Class | Adm No

Candidate Name: ______________________________

H

millennia institute

2024 Preliminary Examinations
Pre-University 3

H2 PHYSICS **9749/1**

Paper 1 Multiple Choice **17 September**

1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Do not turn over this page until you are told to do so.

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, class and admission number on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate OMR Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

Data

speed of light in free space	c	$= 3.00 \times 10^{8}$ m s^{-1}
permeability of free space	μ_0	$= 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	$= 8.85 \times 10^{-12}$ F m^{-1} $= (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	$= 1.60 \times 10^{-19}$ C
the Planck constant	h	$= 6.63 \times 10^{-34}$ J s
unified atomic mass constant	u	$= 1.66 \times 10^{-27}$ kg
rest mass of electron	m_e	$= 9.11 \times 10^{-31}$ kg
rest mass of proton	m_p	$= 1.67 \times 10^{-27}$ kg
molar gas constant	R	$= 8.31$ J K^{-1}mol^{-1}
the Avogadro constant	N_A	$= 6.02 \times 10^{23}$mol^{-1}
the Boltzmann constant	k	$= 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant	G	$= 6.67 \times 10^{-11}$ N m^{2} kg^{-2}
acceleration of free fall	g	$= 9.81$ m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	$\rho g h$
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
temperature	T/K	=	$T/°C + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V} < c^2 >$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t$
	v	=	$\pm\omega\sqrt{(x_0^2 - x^2)}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$\frac{1}{R}$	=	$\frac{1}{R_1} + \frac{1}{R_2} + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 exp(-\lambda t)$
decay constant,	λ	=	$\frac{ln2}{t_{1/2}}$

1 The energy E stored in a certain electronic component is given by

$$E = \frac{Q^n}{2k}$$

where Q is the total charge in the component, n is an unknown integer and k is a physical quantity with SI base units $A^2\,s^4\,kg^{-1}\,m^{-2}$.

What is the value of n?

A -2 **B** -1 **C** 1 **D** 2

2 Three quantities a, b and c are related by the equation

$$a = b^2c$$

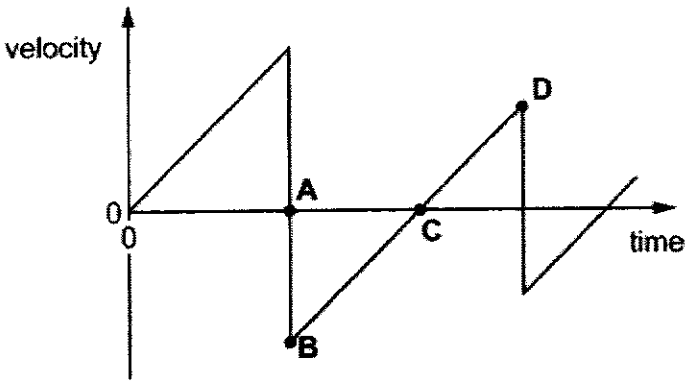
a and b have fractional uncertainties $\frac{\Delta a}{a}$ and $\frac{\Delta b}{b}$ respectively.

What is the fractional uncertainty of c?

A $\frac{\Delta a}{a} + \frac{\Delta b}{b}$ **B** $\frac{\Delta a}{a} - \frac{\Delta b}{b}$ **C** $\frac{\Delta a}{a} + 2\frac{\Delta b}{b}$ **D** $\frac{\Delta a}{a} - 2\frac{\Delta b}{b}$

3 A ball is released from rest above the ground. The graph shows how the veolcity of the bouncing ball varies with time.

At which point on the graph does the ball reach the maximum height after the first bounce?

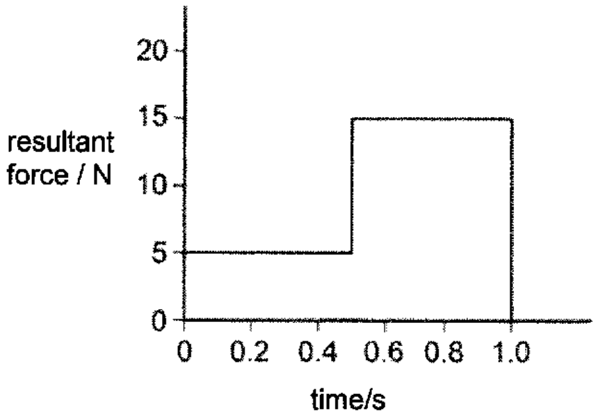


4 The acceleration of free fall on the Moon is one-sixth of that on Earth. On Earth it takes time t for a stone to fall from rest a distance of 2 m.

What is the time taken for a stone to fall from rest a distance of 2 m on the Moon?

A $\frac{t}{6}$ **B** $\frac{t}{\sqrt{6}}$ **C** $t\sqrt{6}$ **D** $6t$

5 The graph shows how the resultant force applied to an object of mass 4.0 kg varies with time. The force is applied in the same direction as the initial velocity.



