IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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88046506

PHYSICS
STANDARD LEVEL
PAPER 3

School code

Monday 8 November 2004 (morning)

Candidate code

1 hour

INSTRUCTIONS TO CANDIDATES

- Write your school code and candidate code 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 candidate box on your cover sheet.

Option A — Mechanics Extension

A1. This question is about gravitation and ocean tides.

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

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(b) Use the following information to deduce that the gravitational field strength at the surface of the Earth is approximately $10\,\text{N}\,\text{kg}^{-1}$. *[2]*

Mass of the Earth $= 6.0\times10^{24}\,\text{kg}$

Radius of the Earth $= 6400\,\text{km}$

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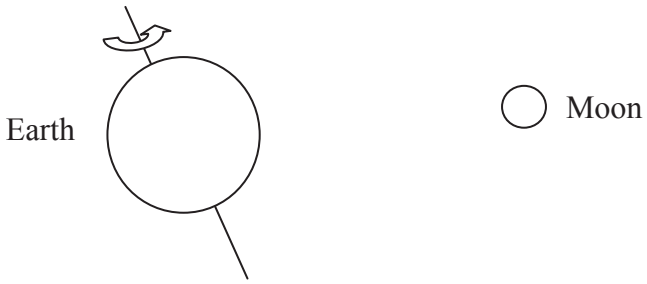
(This question continues on the following page)

(Question A1 continued)

The Moon's gravitational field affects the gravitational field at the surface of the Earth. A high tide occurs at the point where the resultant gravitational field due to the Moon and to the Earth is a minimum.



(c) (i) On the diagram above label, using the letter P, the point on the Earth's surface that experiences the greatest gravitational attraction due to the Moon. Explain your answer. *[2]*

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(ii) On the diagram above label, using the letter H, the location of a high tide. Explain your answer. *[2]*

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(iii) Suggest **two** reasons why high tides occur at different times of the day in different locations. *[2]*

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A2. This question is about friction.

(a) Define what is meant by *coefficient of friction*. *[1]*

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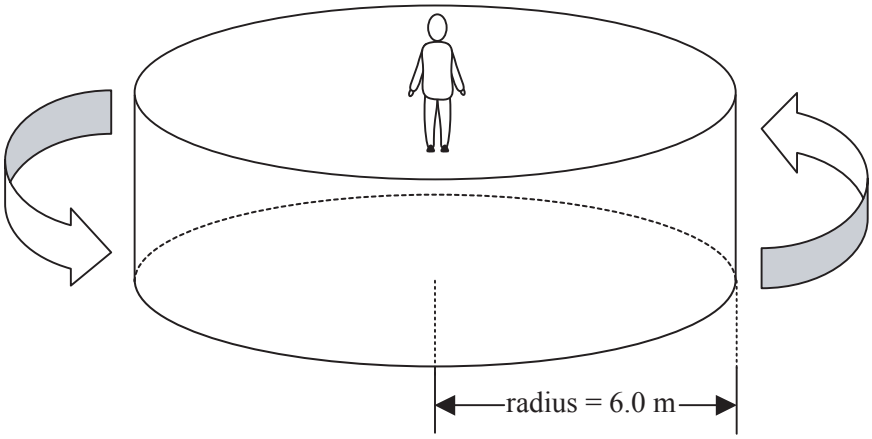
The diagram below shows a particular ride at a funfair (sometimes called "the fly") that involves a spinning circular room. When it is spinning fast enough a person in the room feels "stuck" to the wall. The floor is lowered and they remain held in place on the wall. Friction prevents the person from falling.

General view:



(b) (i) Explain whether the friction acting on the person is static, dynamic **or** a combination of both. *[2]*

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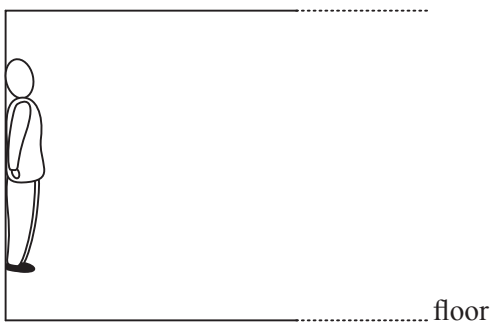
(This question continues on the following page)

(Question A2 continued)

The diagram below shows a cross-section of the ride when the floor has been lowered.



