2020-DSE
PHY

PAPER 2

HONG KONG EXAMINATIONS AND ASSESSMENT AUTHORITY
HONG KONG DIPLOMA OF SECONDARY EDUCATION EXAMINATION 2020

Please stick the barcode label here.

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 and 7.

(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.

A150E2MC

Section A : Astronomy and Space Science

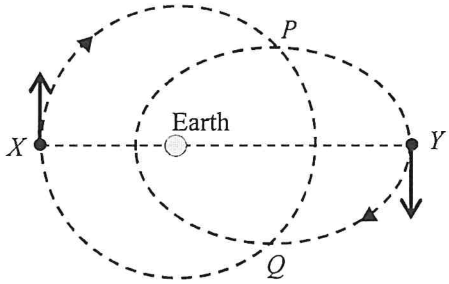
Q.1: Multiple-choice questions

1.1 Which of the following represents the arrangement in descending order of size ?

A. star cluster > galaxy > planetary system
B. star cluster > planetary system > galaxy
C. galaxy > planetary system > star cluster
D. galaxy > star cluster > planetary system

A B C D
○ ○ ○ ○

1.2 Two satellites X and Y are revolving in clockwise direction about the Earth as shown. The diameter of the circular orbit of X equals the length of the major axis of the elliptical orbit of Y. The two orbits intersect at P and Q.



At the instant shown, the two satellites and the Earth are on a straight line. Which deductions are correct ?

(1) X and Y have the same acceleration when they pass P.
(2) The speed of X is greater than that of Y at the instant shown.
(3) The satellites will not meet each other at P or at Q.

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

A B C D
○ ○ ○ ○

1.3 The mass of Mars is 0.107 times that of the Earth. The radius of Mars is 0.532 times that of the Earth. What is the escape velocity of Mars in terms of the escape velocity of the Earth v_E ?

A. 0.201 v_E
B. 0.378 v_E
C. 0.449 v_E
D. 0.615 v_E

A B C D
○ ○ ○ ○

1.4 The luminosity of star P is double that of star Q. The brightness of P is eight times that of Q. What can be deduced about the respective distance of stars P and Q from the Earth ?

A. P's distance from the Earth is 2 times that of Q.
B. Q's distance from the Earth is 2 times that of P.
C. P's distance from the Earth is 4 times that of Q.
D. Q's distance from the Earth is 4 times that of P.

A B C D
○ ○ ○ ○

1.5 The edge-on view of a binary system shows that the wavelength of the calcium K spectral line of one of the stars changes by ±0.3 nm from the same line (λ = 393.4 nm) obtained in a laboratory. The period of the star is 69 hours. Find the radius of its orbit.

A. 2.5×10^6 m
B. 1.5×10^8 m
C. 9.0×10^9 m
D. 5.6×10^{10} m

A B C D
○ ○ ○ ○

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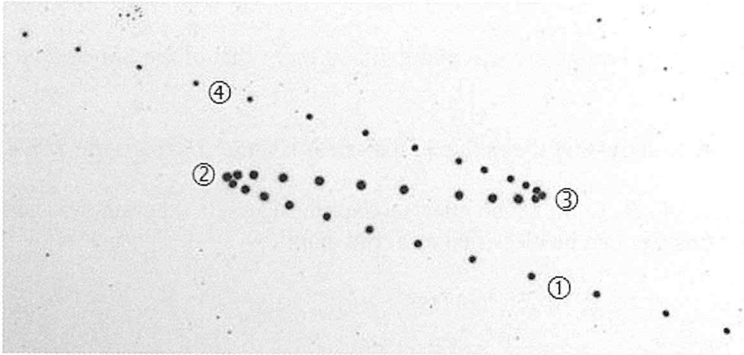
1.6 The figure below shows the motion of Mars from bottom right to top left against the background night sky over a period of about 7 months.

East  West

At which point along the path was Mars closest to the Earth ?

A. somewhere between ① and ②
B. somewhere between ② and ③
C. somewhere between ③ and ④
D. either at turning point ② or at turning point ③

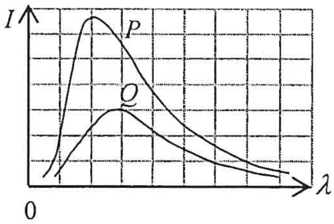
A B C D

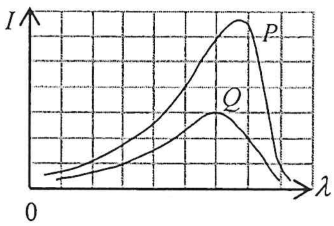
1.7 A star, which is 4.2 light years from the Sun, is observed from the Earth 6 months apart. Estimate the maximum angular difference in the observed positions of this star.