Given that the initial speed of the object is 2.5 m s^{-1}, what is the speed of the object after 1.0 s?

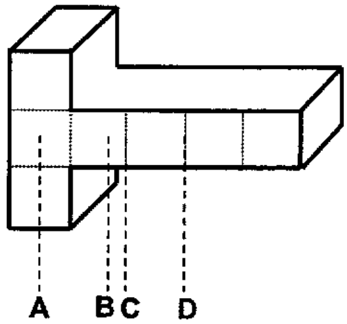
A 2.5 m s^{-1}

B 5.0 m s^{-1}

C 10 m s^{-1}

D 15 m s^{-1}

6 An object of uniform density with uniform cross sectional area is shown in the diagram (drawn to scale). Along which vertical line is its centre of gravity most probably located?



7 A 3.50 g balloon is filled with helium (density = 0.180 kg m^{-3}) to a volume of 5.00 m^3 and is then connected to the top of a table via a light spring of spring constant 100 N m^{-1}. The balloon causes the spring to stretch.

What is the extension of the spring when the balloon is in equilibrium given that the density of air is 1.29 kg m^{-3}?

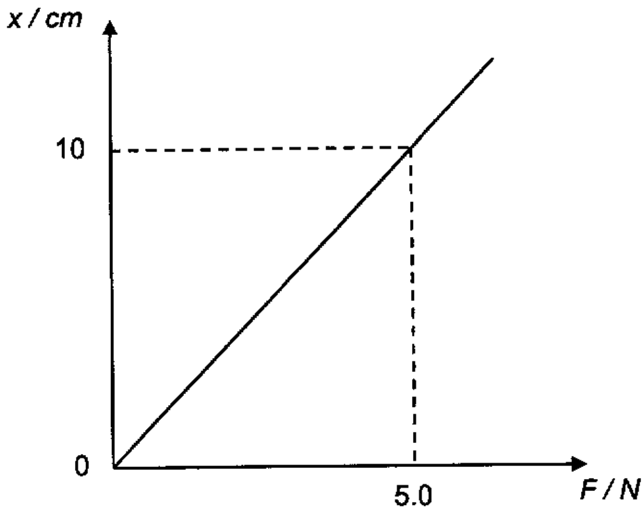
A 0.055 m

B 0.201 m

C 0.544 m

D 0.632 m

8 The variation of the extension x of a light spring with the force F applied is shown below.

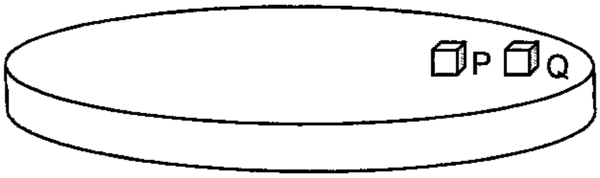


Slotted masses with a total weight of 3.0 N were initially hung on the spring.

What is the decrease in the elastic potential energy stored in the spring when a slotted mass weighing 0.5 N is removed from the system?

A 0.013 J **B** 0.015 J **C** 0.028 J **D** 0.056 J

9 Two identical objects rest on a flat rough horizontal circular disc.



The disc starts from rest and starts spinning about its central axis with increasing rate. When the disc spins at a certain rate, one of the objects slides off the disc.

Which of the following statements is correct?

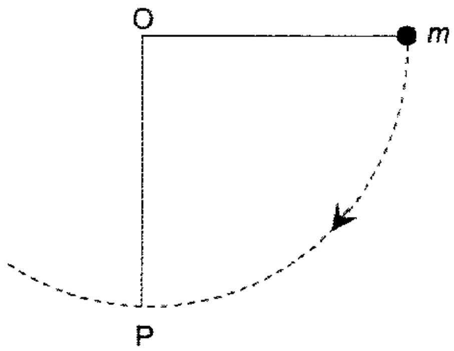
A The friction experienced by P and Q are always equal.

B P experiences larger friction than Q.

C Q will start to slide first due to larger angular velocity.

D Q will start to slide first due to larger radius.

10 A small bob of mass m is suspended from a fixed point O by a light, inextensible cord. The bob is raised until the cord is horizontal and it is then released from rest. It moves in an arc of a circle as shown.



What is the tension in the cord at the lowest point P?

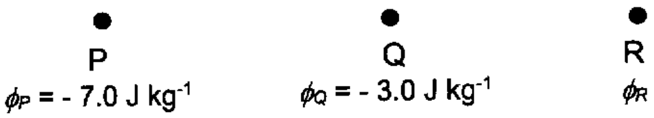
A zero **B** mg **C** $2mg$ **D** $3mg$

11 The planet Jupiter has a radius of 7.15×10^7 m and is approximately 318 times more massive than the Earth.

Given that the Earth has a radius of 6370 km, what is the acceleration due to gravity on the surface of Jupiter?

