RAFFLES INSTITUTION
2022 Preliminary Examination

PHYSICS **9749/01**
Higher 2

26 September 2022
Paper 1 Multiple Choice Questions **1 hour**

Additional Materials: OMR Form

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your index number, name and class on the OMR Form in the spaces provided. Shade the appropriate boxes.

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 OMR Form.

Read the instructions on the OMR Form very carefully.

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

This document consists of **16** printed pages.

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$\left(1/(36\pi)\right) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-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	=	ρgh
gravitational potential	ϕ	=	$-Gm/r$
temperature	T/K	=	$T / ^\circ\mathrm{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	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	=	$v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
resistors in series	R	=	$R_1 + R_2 + \ \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ \ldots$
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	=	$\ln 2 / t_{1/2}$

1 A student makes measurements from which he calculates the speed of sound in air as $335.61\ \text{m s}^{-1}$. He estimates the percentage uncertainty in the speed of sound to be $\pm\ 4.5\%$.

How should the student record the speed of sound, considering the uncertainty?

A $330\ \text{m s}^{-1}$ **B** $335.6\ \text{m s}^{-1}$ **C** $336\ \text{m s}^{-1}$ **D** $340\ \text{m s}^{-1}$

2 The Stefan-Boltzmann law for the rate of thermal energy emitted per unit surface area of a body is given by

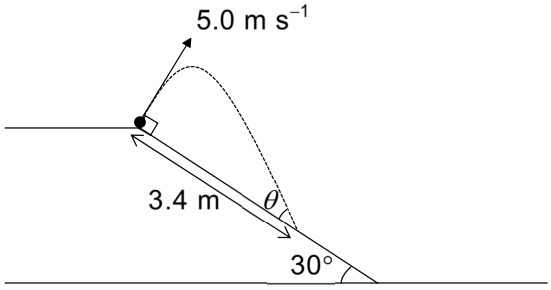
$$\frac{P}{A} = e\sigma T^4 ,$$

where P is the rate of thermal energy emitted, A is the surface area, T is the thermodynamic temperature and e, a dimensionless constant, is the emissivity of the body and σ is the Stefan-Boltzmann constant.

Which is the S.I. base unit for σ?

A $\text{kg s}^{-3}\ \text{K}^{-4}$ **B** $\text{kg s}^{-1}\ \text{K}^{4}$ **C** $\text{W m}^{-2}\ \text{K}^{-4}$ **D** $\text{W m}^{-2}\ ^{\circ}\text{C}^{-4}$

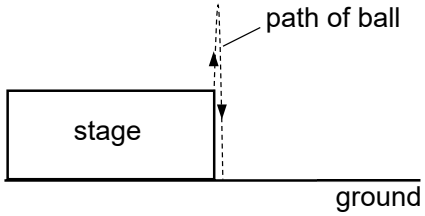
3 A stone is projected perpendicularly to a slope with a velocity of $5.0\ \text{m s}^{-1}$ and lands 3.4 m down the slope. The slope is inclined at an angle of 30° to the horizontal. Air resistance is negligible.



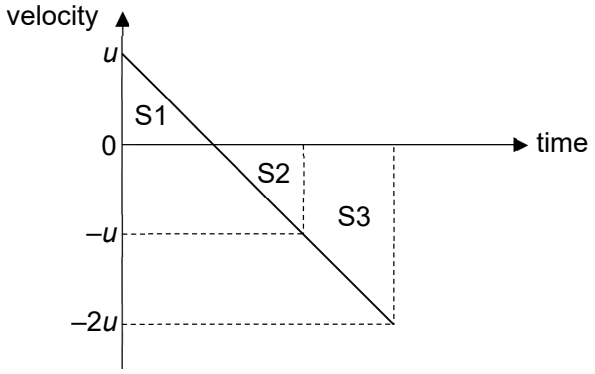
What is the angle θ that the velocity of the stone makes with the slope as it lands?

A 27° **B** 32° **C** 41° **D** 71°

4 A ball is thrown vertically upwards from the edge of a stage with speed u and hits the ground at the foot of the stage with speed $2u$. The time taken for the ball to reach its maximum height is t.

