2023-DSE
PHY
PAPER 2

HONG KONG EXAMINATIONS AND ASSESSMENT AUTHORITY
HONG KONG DIPLOMA OF SECONDARY EDUCATION EXAMINATION 2023

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Candidate Number									

PHYSICS PAPER 2

Question-Answer Book

11:45 am – 12:45 pm (1 hour)
This paper must be answered in English

INSTRUCTIONS

(1) After the announcement of the start of the examination, you should first write your Candidate Number in the space provided on Page 1 and stick barcode labels in the spaces provided on Pages 1, 3, 5, 7 and 9.

(2) This paper consists of **FOUR** sections, Sections A, B, C and D. Each section contains eight multiple-choice questions and one structured question which carries 10 marks. Attempt **ALL** questions in any **TWO** sections.

(3) Write your answers to the structured questions in the **ANSWER BOOK** provided. For multiple-choice questions, blacken the appropriate circle with an HB pencil. You should mark only **ONE** answer for each question. If you mark more than one answer, you will receive **NO MARKS** for that question.

(4) Graph paper and supplementary answer sheets will be provided on request. Write your candidate number, mark the question number box and stick a barcode label on each sheet, and fasten them with string **INSIDE** the Answer Book.

(5) The Question-Answer Book and Answer Book will be collected **SEPARATELY** at the end of the examination.

(6) The diagrams in this paper are **NOT** necessarily drawn to scale.

(7) The last two pages of this Question-Answer Book contain a list of data, formulae and relationships which you may find useful.

(8) No extra time will be given to candidates for sticking on the barcode labels or filling in the question number boxes after the 'Time is up' announcement.

* A 1 5 0 E 2 M C *

Section A : Astronomy and Space Science

Q.1: Multiple-choice questions

1.1 Arrange the celestial bodies below in descending order of diameter:

(1) the Milky Way
(2) our Local Group of galaxies
(3) a globular cluster of stars

A. (1) (3) (2)
B. (2) (1) (3)
C. (2) (3) (1)
D. (1) (2) (3)

A	B	C	D
○	○	○	○

1.2 Which of the following astronomical phenomena **CANNOT** be explained by Ptolemy's geocentric model ?

(1) Mercury can only be seen shortly before sunrise or shortly after sunset.
(2) A solar eclipse can be seen on Earth when sunlight is blocked by the Moon.
(3) Annual stellar parallax of distant stars can be seen on Earth.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

A	B	C	D
○	○	○	○

1.3 The Tiangong space station orbits the Earth at an altitude of about 400 km above the Earth's surface. What is the gravitational acceleration of the scientist inside the space station ? Given that the radius of the Earth is 6400 km and the gravitational acceleration on the Earth's surface is g.

A. zero
B. between zero and g, and closer to zero
C. between zero and g, and closer to g
D. g

A	B	C	D
○	○	○	○

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1.4 The escape velocity from planet P of radius r is v. What is the escape velocity from another planet Q of radius $2r$ and having the same mass as P ?

A. $\frac{v}{\sqrt{2}}$

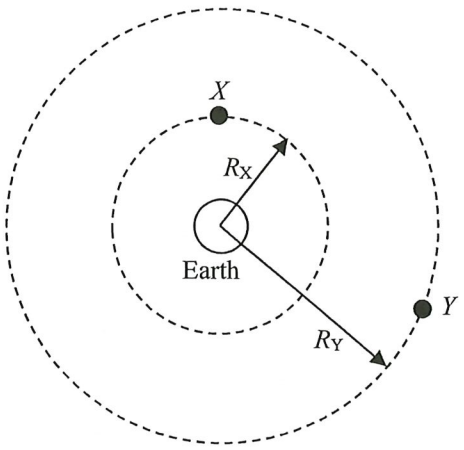
B. v

C. $\sqrt{2}\,v$

D. It depends on the mass of the object escaping from the planet.

A	B	C	D
○	○	○	○

1.5 Two satellites, X and Y, of the same mass are orbiting the Earth in circular orbits of radii R_X and R_Y respectively as shown.



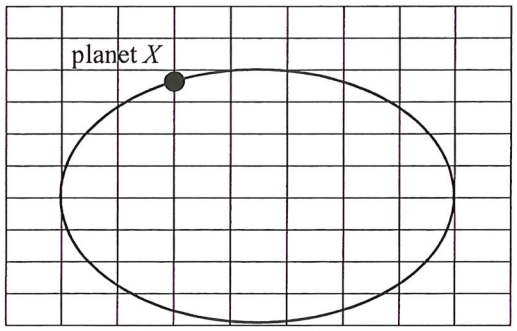
Which of the following comparisons about the energies of the satellites is correct ?