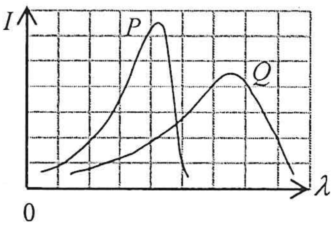
A. 0.8 arc seconds
B. 1.3 arc seconds
C. 1.6 arc seconds
D. 2.6 arc seconds

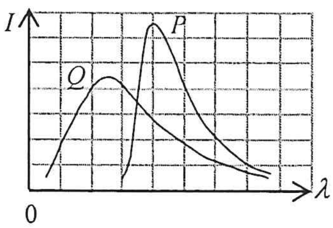
A B C D

1.8 Star P has a higher surface temperature than star Q. However, star Q has a larger radius. Which graph shows the distribution of spectral intensity I (in W m^{-2} per nm) with the wavelength λ (in nm) of the electromagnetic radiation emitted from the surfaces of P and Q ? Blackbody radiation is assumed for both stars.

A. 

B. 

C. 

D. 

A B C D

Q.1: Structured question

A certain star X at a distance of about 50 kpc from the Earth exploded a very long time ago and became Supernova 1987A (SN 1987A). The light from this supernova first reached the Earth in 1987.

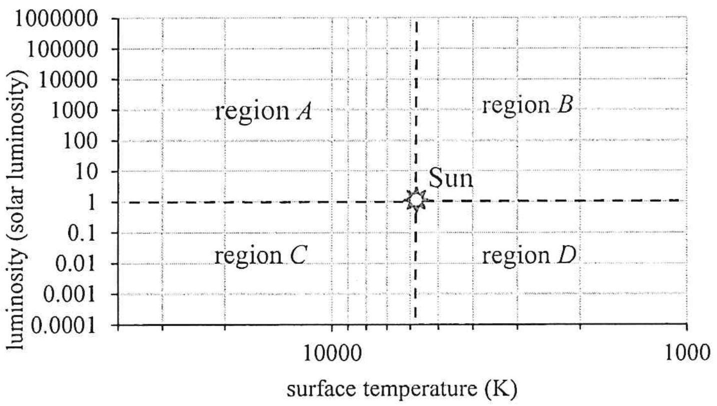
(a) Estimate how long ago the above explosion took place. (Give your answer in years to 3 sig. fig.) (1 mark)

(b) At maximum brightness, SN 1987A has an apparent magnitude of +2.9. Is the *absolute magnitude* of SN 1987A at maximum brightness smaller than, larger than or equal to +2.9 ? Explain your answer. (2 marks)

Before the explosion of star X, its luminosity was about 40000 times that of the Sun and its surface temperature was 3.1 times that of the Sun.

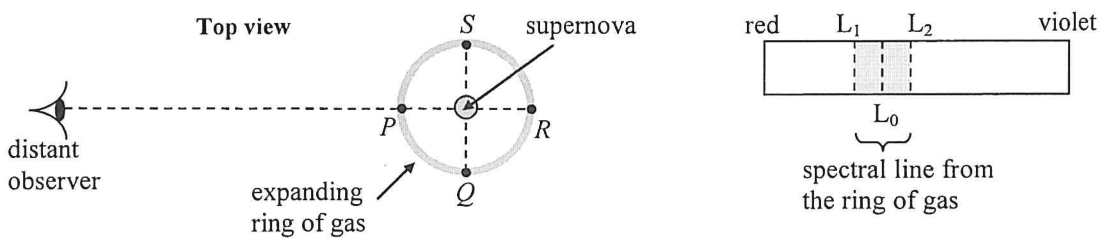
(c) (i) Use Stefan's law to show that the radius of the star X is about 20 times the Sun's radius. (2 marks)

(ii) In which region, A, B, C or D, on the Hertzsprung-Russell diagram was star X located ? Explain whether or not this star can be classified as a 'red giant'. (2 marks)



(d) A special feature of SN 1987A is that a circular ring of gas surrounds the supernova. The gas was ejected by the star X some time before it exploded. As shown in Figure 1.1, each point on this ring is expanding outwards at a constant speed from the supernova.