A 2.41×10^{-5} N kg^{-1} **B** 2.73×10^{-3} N kg^{-1} **C** 24.8 N kg^{-1} **D** 273 N kg^{-1}

12 Two points in space, P and Q, have gravitational potentials of -7.0 J kg^{-1} and -3.0 J kg^{-1} respectively as shown below.



When a mass is moved from P to Q, it gains gravitational potential energy of 20 J. When it is moved from Q to R, it loses gravitational potential energy of 5.0 J.

What is the gravitational potential at R?

A - 8.0 J kg^{-1} **B** - 4.0 J kg^{-1} **C** - 2.0 J kg^{-1} **D** 2.0 J kg^{-1}

13 Two objects at different temperatures are in thermal contact.

Which quantity determines the transfer of thermal energy between the objects?

A the temperature of the objects

B the internal energy of the objects

C the heat capacity of the objects

D the mass of each object

14 A balloon contains 2.0 moles of helium gas at a temperature of 27 °C. The molar mass of helium is 4.0 g mol^{-1}.

What is the average translational kinetic energy of the helium atoms in the balloon?

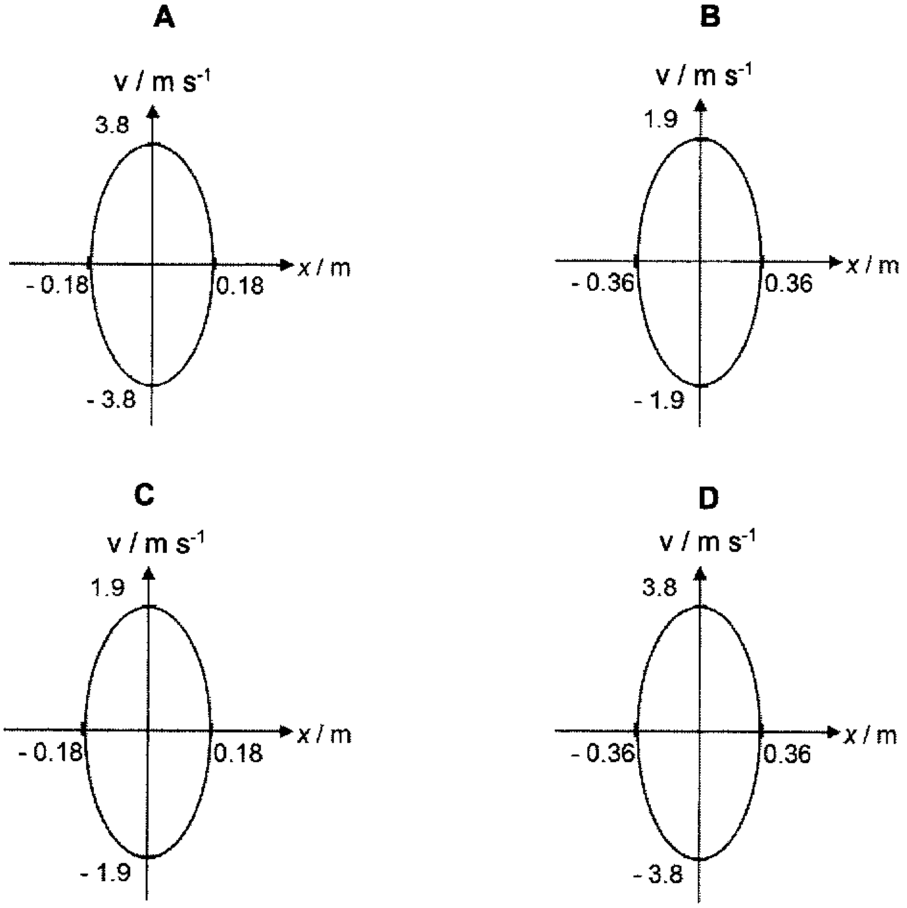
A 5.6×10^{-22} J **B** 6.2×10^{-21} J **C** 30 J **D** 7500 J

15 In a heating experiment, energy is supplied at a constant rate to a liquid. The temperature of the liquid rises at 4.0 K per minute just before it begins to boil.
After 40 minutes of boiling, all the liquid has boiled away.

For this liquid, what is the ratio $\dfrac{\text{specific latent heat of vaporisation}}{\text{specific heat capacity}}$?

A $\dfrac{1}{160}$ K **B** $\dfrac{1}{40}$ K **C** 40 K **D** 160 K

16 An object undergoing simple harmonic motion takes 0.30 s to travel from one point of zero velocity to the next such point. The distance between these two points is 0.36 m. Which of the following shows the correct velocity-displacement graph describing the motion?



17 Which one of the following statements always applies to a damping force acting on a vibrating system?

A It is the same direction as the acceleration.

B It is the opposite direction to the velocity.