(ii) On the diagram above, draw labelled arrows to represent the forces acting on the person. *[3]*

(c) Using the data given below,

mass of person = 80 kg
coefficient of friction between the person and the wall = 0.40
radius of circular room = 6.0 m

calculate each of the following.

(i) The magnitude of the minimum resultant horizontal force on the person. *[2]*

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(ii) The minimum speed of the wall for a person to be "stuck" to it. *[2]*

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Option B — Quantum Physics and Nuclear Physics

B1. This question is about deducing the quark structure of a nuclear particle.

When a K^- meson collides with a proton, the following reaction can take place.

$$K^- + p \rightarrow K^0 + K^+ + X$$

X is a particle whose quark structure is to be determined.

The quark structure of mesons is given below.

particle	quark structure
K^-	$s\bar{u}$
K^+	$u\bar{s}$
K^0	$d\bar{s}$

(a) State and explain whether the original K^- particle is a hadron, a lepton **or** an exchange particle. *[2]*

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(b) State the quark structure of the proton. *[2]*

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(c) The quark structure of particle X is sss. Show that the reaction is consistent with the theory that hadrons are composed of quarks. *[2]*

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B2. Photoelectric emission takes place when ultraviolet light is incident on zinc but it does not take place when visible light is incident on zinc. However, photoelectric emission does take place when visible light is incident on potassium.

(a) Explain what is meant by *photoelectric emission*. *[2]*

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The work function of zinc is 4.2 eV.

(b) (i) Explain whether the work function for potassium is greater **or** less than 4.2 eV. *[1]*

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(ii) Ultraviolet light of wavelength 210 nm is incident on a zinc surface. Calculate the maximum kinetic energy, in eV, of a moving electron emitted from the surface. *[3]*

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(This question continues on the following page)

(Question B2 continued)

(c) The photoelectric effect provides evidence for the particle nature of light. Outline an experiment that provides evidence for the **wave nature of particles**. *[3]*

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B3. A sample of cobalt-60 has an activity of 3.0×10^5 Bq. The half-life of cobalt-60 is 5.3 years.

(a) Define *half-life*. *[1]*

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(b) Determine the decay constant of cobalt-60. *[2]*

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(c) Calculate the time taken for the activity of the cobalt-60 to be reduced to 1.0×10^5 Bq. *[2]*

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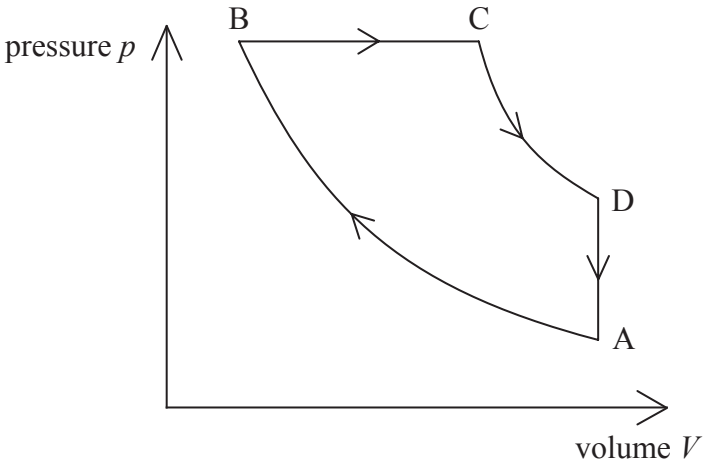
Option C — Energy Extension

C1. This question is about a diesel engine and the Carnot cycle.

The diagram below shows the pressure-volume (p-V) changes of the gas that take place in one cycle of an ideal diesel engine.



A → B and C → D are adiabatic changes.

(a) (i) State what is meant by an *adiabatic change*.