Figure 1.1



Suppose a distant observer on the plane containing the ring views a certain spectral line from the ring of gas and finds that it covers wavelengths between the limits L_1 and L_2 as shown in Figure 1.1. L_0 is the wavelength of that spectral line when observed in the laboratory. State the respective wavelengths that originate from point Q and point R on the ring. Explain your answer. (3 marks)

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Section B : Atomic World

Q.2: Multiple-choice questions

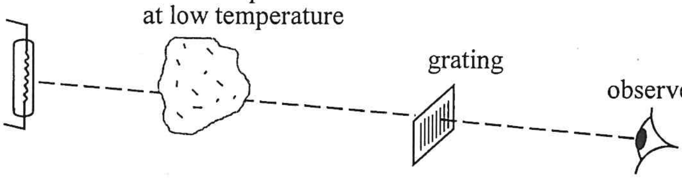
2.1 Which of the following statements about Rutherford's scattering experiment is/are correct ?

(1) Thin gold foil was used so that each α particle would most likely be scattered by one gold nucleus only.
(2) If β particles were directed towards the gold foil instead of α particles, they could be deflected by both the gold nuclei and the electrons in the foil.
(3) Gold foil was used because gold contains free electrons.

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

A B C D
○ ○ ○ ○

2.2

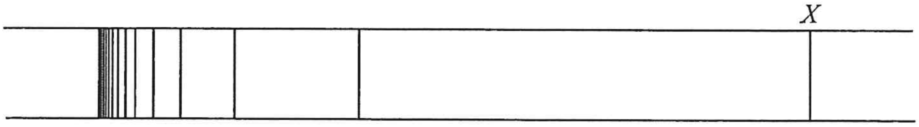


In the experiment shown above, dark lines are observed on a colour background. Which explanation is correct ?

A. No photons corresponding to the dark lines were emitted from the source.
B. No photons corresponding to the dark lines were emitted from the vapour.
C. Photons corresponding to the dark lines from the source were absorbed by the vapour.
D. Photons corresponding to the dark lines from the source were scattered back to the source by the vapour.

A B C D
○ ○ ○ ○

2.3 The figure below shows the emission lines of the hydrogen spectrum associated with electron transitions from excited energy levels to the ground state (n = 1). It is known that the energy level of the ground state is $E_1 = -13.6$ eV.



Which statement is correct ?

A. Spectral line X has the highest frequency.
B. The shortest wavelength of the lines in this spectral series is about 90 nm.
C. These spectral lines are in the infra-red region.
D. Some of these lines also appear in other spectral series of the hydrogen spectrum.

A B C D
○ ○ ○ ○

2.4 Which statements about the Bohr atom model are correct ?

(1) It can explain why α particles can be rebounded by a thin gold foil.
(2) It can give the atomic spectra of a singly ionized helium atom (He^+).
(3) A postulate of this model is that the angular momentum of the electron in an hydrogen atom is quantized.

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 An atom has three energy levels : X, Y, and Z. When the atom transits from X to Y, it emits a photon of wavelength λ_1. The atom transits from Y to Z when it absorbs a photon of wavelength λ_2, with $\lambda_1 > \lambda_2$. These energy levels arranged in descending order is

A. $Z\ X\ Y$.
B. $Z\ Y\ X$.
C. $X\ Z\ Y$.
D. $X\ Y\ Z$.

A B C D
○ ○ ○ ○

2.6 An electron beam accelerated through a potential difference of V is directed to a thin crystal layer. The diffraction pattern obtained is similar to that produced by X-rays of wavelength λ. What potential difference should be used for accelerating the electron beam so as to give a diffraction pattern similar to that produced by X-rays of wavelength 2λ ?

A. $\frac{V}{4}$
B. $\frac{V}{2}$
C. $2V$
D. $4V$

A B C D
○ ○ ○ ○

2.7 Which of the following statements about a scanning tunnelling microscope (STM) is/are correct ?

(1) STM can reveal the internal structure of a specimen as three-dimensional images are produced.
(2) In STM imaging, the surface of the specimen must be electrically conducting.
(3) The resolving power of STM is limited by Rayleigh criterion.