C It is the same direction as the displacement.

D It is proportional to the displacement.

18 Two coherent waves, of intensities I and $4I$, meet in phase at a point. What is the resultant intensity at that point?

A $3I$ **B** $5I$

C $9I$ **D** $25I$

19 A standing wave is set up on a rope of length 1.0 m fixed at both ends.

Which statement is correct?

A The fundamental mode has a wavelength of 1.0 m.
B The midpoint of the rope is always stationary.
C There are two nodes on the rope when the fundamental frequency is doubled.
D A standing wave of wavelength 0.4 m may be set up on the rope.

20 A camera lens with a maximum aperture of 30 mm forms an image of an object 5.0 m away. If a monochromatic light of wavelength 700 nm is used, what is the minimum distance between two points on the object that are just resolved?

A 0.060 mm **B** 0.12 mm **C** 4.2 mm **D** 12 mm

21 Which of the following statements about an electric field is **incorrect**?

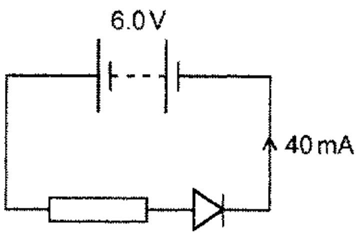
A The electric field strength at a point is a measure of the force exerted on a unit positive charge at that point.

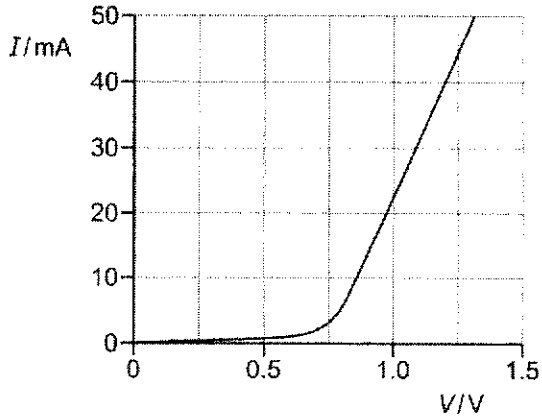
B The electric field strength is zero at all points where the potential is zero.

C The electric field strength at a point is a measure of the potential gradient at that point.

D The electric field strength due to a point charge varies as $\frac{1}{r^2}$ where r is the distance from the charge.

22 A fixed resistor and a diode are connected in series to a battery of electromotive force 6.0 V and negligible internal resistance. The graph shows the variation with potential difference V of the current I for the diode.





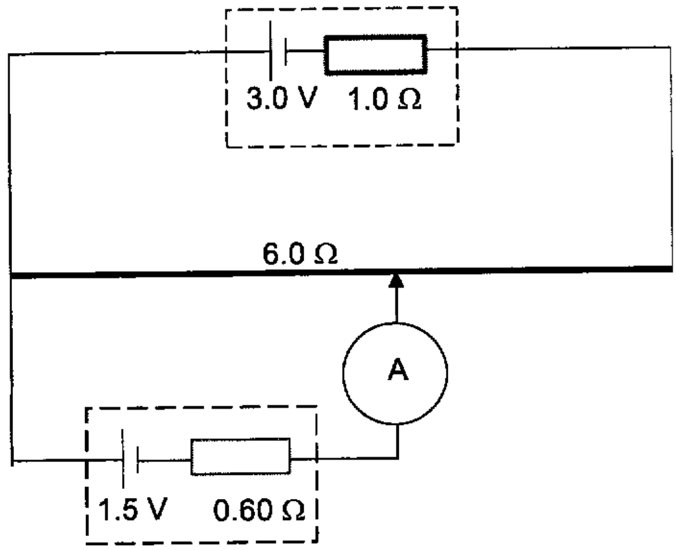
The current in the diode is 40 mA.

What is the resistance of the fixed resistor?

A 30 Ω **B** 120 Ω **C** 150 Ω **D** 180 Ω

23 A potentiometer circuit is set up by connecting a cell with e.m.f. 3.0 V and internal resistance 1.0 Ω across a resistance wire of length 1.0 m and resistance 6.0 Ω.

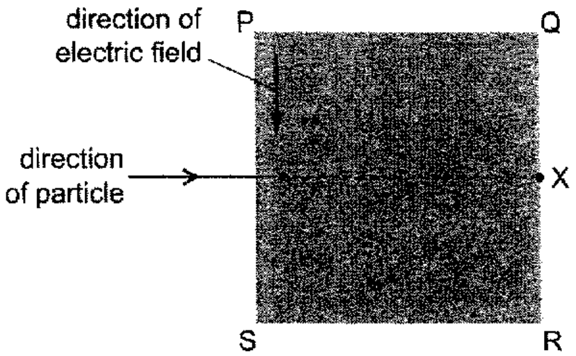
Another cell of e.m.f. 1.5 V and internal resistance 0.60 Ω is connected to the bottom of the potentiometer:



What is the balance length for the circuit?