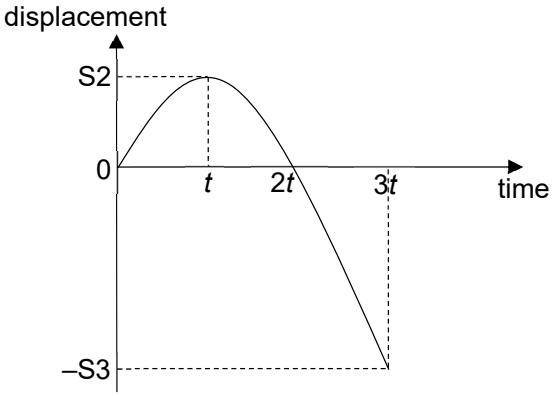


The graph shows how the velocity of the ball varies from the time it is thrown to the time it hits the ground. The areas under different sections of the graph are labelled S1, S2 and S3.

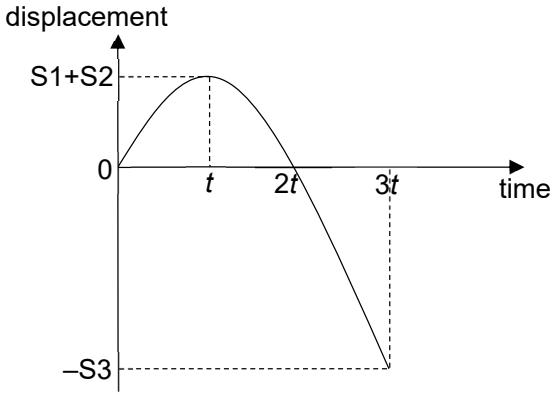


Which graph shows the variation of the displacement of the ball with time?

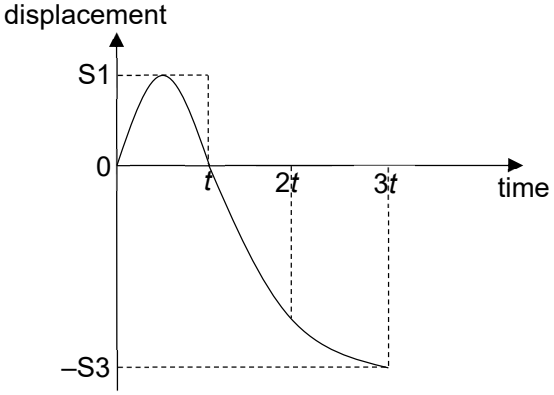
A



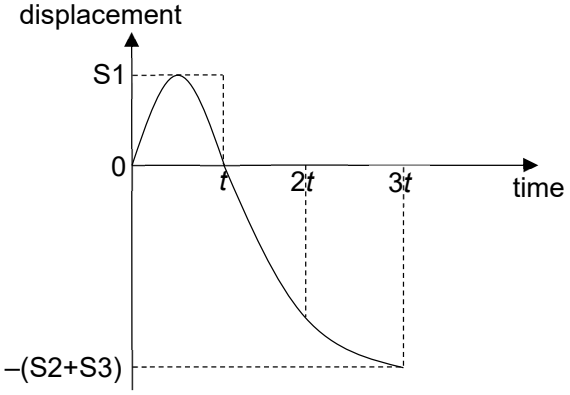
B



C

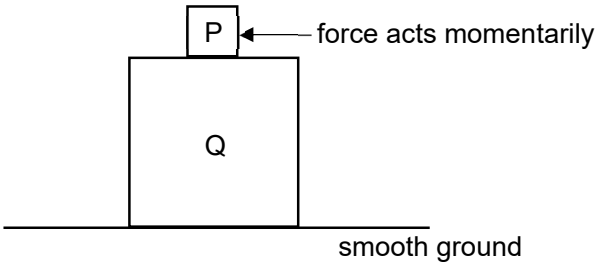


D



5 Block P is resting on a more massive block Q, which is resting on a smooth ground. The surfaces of blocks P and Q that are in contact with each other are rough.