. . . . . *[1]*

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(ii) State what is represented by the area ABCD. *[1]*

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(b) State and explain during which part of the cycle, ABCD, is thermal energy given to the system. *[2]*

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(This question continues on the following page)

(Question C1 continued)

A heat engine that operates in a Carnot cycle has a greater efficiency than the ideal diesel engine. A particular Carnot engine has a hot reservoir at 1000 °C and a cold reservoir at 300 °C.

(c) (i) Outline the processes that take place in a Carnot cycle. *[2]*

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(ii) Calculate the efficiency of this Carnot engine. *[2]*

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(iii) The useful power output of the engine is 2.0 kW. Calculate the rate at which energy is absorbed from the hot reservoir. *[2]*

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C2. This question is about the production of electrical energy.

(a) Outline the principal energy transfers involved in the production of electrical energy from thermal energy in a coal fired power station. *[2]*

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(b) State and explain whether the energy sources used in the following power stations are renewable **or** non-renewable.

(i) Coal fired *[1]*

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(ii) Nuclear *[1]*

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(c) The core of some nuclear reactors contain a moderator and control rods. Explain the function of these components.

(i) The moderator *[2]*

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(ii) The control rods *[2]*

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(This question continues on the following page)

(Question C2 continued)

(d) Discuss **one** advantage of a nuclear power station as opposed to a coal fired power station. *[2]*

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Option D — Biomedical Physics

D1. This question is about scaling and compares the different methods by which an amoeba and a goldfish absorb oxygen.

An amoeba and a goldfish both live in water and need oxygen to survive. An amoeba is a very small animal composed of a single cell, whereas a goldfish is made up of many cells.

The following information is available.

The rate at which an animal uses oxygen is proportional to its mass.
The rate of oxygen absorption by an amoeba is proportional to its surface area.
A typical amoeba is 8.0×10^{-5} m in length.
A typical goldfish is 5.0 cm in length.
An amoeba cannot live if its rate of oxygen absorption per unit mass falls below 10 % of its normal rate.

(a) Explain how the following quantities scale with the linear dimension L of an amoeba.

(i) The surface area. *[1]*

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(ii) The rate of oxygen absorption across the cell surface membrane. *[1]*

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(iii) The rate of oxygen absorption per unit mass. *[2]*

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(This question continues on the following page)

(Question D1 continued)

(b) Consider a "giant" amoeba equal in length to a goldfish. Calculate the ratio

$$\frac{\text{the rate of oxygen absorption per unit mass for the "giant" amoeba}}{\text{the rate of oxygen absorption per unit mass for a typical amoeba}}.$$ *[2]*

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(c) With reference to your answer to (b) suggest **one** reason why a goldfish must have a different means of oxygen intake to an amoeba. *[2]*

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D2. When X-rays are used for diagnostic purposes, beam energies of about 30 keV are used. This results in good contrast on the radiogram because the most important attenuation mechanism is not simple scattering.

(a) Outline the most important attenuation mechanism that is taking place at this energy. *[2]*

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(b) Explain the following terms.

(i) *Attenuation coefficient* *[2]*

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(ii) *Half-value thickness* *[2]*

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(This question continues on the following page)

(Question D2 continued)

(c) The attenuation coefficient at 30 keV varies with the atomic number Z as shown below.

$$\text{Attenuation coefficient} \propto Z^3$$

The data given below list average values of the atomic number Z for different biological materials.

biological material	**atomic number *Z***
fat	5.9
muscle	7.4
bone	13.9

(i) Calculate the ratio

$$\frac{\text{attenuation coefficient for bone}}{\text{attenuation coefficient for muscle}}.$$ *[2]*

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(ii) Suggest why X-rays of 30 keV energy are useful for diagnosing a broken bone but a different technique must be used for examining a fat-muscle boundary. *[4]*

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Option E — The History and Development of Physics

E1. This question is about cathode rays and their properties.

The following is taken from the introduction to an article written in 1895 by Jean Perrin. The article describes an experiment on the newly discovered "cathode rays".