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

A B C D
○ ○ ○ ○

2.8 Which of the following statements about materials in **bulk form** and in **nano size** are correct ?

(1) Most materials exhibit different colour in the states mentioned above.
(2) Most materials in nano size have lower melting point.
(3) Materials in nano size are usually more efficient in serving as catalyst.

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.

Q.2: Structured question

In order to demonstrate photoelectric effect, the electrodes A and C of the photocell in Figure 2.1 are connected to a potential difference V which can be read from the high-resistance voltmeter. This potential difference can vary from 0 V to 2.5 V.

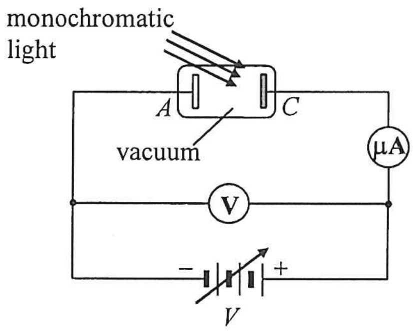


Figure 2.1

When monochromatic light of wavelength 300 nm is incident on electrode C, the microammeter of negligible internal resistance shows a reading.

(a) (i) State the part of the electromagnetic spectrum (ultra-violet, blue, green, red or infra-red) that the incident light belongs to. (1 mark)

(ii) According to wave theory, there should be a 'time delay' for photoelectric emission to occur. However, the experimental result shows that photoelectric emission is immediate. State the implication of such an experimental result. (1 mark)

(b) The applied potential difference is adjusted until the microammeter reading just falls to zero when $V = 1.7$ V.

(i) State and explain whether the microammeter reading would change if an incident light of the same wavelength but higher intensity is used. (2 marks)

(ii) Calculate the work function, in eV, of electrode C. (3 marks)

(c) Now the applied potential difference is adjusted until $V = 0.8$ V and the microammeter registers 0.4 μA.

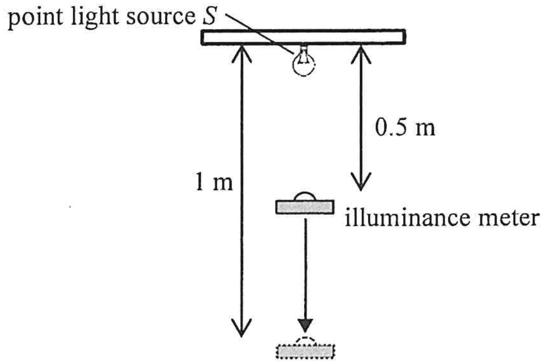
(i) Estimate the number of photoelectrons reaching electrode A in one second. (1 mark)

(ii) State the maximum kinetic energy, in eV, of the photoelectrons reaching A. Explain why not all photoelectrons reaching A possesses this amount of kinetic energy. (2 marks)

Section C : Energy and Use of Energy

Q.3: Multiple-choice questions

3.1 An illuminance meter is placed 0.5 m directly underneath a point light source S emitting a certain luminous flux as shown.



If the luminous flux emitted by S is doubled and the meter is lowered to a position 1 m underneath S, what would be the change in the meter reading ?

A. decreases by 25%
B. decreases by 50%
C. remains unchanged
D. increases by 50%

A B C D
○ ○ ○ ○

3.2 A solar furnace uses a reflector of area 9 m^2 to collect sunlight so as to heat up a piece of iron of mass 2 kg. The efficiency of the furnace is 50%. Estimate the time taken to heat up the piece of iron from 30 °C to 90 °C.
Given: specific heat capacity of iron = 450 J kg^{-1} $°C^{-1}$
solar power per unit area received on the Earth's surface = 1000 W m^{-2}

A. 12 s
B. 24 s
C. 48 s
D. 96 s

A B C D
○ ○ ○ ○

3.3 An electric vehicle's battery of capacity 40 kW h is completely discharged initially. It is charged with a terminal voltage of 220 V at an average current of 32 A. Estimate the time required to fully charge this battery. Assume that 20% energy loss occurs during charging.

A. 4.6 hours
B. 5.7 hours
C. 6.8 hours
D. 7.1 hours

A B C D
○ ○ ○ ○

3.4 What are the reasons for a microwave oven having an 'end-use energy efficiency' of less than 100% ?

(1) Some energy is lost during the transmission of electrical energy from the power plant to the oven.
(2) The microwave oven cannot convert all the electrical energy to the energy of microwave.
(3) Some microwaves are absorbed by the oven's body and does not reach the food.