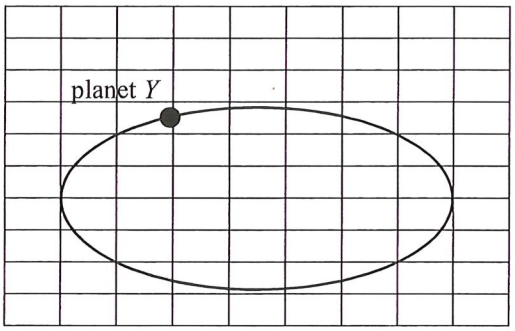
	total energy	**kinetic energy**
A.	$X > Y$	$X < Y$
B.	$X > Y$	$X > Y$
C.	$X < Y$	$X < Y$
D.	$X < Y$	$X > Y$

A	B	C	D
○	○	○	○

Go on to the next page

1.6 Two planets X and Y are equal in mass. The orbit of X around star S_X and that of Y around star S_Y are shown below. S_X and S_Y are massive stars having the same mass, and they are **NOT** shown in the figures.





Which statements about the orbital motion of the planets are correct ?

(1) Their periods are different.
(2) Y has a shorter semi-minor axis.
(3) The shortest distance between X and S_X is different from that between Y and S_Y.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A	B	C	D
○	○	○	○

1.7 The apparent magnitude and absolute magnitude of stars X, Y and Z are tabulated below.

star	apparent magnitude	absolute magnitude
X	− 0.8	− 3.4
Y	1.3	2.7
Z	− 2.7	− 4.3

Arrange the stars in descending order of parallax as observed from Earth.

A. YZX
B. YXZ
C. XZY
D. ZXY

A	B	C	D
○	○	○	○

1.8 On the Hertzsprung-Russell (H-R) diagram, the Sun is one of the main sequence stars. Which of the statements about the stars in the H-R diagram is/are correct ?

(1) All supergiant stars are of lower surface temperature than the Sun.
(2) All main sequence stars with surface temperature higher than the Sun have size larger than the Sun.
(3) All white dwarf stars are less luminous than the Sun.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

A	B	C	D
○	○	○	○

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Q.1: Structured question

Star X of surface temperature $T_X = 20000$ K is a main sequence star which shines at a luminosity 1000 times that of the Sun.

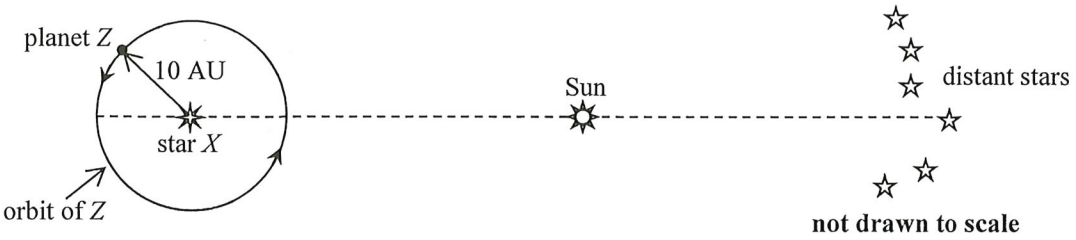
(a) Given that the surface temperature of the Sun is 5800 K, find the radius of X in terms of the solar radius R_S. (2 marks)

(b) Star Y in the main sequence has the same apparent magnitude as X. A student thought that with this information one can determine whether the surface temperature of Y is equal to, greater than or smaller than T_X. Do you agree ? Explain. (3 marks)

(c) The wavelength of a hydrogen emission line measured in the laboratory is 486.1 nm. In the observed spectrum of X, the same spectral line is detected at 485.7 nm. Determine the motion of X relative to the Earth and estimate its minimum speed in km s^{-1}. (3 marks)

(d) The Sun is at a distance of 50 pc from X. There is a planet Z orbiting X in a circular orbit of radius 10 AU. Figure 1.1 (not drawn to scale) shows star X, planet Z, the Sun and some distant stars.

Figure 1.1



Suppose that an observer on planet Z is able to use the parallax method to measure the distance between star X and the Sun. Calculate the parallax angle p of the Sun for this observer in units of arcseconds. (2 marks)

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Section B : Atomic World

Q.2: Multiple-choice questions

2.1 In a Rutherford scattering experiment, most α particles can pass straight through the gold foil while a few being deflected significantly. This proves that an atom has a tiny massive nucleus. Suppose the mass of an atom is evenly distributed within the whole atom,

A. most α particles would be stopped by the gold foil.
B. nearly all α particles would pass straight through the gold foil.
C. most α particles would be deflected significantly and only a few would be able to pass straight through the gold foil.
D. most α particles would rebound by 180°.