A sudden force acts momentarily on block P to start it sliding to the left.



Which statement about the subsequent motions of the blocks is correct?

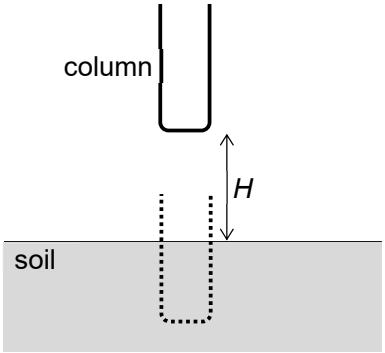
A Block P accelerates as it moves to the left, while block Q remains at rest.

B Block P and block Q accelerate as they move to the left, where the acceleration of block Q is smaller in magnitude compared to the acceleration of block P.

C Block P decelerates and block Q accelerates as they move to the left, where the acceleration of block Q is smaller in magnitude compared to the deceleration of block P.

D Block P decelerates and block Q accelerates as they move to the left, where the magnitudes of the acceleration of block Q and the deceleration of block P are the same.

6 A column of mass M is dropped from height H above the surface of the soil and comes to a stop after travelling for a duration t in the soil.



What is the average resistive force that acts on the column due to the soil?

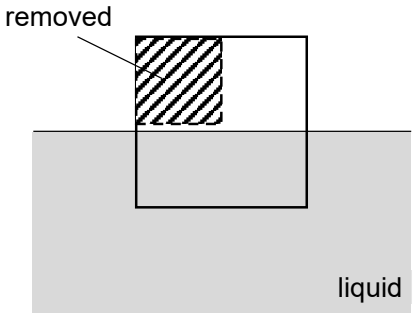
A $Mg\left(1+\sqrt{\frac{2H}{gt^2}}\right)$

B $Mg\sqrt{\frac{2H}{gt^2}}$

C Mg

D $Mg\left(1-\sqrt{\frac{2H}{gt^2}}\right)$

7 A uniform cube is floating in a liquid. A quarter of the cube is then removed.



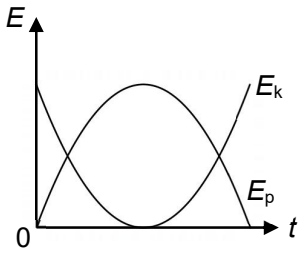
What is the resultant force and resultant moment on the remaining portion of the cube immediately after the quarter of the cube is removed?

	resultant force	resultant moment
A	zero	anticlockwise
B	upwards	clockwise
C	zero	clockwise
D	upwards	anticlockwise

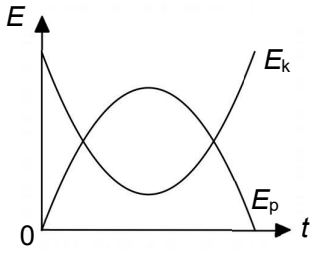
8 A ball is projected with an initial velocity at an angle above a horizonal ground and falls back to the ground in a parabolic path.

Which graph shows the variation with time t of the gravitational potential energy E_p and the kinetic energy E_k of the ball?

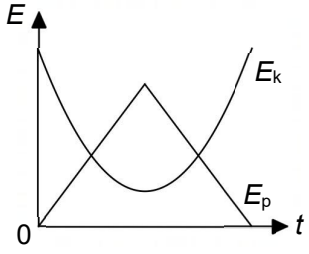
A



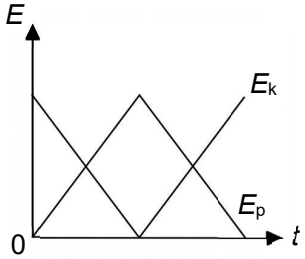
B



C



D



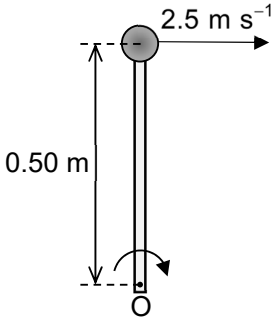
9 Two bodies A and B of masses m and $2m$ respectively are initially at rest on a smooth horizontal surface.