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

A B C D
○ ○ ○ ○

3.5 During summer time, heat flows into a house through its walls of a certain thickness. The rate of heat flow per unit area of the wall would be reduced if

(1) the temperature difference between the outer and inner surfaces of the wall is smaller.
(2) the thickness of the wall is increased.
(3) material of a larger U-value is used for building the wall.

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

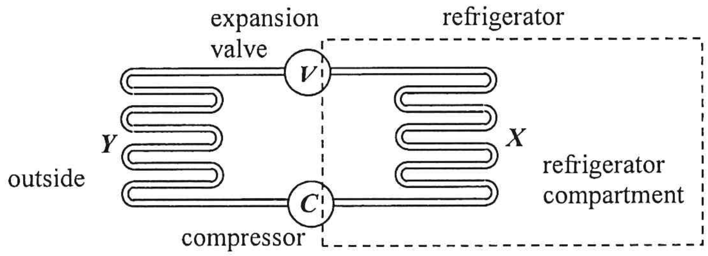
A B C D
○ ○ ○ ○

3.6 A room is kept cool by an air-conditioner of cooling capacity P. The temperatures inside and outside the room are 27 °C and 31 °C respectively. The rate of heat flowing into the room by radiation through windows and that by conduction are in the ratio 1:4. If the cooling capacity is raised to $2P$ while the temperature outside the room is still 31 °C, estimate the temperature inside the room. Assume that the rate of heat flowing into the room by radiation is unchanged.

A. 21 °C
B. 22 °C
C. 23 °C
D. 25 °C

A B C D
○ ○ ○ ○

3.7 A simplified schematic diagram of a refrigerator is as shown.



What is the direction of flow of the refrigerant through the expansion valve V ? Which component, X or Y, contains refrigerant at a higher temperature ?

	direction of flow of the refrigerant through the expansion valve	**component that contains refrigerant at a higher temperature**
A.	$X \rightarrow V \rightarrow Y$	X
B.	$X \rightarrow V \rightarrow Y$	Y
C.	$Y \rightarrow V \rightarrow X$	X
D.	$Y \rightarrow V \rightarrow X$	Y

A B C D
○ ○ ○ ○

3.8 Which of the following is/are 'renewable energy source(s)' ?

(1) wind power
(2) natural gas
(3) nuclear power

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

A B C D
○ ○ ○ ○

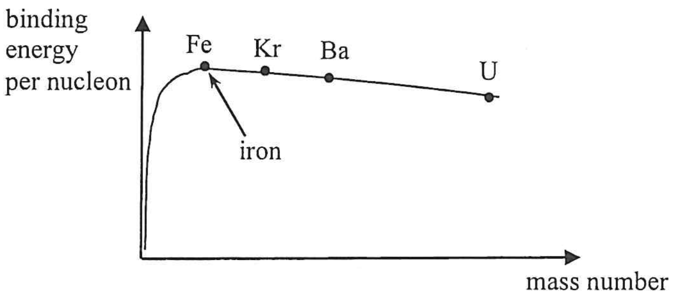
Q.3: Structured question

Pressurized water reactors constitute the majority of the world's nuclear power plants. In the reactor, energy is produced by the fission of uranium-235 nuclei ($^{235}_{92}U$). A typical fission reaction is as follows:

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2^{1}_{0}n$$

(a) Referring to the binding energy curve in Figure 3.1, explain why uranium-235 nuclei tend to undergo fission. (2 marks)

Figure 3.1



(b) The binding energy of a uranium-235 nucleus is 1783 MeV.

(i) What does the above statement mean ? (1 mark)

(ii) Find the energy released, in MeV, in the fission of a uranium-235 nucleus.
Given: Binding energy per nucleon of $^{144}_{56}Ba$ nucleus = 8.27 MeV per nucleon
Binding energy per nucleon of $^{90}_{36}Kr$ nucleus = 8.59 MeV per nucleon (2 marks)

(c) (i) In the reactor of a nuclear power plant, a total energy of 1.30×10^{30} MeV would be released if all uranium-235 nuclei in the fuel rods have undergone fission. Given that the mean power output of the power plant is 500 MW and the efficiency in converting nuclear energy to electrical energy is 40%. Estimate the time, in years, for which the fuel rods can be used. (Take 1 year = 3.15×10^{7} s) (2 marks)

(ii) State a reason why the fuel rods are usually replaced before the time estimated in (c)(i) has elapsed. (1 mark)

(d) Explain the role of the following in a fission reactor:

(i) moderator

(ii) control rods

(2 marks)

Section D : Medical Physics

Q.4: Multiple-choice questions

4.1 When the accommodation of an eye changes from looking at a distant object to a near object, which of the following statements is/are correct ?