A 0.086 m **B** 0.10 m **C** 0.50 m **D** 0.58 m

24 Positively charged particles move through a vacuum with constant velocity. The particles enter a region PQRS where there is a uniform electric field in the direction from P towards S.



A uniform magnetic field is also applied in the region PQRS and is adjusted in magnitude until the charged particles pass undeviated through the region PQRS, emerging at point X.

The strength of the magnetic field is now increased but its direction is not altered. In which direction are the particles now deviated?

A towards PQ

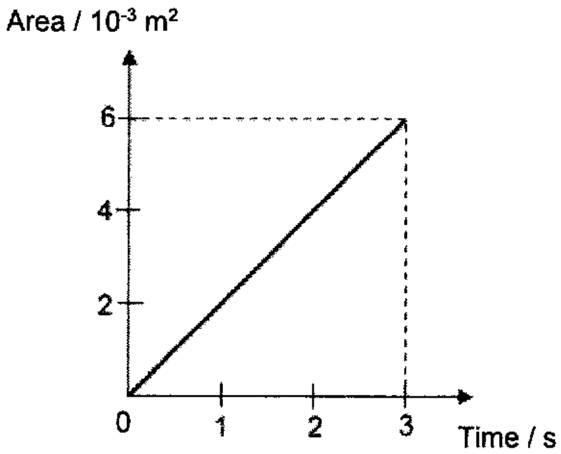
B towards SR

C into the plane of the paper

D out of the plane of the paper

25 A single circular loop of wire moves in a uniform magnetic field of flux density 1.2 T.

The graph shows how the area of the loop perpendicular to the magnetic field varies with time.



What is the e.m.f. induced?

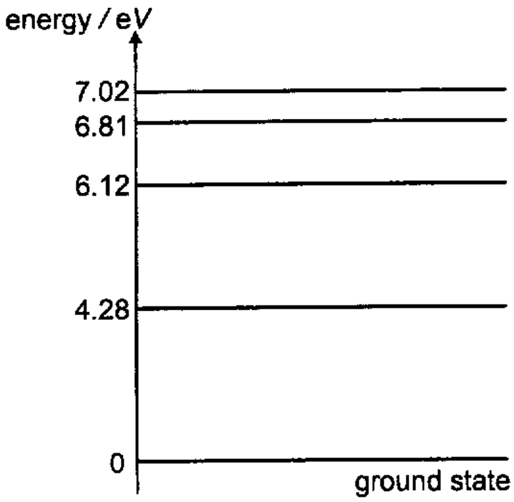
A 1.2×10^{-3} V **B** 2.4×10^{-3} V **C** 3.6×10^{-3} V **D** 7.2×10^{-3} V

26 In an ideal transformer, the ratio of the secondary turns to the primary turns is 1:60. A 120 V a.c. source is connected to the primary coil and a 3.0 Ω resistor is connected to the secondary coil.

What is the current in the primary coil?

A 0.011 A **B** 0.67 A **C** 2.0 A **D** 40 A

27 The diagram shows the first five energy levels of an atom.



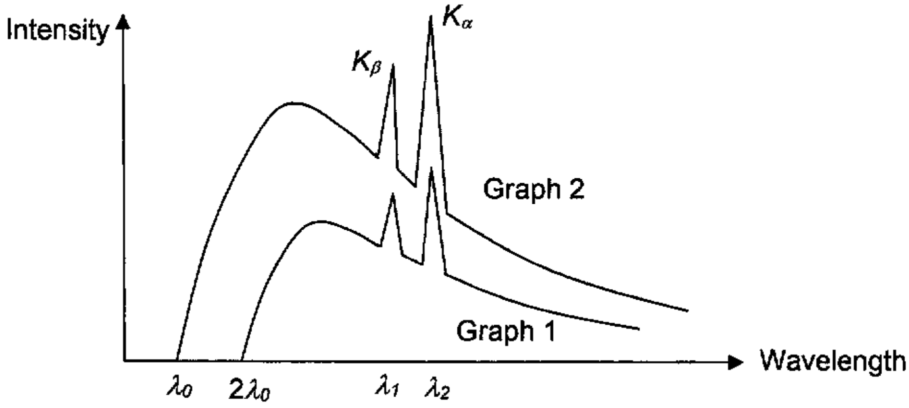
How many transitions between these energy levels result in the emission of visible light?

A 1 **B** 2 **C** 3 **D** 4

28 An X-ray spectrum is shown below.

Graph 1 shows the original spectrum obtained.
Graph 2 shows the new spectrum obtained after a change has been made to the accelerating voltage.

In both graphs, the two peaks correspond to the characteristic lines K_α and K_β.



Which of the following is correct?