A constant force acts on body A for twice the duration that it acts on body B.

What is the ratio $\frac{\text{gain in kinetic energy of body A}}{\text{gain in kinetic energy of body B}}$?

A 1 **B** 2 **C** 4 **D** 8

10 A sphere of mass 0.40 kg is attached to a light, rigid rod of length 0.50 m that is hinged at point O. The sphere is projected with a horizontal speed of $2.5\ \text{m s}^{-1}$ when it is vertically above point O and rotates freely about point O.



What is the magnitude of the force exerted on the sphere by the rod at the instant when the sphere is vertically below point O?

A 3.9 N **B** 8.9 N **C** 17 N **D** 25 N

11 A satellite in orbit experiences atmospheric drag and spirals towards Earth.

Which of the following describes the period and speed of the satellite during this motion?

	orbital period	orbital speed
A	increases	decreases
B	decreases	increases
C	increases	increases
D	decreases	decreases

12 A low-Earth-orbit satellite orbits near the surface of the Earth at a speed of $7.90\ \text{km s}^{-1}$.

The radius of the Earth is 4 times that of the Moon, and the density of the Earth is 1.25 times that of the Moon.

What is the speed of a low-Moon-orbit satellite that orbits near the surface of the Moon?

A $1.77\ \text{km s}^{-1}$ **B** $2.21\ \text{km s}^{-1}$ **C** $3.53\ \text{km s}^{-1}$ **D** $14.1\ \text{km s}^{-1}$

13 An ideal gas has a volume of $3.7\ \text{m}^3$ and contains 1.5 kg of neon-20 atoms. Its temperature is 25 °C.

What is the pressure of the gas?

A 4.2 Pa **B** 50 Pa **C** 4.2 kPa **D** 50 kPa

14 When water is boiled at atmospheric pressure, the steam produced behaves like an ideal gas. A water molecule has a mass of $18u$.

What is the root-mean-square speed of the water molecule in the steam?

A $330\ \text{m s}^{-1}$ **B** $370\ \text{m s}^{-1}$ **C** $640\ \text{m s}^{-1}$ **D** $720\ \text{m s}^{-1}$

15 A piece of metal of mass m, specific heat capacity c and temperature $20\ ^\circ\text{C}$ is placed into a liquid of temperature $100\ ^\circ\text{C}$. The liquid, which is in a well-insulated container, has mass $3m$ and specific heat capacity $2.5c$.

What is the temperature of the liquid when thermal equilibrium is reached?

A 56 °C **B** 60 °C **C** 64 °C **D** 91 °C

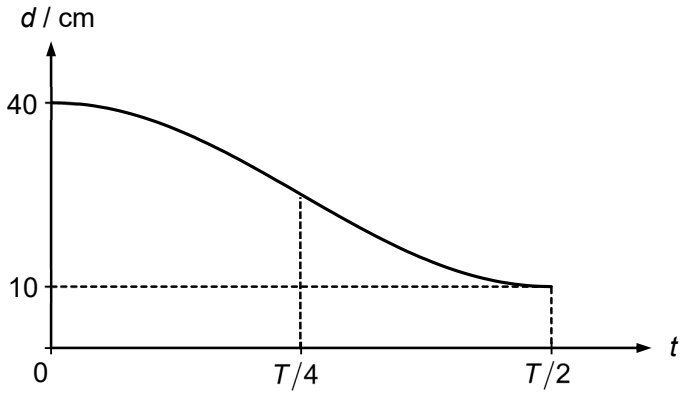
16 A particle oscillates in simple harmonic motion with amplitude x_0 and total energy E.

What is the potential energy of the particle at a displacement of $\frac{1}{3}x_0$ from the equilibrium?

A $\frac{1}{9}E$ **B** $\frac{1}{3}E$ **C** $\frac{2}{3}E$ **D** $\frac{8}{9}E$

17 A mass is attached to a spring that is suspended from a ceiling. The mass is displaced vertically downwards from its equilibrium position and released such that it performs simple harmonic motion with period T.