A	B	C	D
○	○	○	○

2.2 Which statements about atomic spectra are correct ?

(1) Atomic spectra are due to discrete energy levels for electrons in atoms.
(2) Absorption lines in atomic spectra arise when orbital electrons gain energy.
(3) Emission lines in atomic spectra only correspond to the visible part of the electromagnetic spectrum.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A	B	C	D
○	○	○	○

2.3 A hydrogen atom at ground state has an ionization energy of 13.6 eV. Which of the following photons can be absorbed by this hydrogen atom ?

(1) 3.4 eV
(2) 10.2 eV
(3) 13.7 eV

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A	B	C	D
○	○	○	○

Please stick the barcode label here.

2.4 A monochromatic light is used to illuminate the cathodes of two photocells X and Y, with each photocell connected to a sensitive galvanometer. The galvanometer connected to X shows a reading while that connected to Y does not. Which statements are correct ?

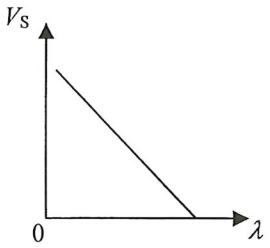
(1) Electrons can escape from the cathode of X but not from the cathode of Y.
(2) Compared to Y, the metallic cathode of X has a smaller threshold frequency.
(3) Compared to Y, the metallic cathode of X has a larger work function.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

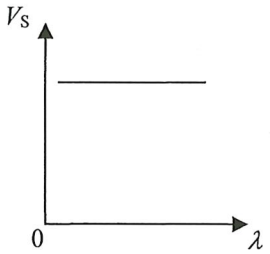
A ○ B ○ C ○ D ○

2.5 In a photoelectric experiment, monochromatic lights of different wavelength λ are incident upon the cathode of the same photocell and the corresponding stopping potential V_S for the photoelectrons emitted is measured. What will be the graph of V_S against λ ?

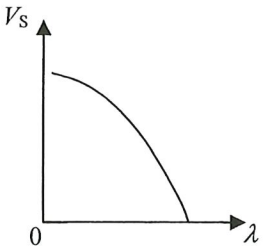
A.



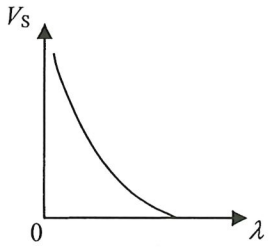
B.



C.



D.



A ○ B ○ C ○ D ○

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2.6 A beam of fast-moving electrons shows wave properties and its de Broglie wavelength is 0.10 nm. What is the average kinetic energy of the beam of electrons ?

A. 151 eV
B. 302 eV
C. 6.2 keV
D. 12.4 keV

A	B	C	D
○	○	○	○

2.7 The angular resolution limit of a transmission electron microscope (TEM) when operated with anode voltage 5 kV is about 4×10^{-10} rad. What is the angular resolution limit of this TEM if it is operated with anode voltage 20 kV ? Assume that its resolution is limited by diffraction only.

A. 1×10^{-10} rad
B. 2×10^{-10} rad
C. 8×10^{-10} rad
D. 16×10^{-10} rad

A	B	C	D
○	○	○	○

2.8 Which phenomena below is/are due to the fact that materials in nanoscale have a much greater surface effect than in their bulk form ?

(1) Titanium dioxide (TiO_2) in nanoscale is a more efficient catalyst.
(2) Silver in nano-sized form has a lower melting point.
(3) An electric current can flow between two surfaces separated at nanoscale even though they are not in contact.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

A	B	C	D
○	○	○	○

Please stick the barcode label here.

Q.2: Structured question

Bohr's model of an atom can be used to explain the discrete line spectrum of hydrogen.

(a) One of Bohr's postulates is that the quantum condition for the stationary orbits of a hydrogen atom is

$$m_e v r = n\frac{h}{2\pi} \quad \text{for } n = 1, 2, 3\ldots$$

where h is the Planck constant and m_e, v and r are the mass, speed and orbital radius of the electron respectively.

Given that the radius of the n^{th} orbit of a hydrogen atom is $r_n = n^2 a_0$, where $a_0 = 5.29 \times 10^{-11}$ m.

(i) Show that the de Broglie wavelength of an electron is quantized (i.e. $\lambda = n \times$ constant) when it is bounded in a hydrogen atom. (1 mark)

(ii) Hence, find λ of an innermost orbital electron of a hydrogen atom. (1 mark)

Some of the energy levels in a hydrogen atom are shown in Figure 2.1.