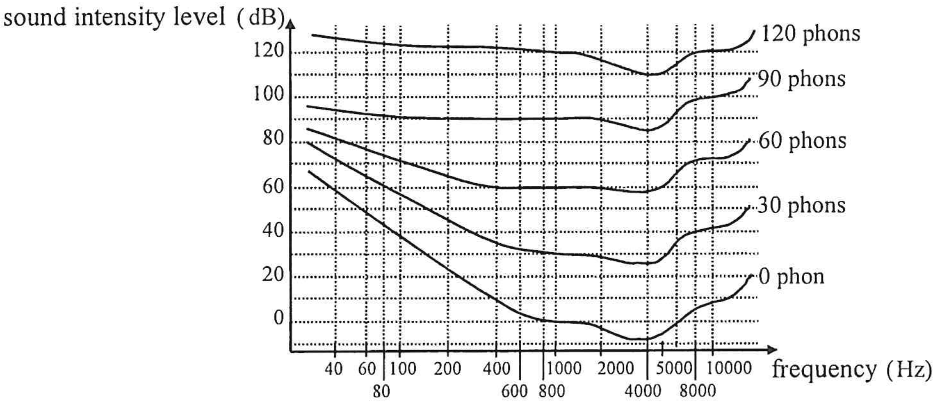
(1) The eye lens becomes less 'convex'.
(2) The optical power of the eye lens increases.
(3) The ciliary muscles around the lens contract.

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

A B C D

○ ○ ○ ○

4.2 The figure shows the relationship of loudness (in phons) to sound intensity level (in dB) for persons with normal hearing. Which statement **CANNOT** be deduced from this figure ?



A. The ear is most sensitive to sounds of frequencies between 2000 Hz and 5000 Hz.
B. A sound of 60 Hz at 40 dB is inaudible.
C. Hearing sensitivity always increases with the increase of frequency of sound.
D. For sounds at frequencies below 1000 Hz, the numerical value of sound intensity level (in dB) is not smaller than its loudness (in phons).

A B C D

○ ○ ○ ○

4.3 A doctor suspects that a patient has tumours in the liver. Which method(s) below can be used to detect the tumours and measure their size ?

(1) examining with an endoscope
(2) taking an ultrasound B-scan
(3) taking a computed tomography (CT) scan

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

A B C D

○ ○ ○ ○

4.4 Which of the following statements about the piezoelectric crystal inside an ultrasound transducer is/are correct ?

(1) The piezoelectric crystal converts electrical signals into mechanical vibrations and vice versa.
(2) The thickness of the piezoelectric crystal is arbitrary.

A. Only (1) is correct.
B. Only (2) is correct.
C. (1) and (2) are correct.
D. (1) and (2) are incorrect.

A B C D
○ ○ ○ ○

4.5 Using the information given below, find the proportion of energy transmitted when ultrasound is incident from air to skin.

	acoustic impedance / kg m^{-2} s^{-1}
air	430
soft tissue	1.5×10^6

A. 5.7×10^{-4}
B. 1.1×10^{-3}
C. 2.8×10^{-3}
D. 1.0×10^{-2}

A B C D
○ ○ ○ ○

4.6 Which sequence about the procedure of radionuclide imaging (RNI) is correct ?

(1) The drug is moved through bloodstream to the target organ.
(2) Inject the drug into the patient's body.
(3) Label the drug with a radioactive isotope.
(4) Reconstruct the image by a computer.
(5) Scan the patient with a gamma camera.