The graph shows the variation with time t of the vertical distance d of the mass from the ceiling.



Which of the following statements is not correct?

A The speed is maximum at $T/4$.

B The amplitude of oscillation is 30 cm.

C The restoring force on the mass is zero at $d = 25$ cm.

D The magnitude of the acceleration of the mass increases from $T/4$ to $T/2$.

18 Three polarisers are held in line one after the other such that the transmission axis of the last polariser is perpendicular to that of the first.

Unpolarised light of intensity $40\ \text{W m}^{-2}$ is incident normally on the first polariser. The intensity of the emergent light after passing through all three polarisers is $2.5\ \text{W m}^{-2}$.

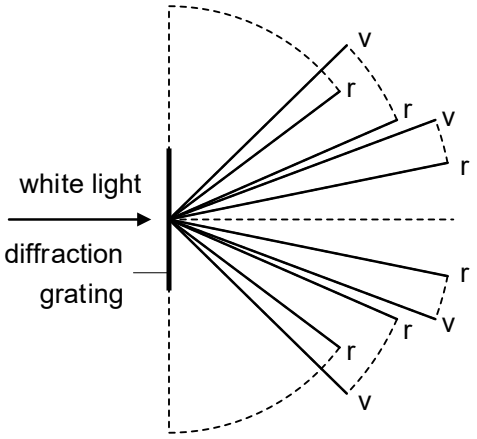
What is the angle between the transmission axes of the first and the second polariser?
(Hint: $\sin 2\theta = 2\sin\theta\cos\theta$)

A 7.2° **B** 15.0° **C** 22.5° **D** 53.5°

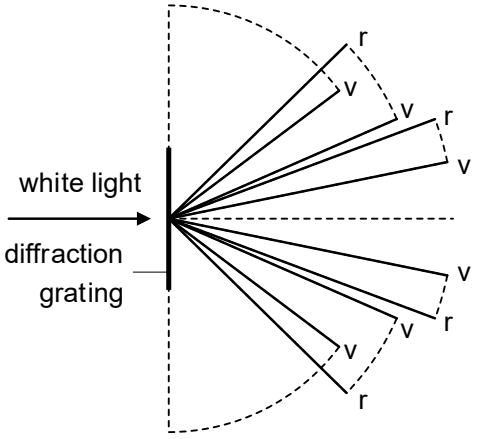
19 White light, which consists of light of wavelengths 400 nm to 700 nm, is incident on a diffraction grating.

Which of the following shows the diffracted spectra where v is for violet and r is for red?