"Two hypotheses have been published to explain the properties of the cathode rays. Some think that this phenomenon, like light, results from vibrations of the ether, or even that it is light of short wavelength… Others think that these rays are formed of matter moving with great velocity…"

(a) Outline how cathode rays were discovered. *[2]*

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(b) The result of Perrin's experiment indicated that cathode rays carry a negative charge. State and explain which of the hypotheses above is supported by this result. *[2]*

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(c) Hertz performed experiments that seemed to indicate that the cathode rays were not deflected by an electric field. State and explain which of the hypotheses is supported by this result. *[2]*

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(This question continues on the following page)

(Question E1 continued)

Two years after Hertz's experiments were performed, experiments were undertaken that enabled the charge-to-mass ratio of the particles in the cathode rays to be measured.

(d) (i) State who was responsible for these experiments. *[1]*

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(ii) Outline the experimental procedure that enabled the charge-to-mass ratio of the particles to be measured. *[3]*

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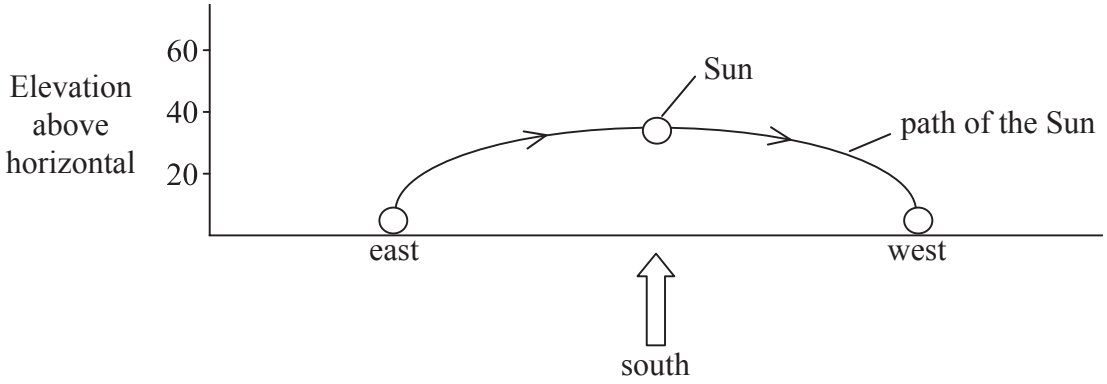
E2. This question is about astronomical observations and their explanation.

The diagram below represents the observed motion of the Sun during a **winter**'s day as seen by an observer **looking south**.



(a) State and explain in which hemisphere the observer is located. *[1]*

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(b) Draw a possible path on the diagram above for the observed motion of the Sun during a summer's day as seen from this location. *[2]*

(c) Explain the path that you have drawn in (b) in terms of

(i) the Aristotelian/Ptolemaic model of the universe. *[2]*

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(ii) the Aristarchian/Copernican model of the universe. *[2]*

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(This question continues on the following page)

(Question E2 continued)

(d) (i) Outline **one** similarity and **one** difference between the observed motion of the stars and that of the planets.

Similarity: . . . . . *[1]*

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Difference: . . . . . *[1]*

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(ii) State the evidence on which Kepler based his laws of planetary motion. *[1]*

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Option F — Astrophysics

*There is only **one** question for this option.*

F1. This question is about the properties of the star Arcturus.

The following data is for the star Arcturus.

Distance from Earth / m	Apparent magnitude	Absolute magnitude	Spectral type	Luminosity / W
3.39×10^{17}	– 0.1	– 0.3	K	3.8×10^{28}

(a) Explain the difference between *apparent magnitude* and *absolute magnitude*. *[2]*

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(b) State and explain, with reference to the data, whether Arcturus would be visible without the aid of a telescope on a clear night. *[1]*

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Techniques for determining stellar distances include the use of stellar parallax, spectroscopic parallax and Cepheid variables.