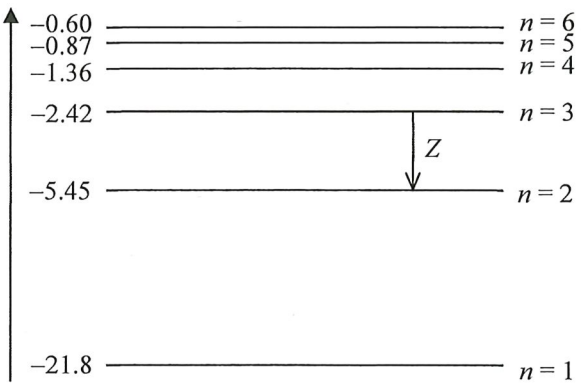
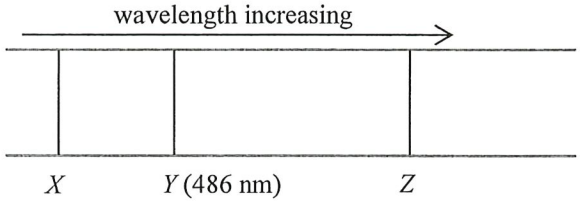


Figure 2.1

Hydrogen in ground state is illuminated by a monochromatic radiation source. Emission lines are then observed and **only three** of them (X, Y and Z) are visible. The wavelength of spectral line Y is 486 nm.
Given: the energy of photons in the visible spectrum lies between 2.84×10^{-19} J and 4.97×10^{-19} J.



(b) (i) Spectral line Z originates from the electron transition between $n = 3$ and $n = 2$ (see Figure 2.1). State the electron transition that gives spectral line X. (1 mark)

(ii) Find the wavelength of X. (2 marks)

(iii) Determine whether **a single transition** of an electron from $n = 6$ can give a visible spectral line. Hence, state and explain the energy level that the hydrogen atom being excited to by this monochromatic radiation source. (3 marks)

(c) Find the energy of this monochromatic radiation in eV and state the region of the electromagnetic spectrum (infra-red, visible or ultra-violet) that it belongs to. (2 marks)

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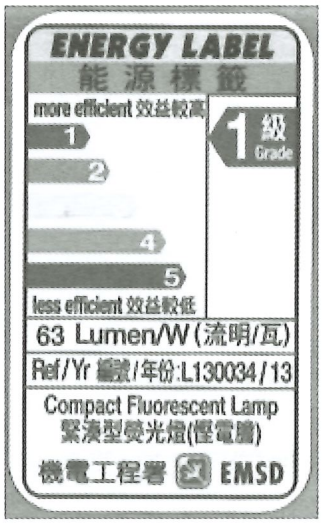
Section C : Energy and Use of Energy

Q.3: Multiple-choice questions

3.1 The energy label of a 12 W compact fluorescent lamp is shown below.



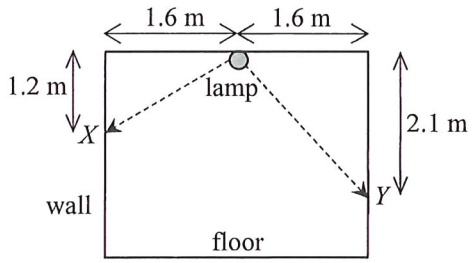
Which of the following statements are correct ?

(1) The efficacy of the lamp is 63 lm W^{-1}.
(2) The illuminance of the lamp is 756 lx.
(3) Compared to other 12 W compact fluorescent lamps, the efficacy of this lamp is above average.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A	B	C	D
○	○	○	○

3.2 In the room shown below, a lamp fixed at the centre of the ceiling is the only light source. It is 1.6 m from each wall.



Point X on the wall is at 1.2 m below the ceiling while point Y on the opposite wall is at 2.1 m below the ceiling. Find the ratio $\frac{\text{illuminance on the wall around point } X}{\text{illuminance on the wall around point } Y}$. Neglect any light reflecting off the ceiling, the floor and the walls.

A. 0.43
B. 0.76
C. 1.32
D. 2.30

A	B	C	D
○	○	○	○

3.3 The information of heat transfer of a house is tabulated below:

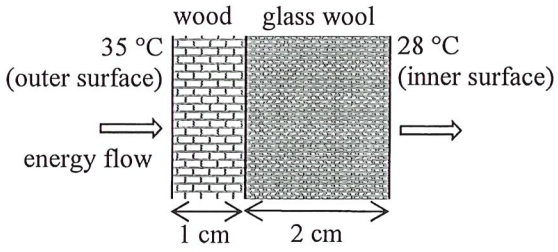
interface with the environment	walls	roof	windows
total area / m^2	102	70	x
annual average rate of heat gain per unit area / W m^{-2}	10.0	25.0	116

The Overall Thermal Transfer Value (OTTV) of the house is 22.4 W m^{-2}. Find the total area of windows, x.