	Ratio of accelerating voltage associated with Graph 2 to accelerating voltage associated with Graph 1	Target metal used to obtain both graphs
A	$\frac{1}{2}$	Different
B	2	Different
C	$\frac{1}{2}$	Same
D	2	Same

29 When an isotope of boron, $^{10}_{5}B$ captures a slow neutron, it splits into lithium $^{7}_{3}Li$ and an alpha particle. An emission of γ-ray occurs during this reaction.

The nuclear binding energies of the reactants and products are

$^{10}_{5}B$: 64.94 MeV

$^{7}_{3}Li$: 39.25 MeV

$^{4}_{2}He$: 28.48 MeV

If the total kinetic energies of the products produced is 2.31 MeV, what is the energy of the γ-ray emitted?

A 0.48 MeV

B 2.79 MeV

C 10.77 MeV

D 25.69 MeV

30 Which of the following is a valid observation that leads to the prediction of the existence of the neutrino?

A There is a range of energies for the emitted β-particles during β-decay.

B The total charge of the daughter nuclide and β-particle is not equal to the charge of the parent nuclide that undergoes β-decay.

C There is loss in mass during β-decay.

D The track for a particle, different from that of β-particles, can be observed in a cloud chamber for a radioactive β-emitter.

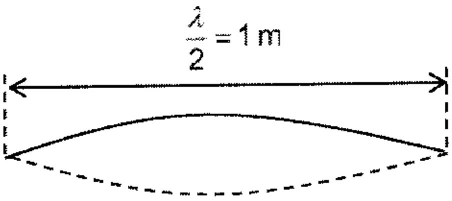
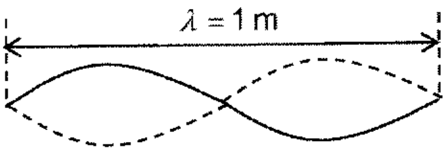
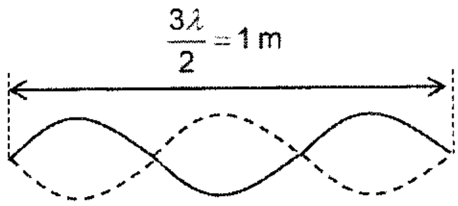
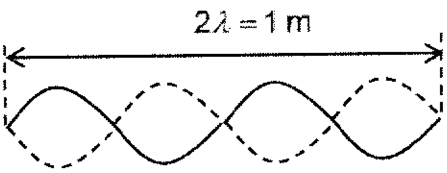
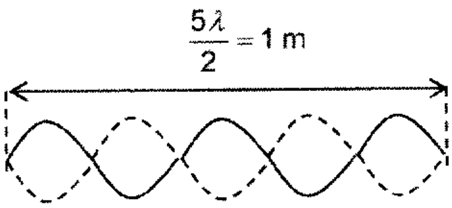
End of Paper

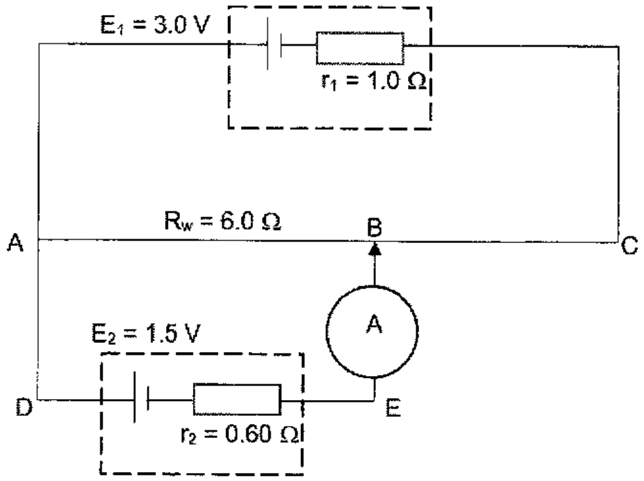
H2 Physics PU3 Preliminary Examination Paper 1 Answers

S/N	Answer	Explanation
1	D	$[E] = \frac{\lvert Q \rvert^n}{\lvert k \rvert}$ $\text{kg m}^2\text{ s}^{-2} = \frac{A^n \text{ s}^n}{A^2 \text{ s}^4 \text{ kg}^{-1} \text{ m}^{-2}}$ $n = 2$
2	C	$a = b^2c$ $c = \frac{a}{b^2}$ $\frac{\Delta c}{c} = \frac{\Delta a}{a} + 2\frac{\Delta b}{b}$
3	C	At point A: object just reached the ground for the first time At point B: object just about the leave the ground after first bounce At point C: object reached the maximum height after first bounce At point D: object just reached the ground for the second time
4	C	$s = ut + \frac{1}{2}at^2$ u = o since the stone falls from rest. $2 = \frac{1}{2}at^2$ $\frac{4}{a} = t^2$ $t = \frac{2}{\sqrt{a}}$ ---------- (1) where t is the time taken for stone to fall on Earth Acceleration of free fall of moon = $\frac{a}{6}$, where a is the acceleration of free fall on Earth. Sub $\frac{a}{6}$ into equation (1) $t_{moon} = \frac{2}{\sqrt{\frac{a}{6}}} = \frac{2}{\sqrt{a}}\left(\sqrt{6}\right) = t\sqrt{6}$
5	B	Area under the force-time graph = change in momentum = impulse Total area = (5 x 0.5) + (15 x 0.5) = 10 $\Delta p = m \Delta v = 10$ $\Delta v = v - 0$ ➔ $v = 10 / 4 = 2.5 \text{ m s}^{-1}$ $2.5 \text{ m s}^{-1} + 2.5 \text{ m s}^{-1} = 5.0 \text{ m s}^{-1}$

