why this cycle is not a suitable model for a working heat pump. [2]

End of Option B

Option C — Imaging

11. (a) A student places an object 5.0 cm from a converging lens of focal length 10.0 cm.



(i) Construct rays, on the diagram, to locate the image of this object formed by the lens. Label this with the letter I. [2]

(ii) Determine, by calculation, the linear magnification produced in the above diagram. [2]

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(iii) Suggest an application for the lens used in this way. [1]

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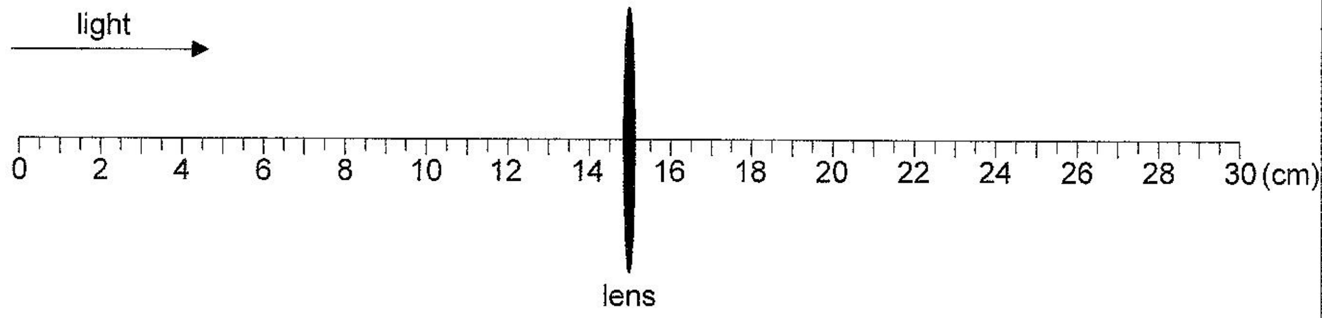
(Option C continues on the following page)

(Option C, question 11 continued)

(b) The student mounts the same lens on a ruler and light from a distant object is incident on the lens.



(i) Identify, with a vertical line, the position of the focussed image. Label the position I. [1]

(ii) The image at I is the object for a second converging lens. This second lens forms a final image at infinity with an overall angular magnification for the two lens arrangement of 5. Calculate the distance between the two converging lenses. [2]

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(iii) A new object is placed a few meters to the left of the original lens. The student adjusts spacing of the lenses to form a virtual image at infinity of the new object. Outline, without calculation, the required change to the lens separation. [2]

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(Option C continues on the following page)

(Option C continued)

12. (a) Outline the differences between step-index and graded-index optic fibres. [2]

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(b) The refractive index *n* of a material is the ratio of the speed of light in a vacuum *c*, to the speed of light in the material *v* or $n = \frac{c}{v}$.

The speed of light in a vacuum *c* is $2.99792 \times 10^{8}\,\text{m s}^{-1}$. The following data are available for the refractive indices of the fibre core for two wavelengths of light:

Wavelength (λ)	Refractive index (n)
1299 nm	1.45061
1301 nm	1.45059

(i) Determine the difference between the speed of light corresponding to these two wavelengths in the core glass. [2]

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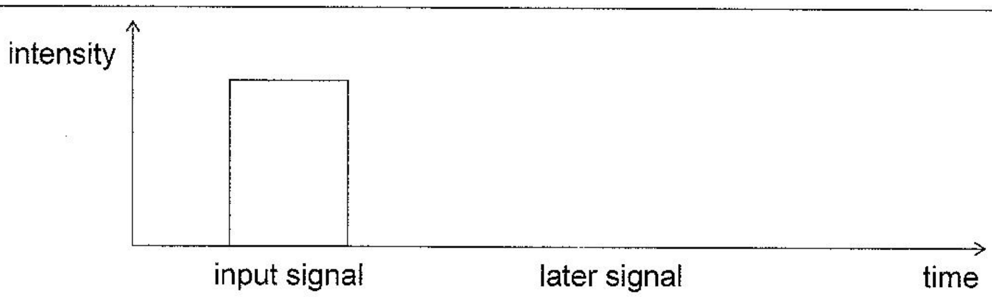
(ii) An input signal to the fibre consists of wavelengths that range from 1299 nm to 1301 nm. The diagram shows the variation of intensity with time of the input signal.



Sketch, on the axes, the variation of signal intensity with time after the signal has travelled a long distance along the fibre. [2]

(Option C continues on the following page)

(Option C, question 12 continued)

(iii) Explain the shape of the signal you sketched in (b)(ii). [2]

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(iv) A signal consists of a series of pulses. Outline how the length of the fibre optic cable limits the time between transmission of pulses in a practical system. [2]

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End of Option C

Option D — Astrophysics

13. (a) (i) Outline the processes that produce the change of luminosity with time of Cepheid variables. [2]

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(ii) Explain how Cepheid variables are used to determine distances. [2]

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(Option D continues on the following page)

(Option D, question 13 continued)

(b) The following data are available for the Cepheid variable δ-Cephei.