A. 7.8 m^2
B. 9.3 m^2
C. 11.6 m^2
D. 23.9 m^2

A B C D
○ ○ ○ ○

3.4 A wall is composed of wood and glass wool of thickness 1 cm and 2 cm respectively. The outer surface of the wall is at a temperature of 35 °C while its inner surface is kept at 28 °C.



Given: thermal conductivity of wood = 0.15 W m^{-1} K^{-1}
thermal conductivity of glass wool = 0.03 W m^{-1} K^{-1}
Estimate the temperature at the wood and glass wool interface.

A. 28.6 °C
B. 30.0 °C
C. 33.0 °C
D. 34.4 °C

A B C D
○ ○ ○ ○

3.5 An electric vehicle of mass 1500 kg is equipped with a regenerative braking system. When the brakes are applied, the speed of the vehicle is reduced from 70 km h^{-1} to 35 km h^{-1}. In this process 57.6 kJ of chemical energy is stored in its battery. Estimate the overall efficiency of the regenerative braking system.

A. 22%
B. 25%
C. 27%
D. 30%

A B C D
○ ○ ○ ○

Go on to the next page

3.6 Solar panels usually have a dark appearance. This is because

A. the cost to manufacture dark colour solar panels is lower.
B. a transparent anti-reflection film is coated onto the top surface of the panel.
C. the panels are painted dark so as to absorb more radiation.
D. the panels are painted dark so that it won't be necessary to clean them as frequently.

A	B	C	D
○	○	○	○

3.7 There are a total of 100 wind turbines used to generate electricity. Each turbine has blade length 6 m and an efficiency of 23%. Now they are replaced by N turbines of a newer model, with blade length 8 m and an efficiency of 28%. Estimate N assuming the total output power is almost unchanged.

A. 46
B. 62
C. 69
D. 91

A	B	C	D
○	○	○	○

3.8 Which of the following statements about nuclear energy is/are correct ?

(1) It is a kind of renewable energy.
(2) If the magnitude of the total binding energy increases after a nuclear reaction, energy will be released.
(3) Unstable nuclei tend to release energy through nuclear reactions to become more stable.

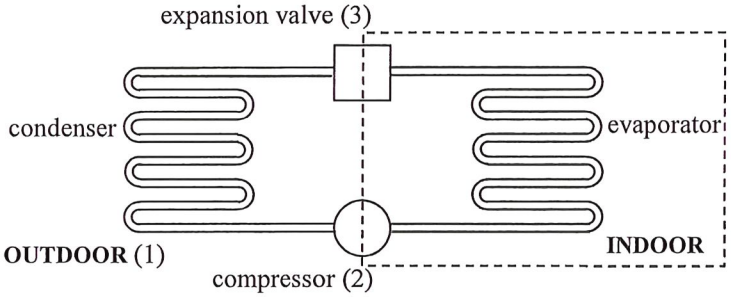
A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

A	B	C	D
○	○	○	○

Q.3: Structured question

Figure 3.1 shows the major components of an air-conditioner, which include the compressor, the condenser, the expansion valve and the evaporator. Refrigerant is driven to circulate in the loop.

Figure 3.1



(a) (i) With reference to the change of state of the refrigerant in these components, explain how an air-conditioner can remove heat from indoor to outdoor. (2 marks)

(ii) Which of the temperatures below is the highest ?

(1) outdoor air temperature
(2) temperature of the refrigerant leaving the compressor
(3) temperature of the refrigerant leaving the expansion valve

(1 mark)

(iii) State a reason why the total amount of heat released to outdoor Q_H must be larger than that removed from indoor Q_C. (1 mark)

(b) An air-conditioner installed in a classroom has been switched on for 4.0 minutes during which 2.04×10^6 J of heat is removed from the classroom.