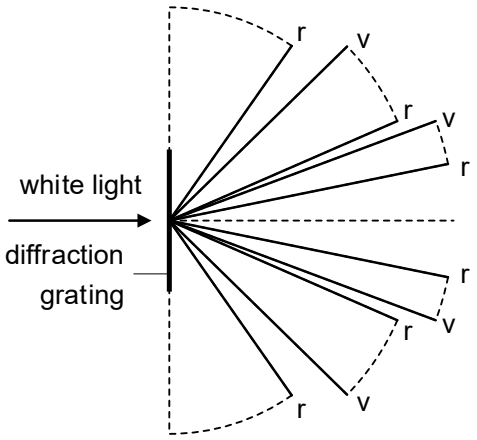
A



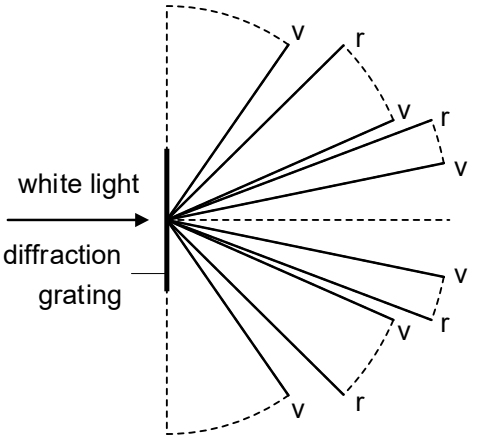
B



C

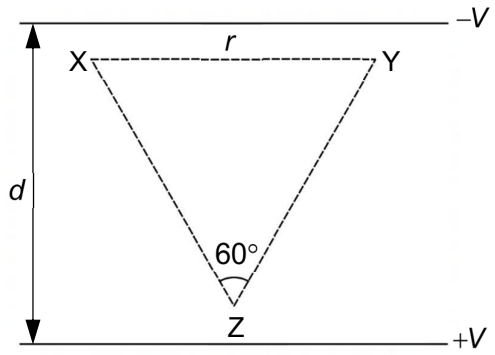


D



20 Two large horizontal metal plates are distance d apart. The upper and lower plates are at potentials $-V$ and $+V$ respectively.

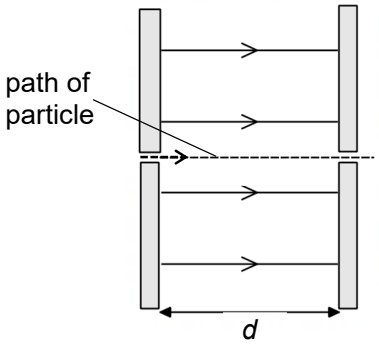
X, Y and Z are points between the metal plates such that they form an equilateral triangle with sides of length r. Side XY is parallel to the plates.



Which of the following shows the work done against the electric force in moving an electron at constant speed from X to Y, Y to Z and Z to X?

	X to Y	Y to Z	Z to X
A	$+\left(\frac{2V}{d}\right)er$	$+\left(\frac{2V}{d}\right)er\cos 60°$	$-\left(\frac{2V}{d}\right)er\cos 60°$
B	0	$-\left(\frac{2V}{d}\right)er\sin 60°$	$+\left(\frac{2V}{d}\right)er\sin 60°$
C	0	$+\left(\frac{2V}{d}\right)er\sin 60°$	$-\left(\frac{2V}{d}\right)er\sin 60°$
D	0	$-\left(\frac{2V}{d}\right)er\cos 60°$	$+\left(\frac{2V}{d}\right)er\cos 60°$

21 A particle of mass m and charge q is accelerated from rest in a uniform electric field between two parallel plates. After travelling a distance d between the plates, it leaves the field with a final speed v.



The electric field strength and the distance between the plates are doubled. A second particle of mass $3m$ and charge $3q$ is accelerated from rest between the plates.

What is the final speed of the second particle when it leaves the field?

A v **B** $2v$ **C** $3.5v$ **D** $4v$

22 Two resistors of resistances R_1 and R_2 are connected in parallel to a battery.

The combined resistance R_T of the two resistors is given by

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}.$$

Which concept is used in the derivation of this formula?

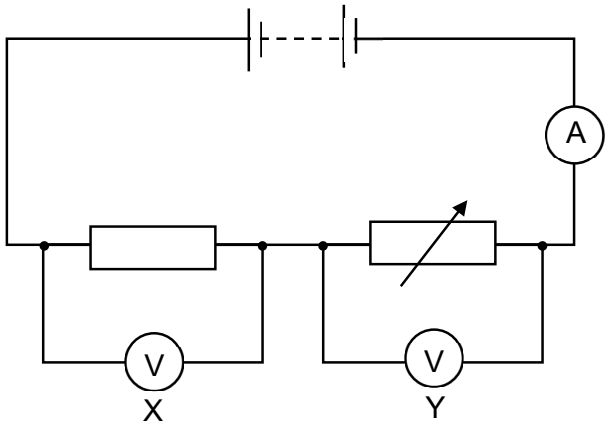
A There is no power loss in the battery.

B The current through each resistor is the same.

C The potential difference across each resistor is the same.

D The ratio of the currents through the resistors is equal to the ratio of their resistances.