A. (2) → (3) → (1) → (5) → (4)
B. (2) → (3) → (1) → (4) → (5)
C. (3) → (2) → (1) → (5) → (4)
D. (3) → (2) → (1) → (4) → (5)

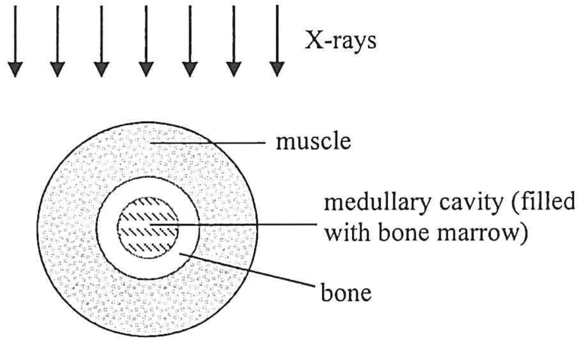
A B C D
○ ○ ○ ○

4.7 Radionuclide imaging can be used to study kidney diseases. Which radioactive isotope below would be the most suitable ?

radioactive isotope	radiation emitted	half-life
A.	γ	20.3 minutes
B.	γ	6.0 hours
C.	β, γ	2.7 days
D.	β	3.3 hours

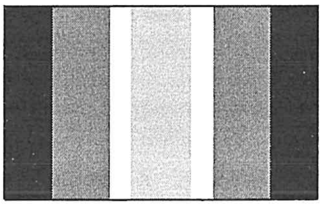
A B C D
○ ○ ○ ○

4.8 The figure shows a simplified diagram of the cross-section of human arm. The medullary cavity is the central cavity that is filled with bone marrow. The linear attenuation coefficient of bone marrow is roughly the same as that of muscle.

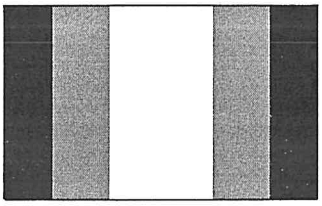


Which figure below best represents the X-ray radiographic image of the arm ?

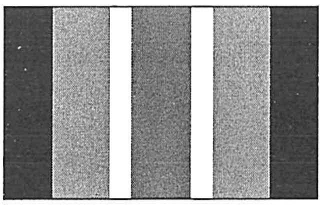
A.



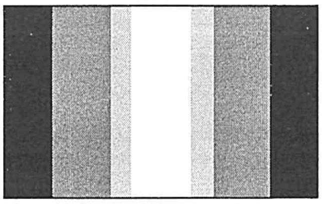
B.



C.



D.



A B C D

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Q.4: Structured question

(a) State briefly how X-rays are produced. (1 mark)

(b) The table below shows the linear attenuation coefficients of soft tissue and bone for an X-ray beam.

	linear attenuation coefficient
soft tissue	$\mu_s = 0.51\ \text{cm}^{-1}$
bone	$\mu_b = 2.46\ \text{cm}^{-1}$

(i) State one factor contributing to a higher linear attenuation coefficient of bone compared to soft tissue. (1 mark)

(ii) X-ray beam of intensity I_0 passes through soft tissue that is 5.6 cm in thickness and is attenuated to intensity I. What thickness of bone would yield the same degree of attenuation of the same X-ray beam ? Show your calculation. (2 marks)

(iii) Explain why X-ray radiographic imaging of the breast usually employs X-rays of lower energy (~20 keV) while examination of bony structures employs X-rays of energy around 100 keV. (2 marks)

(c) People are often concerned about the radiation exposure during medical examinations like X-ray radiographic imaging and computed tomography (CT) scans. Some information about the radiation dose is given below:

source / item	**equivalent dose**
Taking an X-ray radiographic image	0.1 – 0.2 mSv
A CT scan	1 – 10 mSv
Average weekly natural background dose for a person	about 0.05 mSv

(i) State one potential hazard of exposure to ionizing radiation on human bodies. (1 mark)

(ii) Explain why the equivalent dose of a CT scan is higher than that of taking an X-ray radiographic image. (2 marks)

(iii) Name one source contributing to the natural background dose. (1 mark)

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.

List of data, formulae and relationships

Data

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

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
$\left\lvert\frac{\Delta f}{f_0}\right\rvert \approx \frac{v}{c} \approx \left\lvert\frac{\Delta\lambda}{\lambda_0}\right\rvert$	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
$P = \frac{1}{2}\rho Av^3$	maximum power by wind turbine

Atomic World

$\frac{1}{2}m_e v_{\max}^2 = hf - \phi$	Einstein's photoelectric equation
$E_n = -\frac{1}{n^2}\left\{\frac{m_e q_e^4}{8h^2\varepsilon_0^2}\right\} = -\frac{13.6}{n^2}\ \text{eV}$	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.	$N = N_0 e^{-kt}$	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