(i) Find the cooling capacity C_p of this air-conditioner. (2 marks)

(ii) Estimate the drop in air temperature of the classroom, measuring 13.4 m × 5.0 m × 3.0 m, at the end of 4.0 minutes. Given: The specific heat capacity of air is 1000 J kg^{-1} $°C^{-1}$ and the density of air is 1.20 kg m^{-3}. (2 marks)

(iii) If the COP (coefficient of performance) of the air-conditioner is 6.2, estimate the total amount of heat released to outdoor Q_H during this period. (2 marks)

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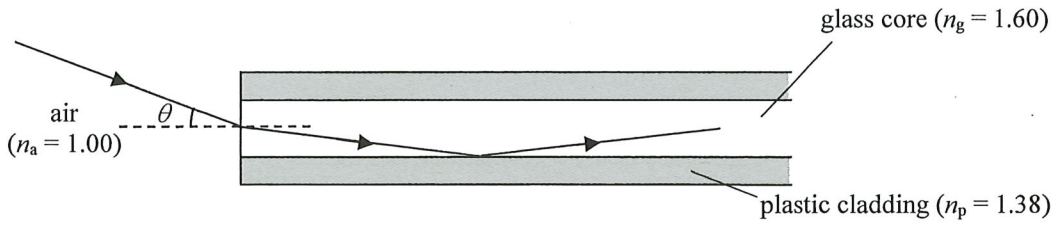
Section D : Medical Physics

Q.4: Multiple-choice questions

4.1 A straight optical fibre has a glass core of refractive index 1.60 and a plastic cladding of refractive index 1.38. A light ray enters the core at an incident angle θ as shown.

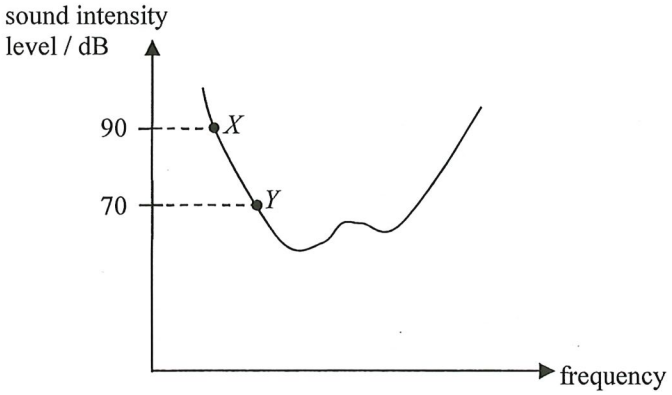


This light ray can emerge from the other end of the glass core when total internal reflection occurs. Find the range of θ that fulfils this condition.

A. smaller than 54.1°
B. larger than 54.1°
C. smaller than 59.6°
D. larger than 59.6°

A	B	C	D
○	○	○	○

4.2 The curve below shows sounds of different frequencies that have a loudness of 70 phons. X and Y are two notes on the curve.



Which statement below is correct ?

A. X is louder than Y by 20 dB.
B. Y is louder than X by 20 dB.
C. The notes are equally loud but the sound intensity of X is 20 times that of Y.
D. The notes are equally loud but the sound intensity of X is 100 times that of Y.

A	B	C	D
○	○	○	○

4.3 The table shows the typical frequencies and some properties of ultrasound used in ultrasound scans :

frequency (MHz)	typical penetration depth	resolution along the beam direction (mm)
3 – 5	10 cm – 20 cm	1.0
5 – 10	5 cm	0.2
10 – 15	1 cm	0.1
50	a few mm	0.05

Which of the following statements is/are correct ?

(1) Ultrasound beams of higher frequency give a better resolution.
(2) Large penetration depth and high resolution can be achieved by ultrasound of a certain frequency.
(3) To investigate the whole liver, it is best to use a 5 – 10 MHz ultrasound scan.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

A B C D
○ ○ ○ ○

4.4 Which statement about computed tomography (CT) scan is **INCORRECT** ?

A. The grey levels in CT images correspond to X-ray attenuation coefficient of the body tissue.
B. CT image reconstruction involves back projecting the intensity readings of X-ray beams across an image plane viewed at different angles.
C. CT scans provide both anatomical and functional information of an organ.
D. The radiation dose received by the patient in a CT scan is higher than that in a conventional X-ray imaging.

A B C D
○ ○ ○ ○

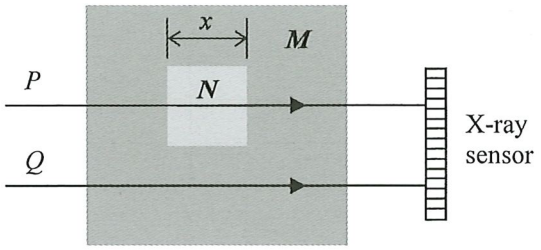
4.5 Which of the following imaging methods is/are **NOT SUITABLE** for allowing a needle to be guided accurately as it is inserted into the body ?

(1) ultrasound scan
(2) endoscopy
(3) radionuclide imaging

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

A B C D
○ ○ ○ ○

4.6 Two identical X-ray beams P and Q pass through the same thickness of body tissues as shown. There is a mass N of thickness x embedded in tissue M in the path of beam P. The linear attenuation coefficients of M and N are μ_1 and μ_2 respectively.