(c) (i) Calculate the distance, in pc, of Arcturus from the Earth. *[1]*

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(ii) State and explain which technique would be most suitable for determining the distance to Arcturus. *[2]*

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(This question continues on the following page)

(Question F1 continued)

(iii) Outline the method you have chosen in your answer to (c) (ii). *[4]*

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(d) State how it may be deduced from the data that the surface temperature of Arcturus is lower than that of the Sun. *[2]*

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(This question continues on the following page)

(Question F1 continued)

The temperature of Arcturus is 4000K.

(e) Calculate

(i) the surface area of Arcturus. *[2]*

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(ii) the radius of Arcturus. *[2]*

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(iii) the wavelength at which the light from Arcturus has its maximum intensity. *[2]*

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(f) Using your answers to (e) deduce the stellar type to which Arcturus belongs. *[2]*

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Option G — Relativity

G1. This question is about the postulates of relativity.

(a) State the **two** postulates of special relativity. *[2]*

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(b) State and explain which postulate can be predicted from Maxwell's electromagnetic theory of light. *[2]*

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(c) Outline **one** piece of experimental evidence that supports the special theory of relativity. *[3]*

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G2. This question is about relativistic motion.

The radioactive decay of a nucleus of actinium-228 involves the release of a β-particle that has a **total energy** of 2.51 MeV as measured in the laboratory frame of reference. This total energy is significantly larger than the **rest mass energy** of a β-particle.

(a) Explain the difference between *total energy* and *rest mass energy*. *[2]*

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(b) Deduce that the Lorentz factor, as measured in the laboratory reference frame, for the β-particle in this decay is 4.91. *[3]*

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A detector is placed 37 cm from the actinium source, as measured in the laboratory reference frame.

(c) Calculate, for the laboratory reference frame,

(i) the speed of the β-particle. *[2]*

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(ii) the time taken for the β-particle to reach the detector. *[2]*

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(This question continues on the following page)

(Question G2 continued)

The events described in (c) can be described in the β-particle's frame of reference.

(d) For this frame,

(i) identify the moving object. *[1]*

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(ii) state the speed of the moving object. *[1]*

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(iii) calculate the distance travelled by the moving object. *[2]*

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Option H — Optics

H1. This queston is about the human eye.

The human eye produces images of objects that are placed between the near point and the far point of the eye.

(a) Explain what is meant by

(i) *near point.* *[1]*

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(ii) *far point.* *[1]*

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The optical working of the eye may be modelled as a single lens of variable focal length. In this model, when the eye is focused on a distant object which is not on the principal axis, the eye lens has a focal length of 1.7 cm.

(b) (i) Draw a labelled ray diagram to show how the eye lens forms an image of the distant object. *(**Note:** this is a sketch and does not need to be drawn to scale.)* *[3]*

(This question continues on the following page)

(Question H1 continued)

(ii) State the distance from the lens to the image. *[1]*

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To focus on an object 50 cm away from the eye, the eye lens in the model changes shape to change its focal length. This enables the image distance to remain the same for all object distances.

(c) (i) Determine the new focal length of the eye lens. *[2]*

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(ii) Suggest what change takes place in the shape of the lens in this model. Explain your answer. *[2]*

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(This question continues on the following page)

(Question H1 continued)

In the human eye most of the refraction actually takes place due to the change of medium from air to the cornea (the transparent structure at the front of the eye). The following refractive indices are known.

Material	**Refractive index**
air	1.00
cornea	1.34
water	1.33

(d) (i) Explain what is meant by *refractive index*. *[2]*

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(ii) Use the information to suggest why it is impossible for a person to see objects clearly when swimming underwater. *[2]*

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H2. This question is about waves.

(a) Explain what is meant by

(i) *monochromatic.* *[1]*

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(ii) *coherent.* *[1]*

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(b) The table below compares waves from different sources. The first two rows have been completed for you. Complete the final three rows of the table. *[3]*

	electromagnetic	monochromatic	coherent
light from a laser	Yes	Yes	Yes
sound from a loudspeaker	No	No	No
light from a filament lamp			
γ-rays from a radioactive source			
infra-red rays from the Sun			

(c) State an application of laser light. *[1]*

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