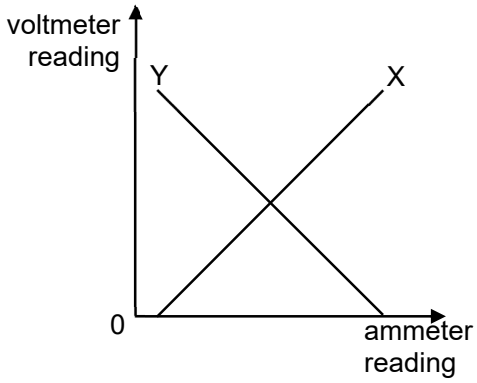
23 A battery is connected in series with an ammeter, a fixed resistor and a variable resistor. Voltmeters X and Y are connected across the fixed resistor and the variable resistor respectively.



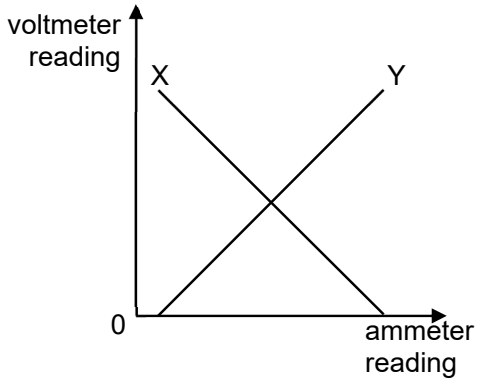
The resistance of the variable resistor is reduced from its maximum resistance to 0 Ω.

Which graph shows the variation of the voltmeter readings with the ammeter reading?

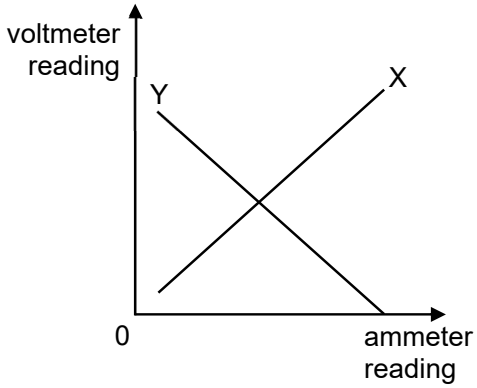
A



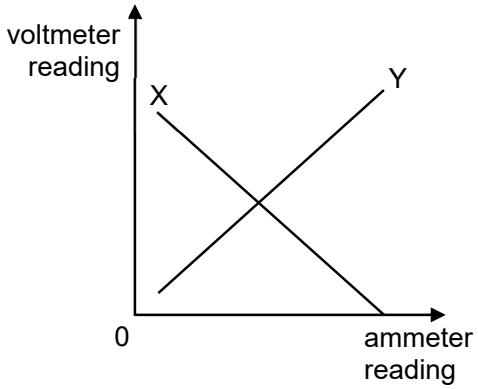
B



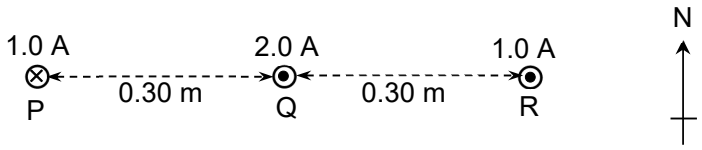
C



D



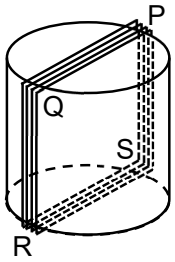
24 Three long vertical wires P, Q and R are carrying currents 1.0 A, 2.0 A and 1.0 A, respectively. The diagram shows the top view of the wires with the directions of their currents and the distances between them. The component of the Earth's magnetic field that is parallel to the Earth's surface is 2.0×10^{-5} T.



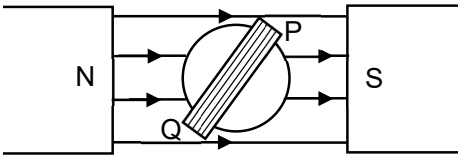
What is the magnitude and direction of the force per unit length acting on wire Q?

	magnitude	direction
A	1.3×10^{-6} N m^{-1}	East
B	2.7×10^{-6} N m^{-1}	East
C	1.9×10^{-5} N m^{-1}	West
D	3.7×10^{-5} N m^{-1}	West

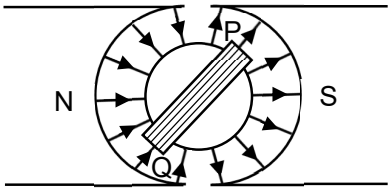
25 A long copper wire is wound round an iron cylinder to form a rectangular coil PQRS. A current flows through the coil.