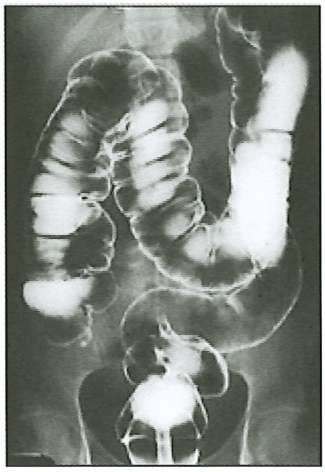


The X-ray sensor detects an intensity of I where beam Q falls on it. Deduce the corresponding intensity of beam P.

A. $Ie^{-\mu_2 x}$
B. $Ie^{-(\mu_2-\mu_1)x}$
C. $Ie^{-(\mu_2+\mu_1)x}$
D. $Ie^{-\mu_1 x} - Ie^{-\mu_2 x}$

A B C D
○ ○ ○ ○

4.7 With the aid of a contrast medium, the X-ray radiographic image shown below is obtained.



Which statement below is **INCORRECT** ?

A. The contrast medium absorbs X-rays and looks white on the image.
B. The contrast medium enhances the tissue and structure absorption differentials.
C. Elements of low atomic number are used for the contrast medium.
D. Low energy X-rays are used to produce the image.

A B C D
○ ○ ○ ○

4.8 A tracer labelled with ^{125}I is used in radionuclide imaging. ^{125}I has a physical half-life of 60 days. If the effective half-life of this radioactive tracer is 16 days, estimate the biological half-life of this tracer when it is introduced into the body.

A. 12 days
B. 22 days
C. 38 days
D. 44 days

A B C D
○ ○ ○ ○

Q.4: Structured question

(a) Describe the differences between **rods** and **cones** in their functions in vision. (2 marks)

The table below shows the change of near point of a person with age. Given that, for all ages, the person can view distant objects clearly while the separation between the eye lens and the retina is kept at 2.5 cm.

age / year	near point / cm
20	10
30	14
40	25
50	40
60	80
70	100

(b) (i) What is the meaning of **near point** ? (1 mark)

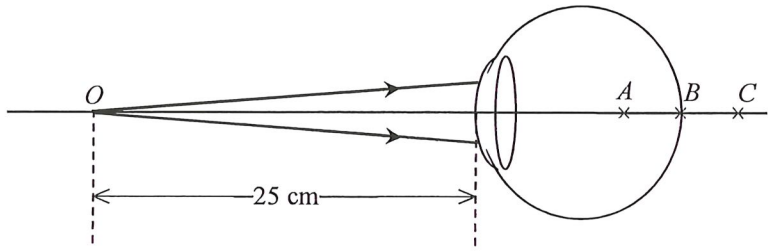
(ii) The above table reveals that the power of the eyes decreases with age. State a reason why the power decreases. (1 mark)

(iii) What is meant by **accommodation** of the eyes ? (1 mark)

(iv) (I) Find the range of the power of the eyes, in dioptre D, between far point and near point of the person at 20 years of age.
(II) By how much does this range decrease when the person reaches 70 years old ?
(3 marks)

(c) Suppose the person is now at 50 years of age. Figure 4.1 shows this person looking at point *O* of a newspaper at 25 cm distance from the eyes. Should the rays from *O* converge at point *A*, point *B* or point *C* to form an image ? In order to see point *O* clearly, state the direction that the newspaper needs to move and the least distance of movement needed. (2 marks)

Figure 4.1



END OF PAPER

Sources of materials used in this paper will be acknowledged in the *HKDSE Question Papers* booklet published by the Hong Kong Examinations and Assessment Authority at a later stage.

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Answers written on this page will not be marked.

List of data, formulae and relationships

Data

molar gas constant	$R = 8.31$ J mol^{-1} K^{-1}
Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}
acceleration due to gravity	$g = 9.81$ m s^{-2} (close to the Earth)
universal gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
speed of light in vacuum	$c = 3.00 \times 10^8$ m s^{-1}
charge of electron	$q_e = 1.60 \times 10^{-19}$ C
electron rest mass	$m_e = 9.11 \times 10^{-31}$ kg
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2}
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}
atomic mass unit	u = 1.661×10^{-27} kg (1 u is equivalent to 931 MeV)
astronomical unit	AU = 1.50×10^{11} m
light year	ly = 9.46×10^{15} m
parsec	pc = 3.09×10^{16} m = 3.26 ly = 206265 AU
Stefan constant	$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}
Planck constant	$h = 6.63 \times 10^{-34}$ J s