Peak luminosity $= 7.70 \times 10^{29}$ W
Distance from Earth $= 273$ pc
Peak wavelength of light $= 4.29 \times 10^{-7}$ m

(i) Determine the peak apparent brightness of δ-Cephei as observed from Earth. [2]

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(ii) Calculate the peak surface temperature of δ-Cephei. [1]

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(c) Astronomers claim to know the properties of distant stars. Outline how astronomers can be certain that their measurement methods yield correct information. [1]

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(Option D continues on page 25)

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(Option D continued)

14. The Hubble constant is $2.3 \times 10^{-18}\,s^{-1}$.

(a) (i) A galaxy is 1.6×10^{8} ly from Earth. Show that its recessional speed as measured from Earth is about $3.5 \times 10^{6}\,m\,s^{-1}$. [2]

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(ii) A line in the hydrogen spectrum when measured on Earth has a wavelength of 486 nm. Calculate, in nm, the wavelength of the same hydrogen line when observed in the galaxy's emission spectrum. [2]

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(b) Outline how observations of spectra from distant galaxies provide evidence that the universe is expanding. [1]

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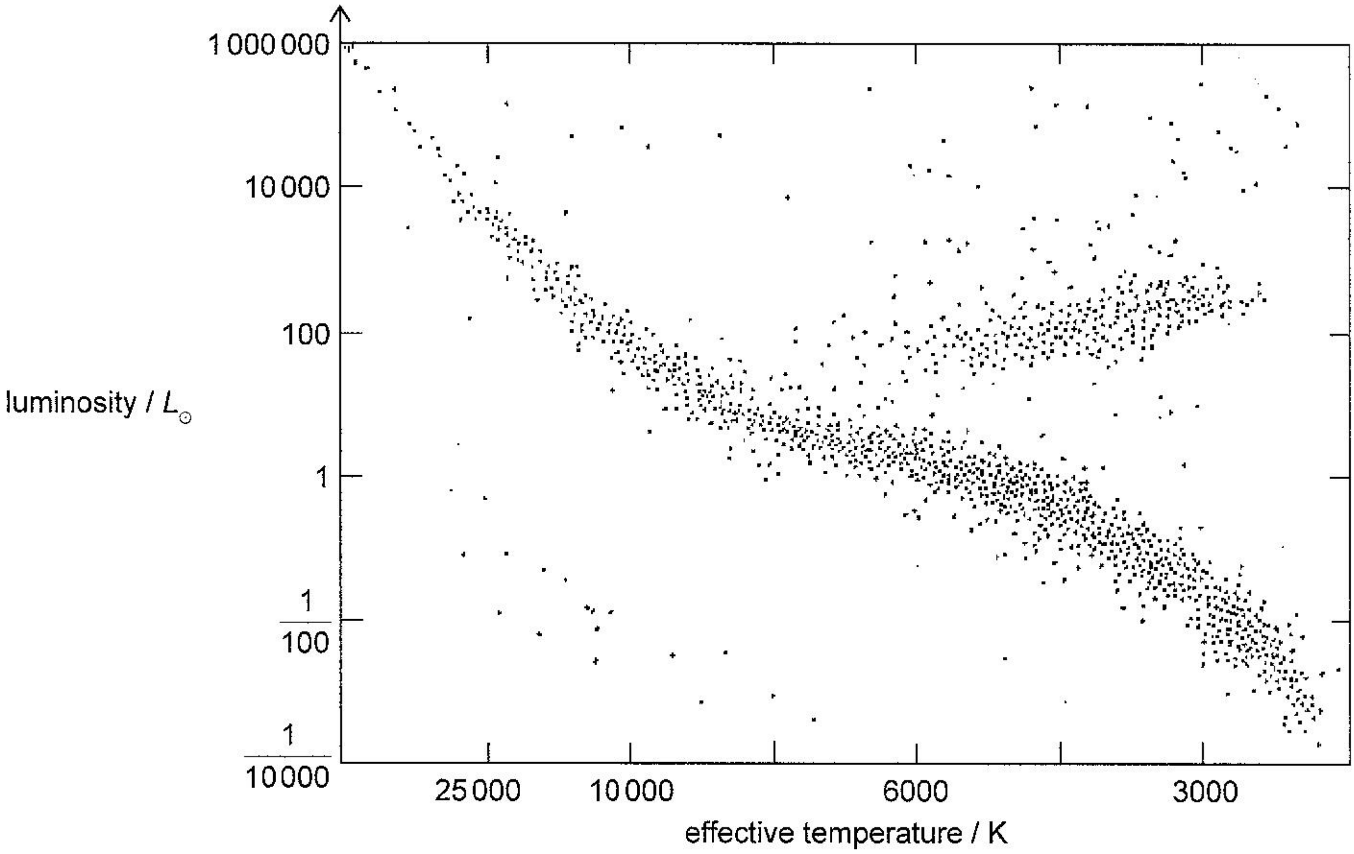
(Option D continues on the following page)

(Option D continued)

15. The Hertzsprung-Russell (HR) diagram shows several star types. The luminosity of the Sun is $L_{\odot}$.



(a) Identify, on the HR diagram, the position of the Sun. Label the position S. [1]

(b) Suggest the conditions that will cause the Sun to become a red giant. [3]

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(Option D continues on the following page)

(Option D, question 15 continued)

(c) Outline why the Sun will maintain a constant radius after it becomes a white dwarf. [1]

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(d) During its evolution, the Sun is likely to be a red giant of surface temperature 3000 K and luminosity $10^4 L_{\odot}$. Later it is likely to be a white dwarf of surface temperature 10000 K and luminosity $10^{-4} L_{\odot}$. Calculate the $\frac{\text{radius of the Sun as a white dwarf}}{\text{radius of the Sun as a red giant}}$. [2]

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End of Option D