The cylinder and the coil are placed in turn within magnetic fields X and Y and are free to rotate.



top view of coil in field X



top view of coil in field Y

Which of the following statements is not correct?

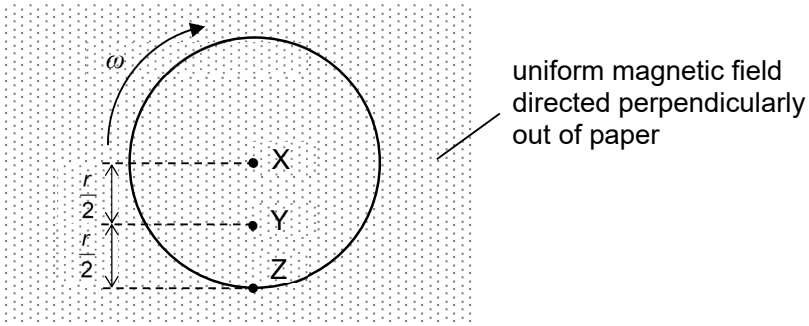
A The torque on the coil in each field varies sinusoidally as it rotates.

B The angular velocity of the coil in each field is not constant.

C Increasing the area of the coil will increase the torque on the coil in each field.

D The magnitude of the force on the side QR of the coil in each field remains constant as the coil rotates.

26 A metal disc of radius *r* rotates about its centre X at a constant angular speed ω in a uniform magnetic field. Point Z is on the rim of the disc and point Y is a distance $\frac{r}{2}$ from point X.



The potential difference between X and Z is *V*.

What is the potential difference between X and Y?

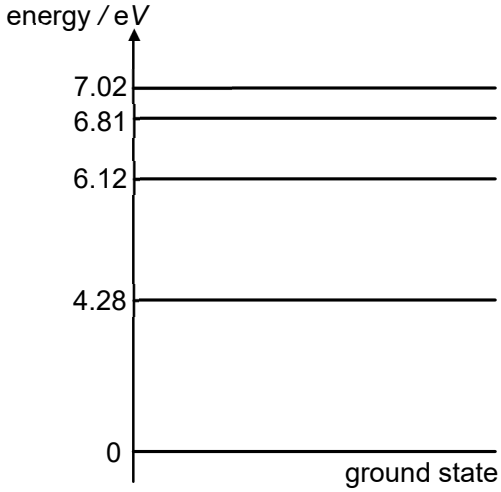
A 0 **B** $\frac{1}{4}V$ **C** $\frac{1}{2}V$ **D** $\frac{3}{4}V$

27 The primary coil of a transformer is connected to a 120 V r.m.s. sinusoidal a.c. supply. The secondary coil has 250 turns and a peak output of 8.0 V.

What is the number of turns on the primary coil?

A 2650 **B** 3750 **C** 5300 **D** 7500

28 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

29 Electrons that are accelerated from rest through a potential difference of 30 kV are made to collide with a metal target to produce X-rays.

What is the shortest wavelength of the X-rays produced?

A 6.6×10^{-30} m **B** 2.8×10^{-21} m **C** 7.1×10^{-12} m **D** 4.1×10^{-11} m

30 A radioactive source has a half-life of 20 hours. At the start of an experiment, a Geiger counter records an average count-rate of 20 s^{-1} in the absence of the source. When the source is placed in front of the Geiger counter, the average count-rate recorded is 100 s^{-1}.

What is the average count-rate recorded by the Geiger counter after 60 hours?

A 10 s^{-1} **B** 13 s^{-1} **C** 30 s^{-1} **D** 47 s^{-1}

End of Paper 1