6	**B**	A and D obviously wrong. Try taking moments about C, clockwise moment = $(3m)(1.5x) = 4.5mx$ anti-clockwise moment = $(3m)(1.5x) + (m)(0.5x) = 4.5mx + 0.5mx = 5\ mx$ Therefore C is also wrong and centre of gravity is slightly to the left side of C.
7	**C**	Since the balloon is in equilibrium, upthrust on balloon = weight of balloon and helium + force by spring $\rho_{air}V_{balloon}g = \rho_{helium}V_{balloon}g + m_{balloon}g + kx$ $(1.29)(5.0)g = (0.180)(5.0)g + (\frac{3.5}{1000})g + (100)x$ $x = 0.544$ m
8	**C**	Force constant, $k = \frac{5.0}{0.1} = 50$ N m^{-1} Initial extension $= \frac{F}{k} = \frac{3}{50} = 0.06$ m and final extension $= \frac{F}{k} = \frac{2.5}{50} = 0.05$ m Change in E.P.E.$= \frac{1}{2}kx_f^2 - \frac{1}{2}kx_i^2 = \frac{1}{2}(50)(0.05)^2 - \frac{1}{2}(50)(0.06)^2 = -0.028$ J
9	**D**	Frictional force on the object provides the centripetal force $mr\omega^2$. Both objects have the same angular velocity and same mass, but the centripetal force required for Q is larger due to larger radius. When the centripetal force required exceeds the frictional force available, Q starts to slide.
10	**D**	Using COE: $E_i = E_f$ $GPE_i = KE_f$ $mgr = \frac{1}{2}mv^2$ $2mgr = mv^2$ ------------ (1) $T_{bottom} - mg = \frac{mv^2}{r}$ $T_{bottom} = \frac{mv^2}{r} + mg$ sub (1) into eqn $= \frac{2mgr}{r} + mg$ $= 3mg$

11	**C**	$g = \frac{GM}{r^2}$ $g \propto \frac{M}{r^2}$ Let the quantities with subscript '*J*' represent that of Jupiter while those with subscript '*E*' represent that of Earth. $\frac{g_J}{g_E} = \frac{M_J}{M_E}\left(\frac{r_E^2}{r_J^2}\right)$ $\frac{g_J}{g_E} = (318)\left(\frac{6370\times10^3}{7.15\times10^7}\right)^2$ Since g_E = 9.81 N kg^{-1}, $g_J = (318)\left(\frac{6370\times10^3}{7.15\times10^7}\right)^2(9.81)$ = 24.8 N kg^{-1}
12	**B**	$\Delta U = m\Delta\phi \propto \Delta\phi$ $\frac{\Delta U_{BC}}{\Delta U_{AB}} = \frac{\Delta\phi_{BC}}{\Delta\phi_{AB}} \Rightarrow \frac{-5.0}{+20} = \frac{\phi_C + 3.0}{-3.0+7.0}$ $\Rightarrow \phi_C = -4.0$ J kg^{-1}
13	**A**	When two objects A and B are placed in thermal contact, heat flows from the hotter object to the colder object B, until they reached thermal equilibrium. At thermal equilibrium, both objects A and B are at the same temperature.
14	**B**	Average K.E. $= \frac{3}{2}kT = \frac{3}{2}(1.38\times10^{-23})(27+273.15) = 6.2\times10^{-21}$ J
15	**D**	$mc\frac{\Delta\theta}{t} = \frac{m}{t}L$ $\frac{L}{c} = \frac{\Delta\theta}{t}(t)$ $= 4\times40$ $= 160$
16	**C**	Amplitude, x_0 = 0.36/2 = 0.18 m $V_{max} = \omega x_0$ $= (2\pi/T)\, x_0$ $= (2\pi/0.60)(0.18)$ = 1.9 m s^{-1}
17	**B**	Damping force opposes motion.
18	**C**	Since *I* is proportional to A^2, A_R = A + (2A) = 3A Hence, 9 *I*