Rectilinear motion

For uniformly accelerated motion :

$$v = u + at$$
$$s = ut + \frac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

Mathematics

Equation of a straight line	$y = mx + c$
Arc length	$= r\theta$
Surface area of cylinder	$= 2\pi rh + 2\pi r^2$
Volume of cylinder	$= \pi r^2 h$
Surface area of sphere	$= 4\pi r^2$
Volume of sphere	$= \frac{4}{3}\pi r^3$

For small angles, $\sin\theta \approx \tan\theta \approx \theta$ (in radians)

Astronomy and Space Science

$U = -\frac{GMm}{r}$	gravitational potential energy
$P = \sigma AT^4$	Stefan's law
$\left\|\frac{\Delta f}{f_0}\right\| \approx \frac{v}{c} \approx \left\|\frac{\Delta\lambda}{\lambda_0}\right\|$	Doppler effect

Energy and Use of Energy

$E = \frac{\Phi}{A}$	illuminance
$\frac{Q}{t} = \kappa\frac{A(T_H - T_C)}{d}$	rate of energy transfer by conduction
$U = \frac{\kappa}{d}$	thermal transmittance U-value
$P = \frac{1}{2}\rho A v^3$	maximum power by wind turbine

Atomic World

$\frac{1}{2}m_e v_{max}{}^2 = hf - \phi$	Einstein's photoelectric equation
$E_n = -\frac{1}{n^2}\left\{\frac{m_e q_e^4}{8h^2\varepsilon_0^2}\right\} = -\frac{13.6}{n^2}$ eV	energy level equation for hydrogen atom
$\lambda = \frac{h}{p} = \frac{h}{mv}$	de Broglie formula
$\theta \approx \frac{1.22\lambda}{d}$	Rayleigh criterion (resolving power)

Medical Physics

$\theta \approx \frac{1.22\lambda}{d}$	Rayleigh criterion (resolving power)
power $= \frac{1}{f}$	power of a lens
$L = 10\log\frac{I}{I_0}$	intensity level (dB)
$Z = \rho c$	acoustic impedance
$\alpha = \frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$	intensity reflection coefficient
$I = I_0 e^{-\mu x}$	transmitted intensity through a medium

A1.	$E = mc\,\Delta T$	energy transfer during heating and cooling
A2.	$E = l\,\Delta m$	energy transfer during change of state
A3.	$pV = nRT$	equation of state for an ideal gas
A4.	$pV = \frac{1}{3}Nm\overline{c^2}$	kinetic theory equation
A5.	$E_K = \frac{3RT}{2N_A}$	molecular kinetic energy

B1.	$F = m\frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$	force
B2.	moment $= F \times d$	moment of a force
B3.	$E_P = mgh$	gravitational potential energy
B4.	$E_K = \frac{1}{2}mv^2$	kinetic energy
B5.	$P = Fv$	mechanical power
B6.	$a = \frac{v^2}{r} = \omega^2 r$	centripetal acceleration
B7.	$F = \frac{Gm_1m_2}{r^2}$	Newton's law of gravitation

C1.	$\Delta y = \frac{\lambda D}{a}$	fringe separation in double-slit interference
C2.	$d\sin\theta = n\lambda$	diffraction grating equation
C3.	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$	equation for a single lens

D1.	$F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$	Coulomb's law
D2.	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$	electric field strength due to a point charge
D3.	$E = \frac{V}{d}$	electric field between parallel plates (numerically)
D4.	$R = \frac{\rho l}{A}$	resistance and resistivity
D5.	$R = R_1 + R_2$	resistors in series
D6.	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$	resistors in parallel
D7.	$P = IV = I^2R$	power in a circuit
D8.	$F = BQv\sin\theta$	force on a moving charge in a magnetic field
D9.	$F = BIl\sin\theta$	force on a current-carrying conductor in a magnetic field
D10.	$B = \frac{\mu_0 I}{2\pi r}$	magnetic field due to a long straight wire
D11.	$B = \frac{\mu_0 NI}{l}$	magnetic field inside a long solenoid
D12.	$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$	induced e.m.f.
D13.	$\frac{V_s}{V_p} \approx \frac{N_s}{N_p}$	ratio of secondary voltage to primary voltage in a transformer

E1.	$N = N_0e^{-kt}$	law of radioactive decay
E2.	$t_{\frac{1}{2}} = \frac{\ln 2}{k}$	half-life and decay constant
E3.	$A = kN$	activity and the number of undecayed nuclei
E4.	$\Delta E = \Delta mc^2$	mass-energy relationship