19	**D**	 At the fundamental mode, $\frac{\lambda}{2} = 1$ m, $\lambda = 2$ m → Option A is incorrect. The mid-point of the rope is not stationary at fundamental mode. Option B is incorrect. 2[nd] Harmonic- $\lambda = 1$ m  3[rd] Harmonic- $\lambda = 0.667$ m  4[th] Harmonic- $\lambda = 0.5$ m  5[th] Harmonic- $\lambda = 0.4$ m  When the fundamental frequency is doubled, there are 3 nodes on the rope. Option C is incorrect. At the 5[th] harmonic, the wavelength is 0.4 m. Option D is correct.
20	**B**	Using Rayleigh's criterion for resolution: $\theta = \frac{\lambda}{b}$ For small angle, θ = sin θ = tan θ $(700 \times 10^{-9}) / (30 \times 10^{-3}) = x / 5.0$ $x = 1.2 \times 10^{-4}$ m = 0.12 mm
21	**B**	$E = -\frac{dV}{dr} = 0$ where V = constant If the electric field strength is zero at a point, it only means that the potential gradient is zero at that point. But the value of the potential at that point need not be zero.
22	**B**	From graph, when current is 40 mA, p.d. is approximately 1.2 V. Therefore, p.d. across resistor = 6.0 – 1.2 = 4.8 V R = V/I = (4.8)/(0.040) = 120 Ω

23	**D**	 At balance, $V_{AB} = V_{DE}$ Since no current flows through the bottom cell at balance, $V_{DE} = E_2$ Also, $\frac{L_{AB}}{L_{AC}} = \frac{V_{AB}}{V_{AC}} = \frac{V_{DE}}{V_{AC}} = \frac{E_2}{V_{AC}}$ Then, $V_{AC} = E_1 \frac{R_w}{R_w + r_1}$ (apply potential divider principle to the top loop) $= 3.0 \times \frac{6.0}{6.0+1.0}$ $= 2.571$ V So balance length, $L_{AB} = L_{AC} \frac{E_2}{V_{AC}}$ $= 1.0 \times \frac{1.5}{2.571}$ $= 0.58$ m
24	**A**	The electric force on a positively charged particle is directed towards SR. To pass through undeviated, the magnetic force must be directed towards PQ. When the strength of the magnetic field is increased, the magnetic force increases but the electric force remains the same. So the particles will now be deflected towards PQ.
25	**B**	$\varepsilon = -\Delta$(flux linkage) / Δt $\varepsilon = -N B \Delta A / \Delta t$ $\varepsilon = -(1)(1.2)(6 \times 10^{-3} - 0)/(3 - 0)$ $\varepsilon = -0.0024$ V

26	**A**	$\frac{V_s}{V_p}=\frac{N_s}{N_p}$ $\frac{V_s}{120}=\frac{1}{60}$ $V_s=2.0$ V Then $I_s = V_s/R = 2.0/3.0 = 0.667$ A For ideal transformer, $V_pI_p=V_sI_s$ $120\times I_p=2.0\times 0.667$ $I_p=0.011$ A
27	**C**	The range of wavelengths for visible light is 400 nm to 700 nm. Since $E=\frac{hc}{\lambda}$, the energies of these photons range from $\frac{(6.63\times10^{-34})(3.00\times10^{8})}{(700\times10^{-9})(1.60\times10^{-19})}=1.7759$ eV to $\frac{(6.63\times10^{-34})(3.00\times10^{8})}{(400\times10^{-9})(1.60\times10^{-19})}=3.1078$ eV. Only 3 transitions will result in emissions of such photons: $6.12-4.28=1.84$ eV $6.81-4.28=2.53$ eV $7.02-4.28=2.74$ eV
28	**D**	For the cut-off wavelength, $eV=\frac{hc}{\lambda_{min}}$ Since the λ_{min} for graph 2 is halved of graph 1, that means that the accelerating potential for graph 2 is doubled that of graph 1. Since the characteristic wavelength remain the same for graph 1 and graph 2, this means that the target metal is the same.
29	**A**	Difference in binding energies of products and reactants = Gain in kinetic energies of products + Energy of gamma ray (39.25 + 28.48 – 64.94) = 2.31 + E E = 0.48 MeV

30	**A**	A range of (kinetic) energies indicates a range of speeds for the β particles. Since beta particles are emitted with a range of speeds, the products of a beta decay process cannot just consist of the daughter nuclide (product nuclide) and the beta particle as this would imply definite speeds for both products, in order for linear momentum to be conserved. Option B is wrong. There is no such observation. Neutrino is chargeless. The total charge of the decay products is equal to the charge of the parent nuclide. Option C is wrong. It is a true observation, but the loss in mass during β decay is due to conversion to energy released, and not the existence of the neutrino. Option D is wrong. There is no such observation. Neutrino is chargeless so has no ionising power, and therefore cannot be observed in a cloud chamber.