RAFFLES INSTITUTION
2023 Preliminary Examination

PHYSICS
Higher 2
Paper 1 Multiple Choice

9749/01
September 2023
1 hour

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

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

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 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 rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

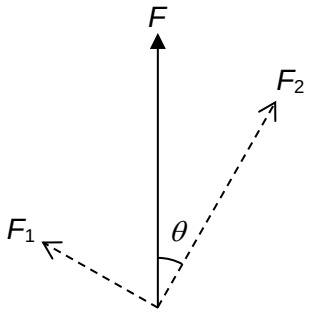
Data

speed of light in free space	c	=	3.00×10^{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 / °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	=	$\frac{\mu_0 N I}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 n I$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{1/2}}$

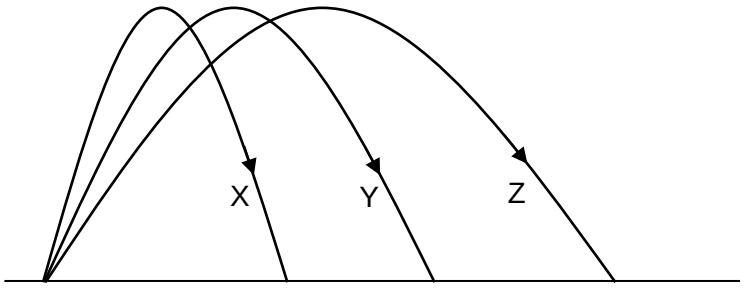
1 A vector F can be resolved into two perpendicular components F_1 and F_2. The angle between F and F_2 is θ.



How do the magnitudes of F_1 and F_2 change as θ is increased from 0° to 90°?

	F_1	F_2
A	increase	increase
B	increase	decrease
C	decrease	increase
D	decrease	decrease

2 Three paths of a kicked football are shown.



Ignoring the effects of air resistance, which of the following statements is **not** correct?

A The initial speed for path Z is the largest.

B The three paths have the same time of flight.

C The vertical component of the initial velocity for path X is the largest.

D The horizontal component of the initial velocity for path X is the smallest.

3 Two forces F_1 and F_2 are applied to an object initially at rest. F_1 is constant while F_2 acts in the opposite direction of F_1 with a magnitude that is proportional to the square of the speed of the object.

Which statement best describes the motion of the object?

A Its speed will increase from zero to a maximum.

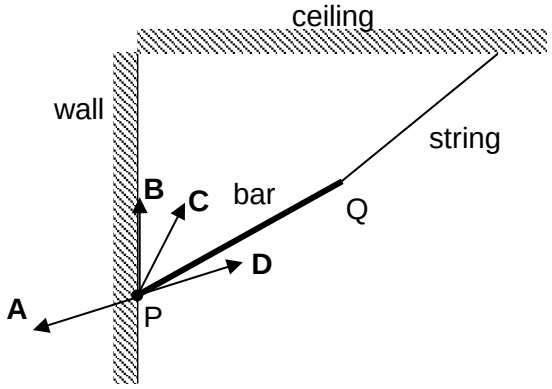
B Its speed will increase from zero to a maximum and then decrease.

C Its acceleration will increase from zero to a maximum.

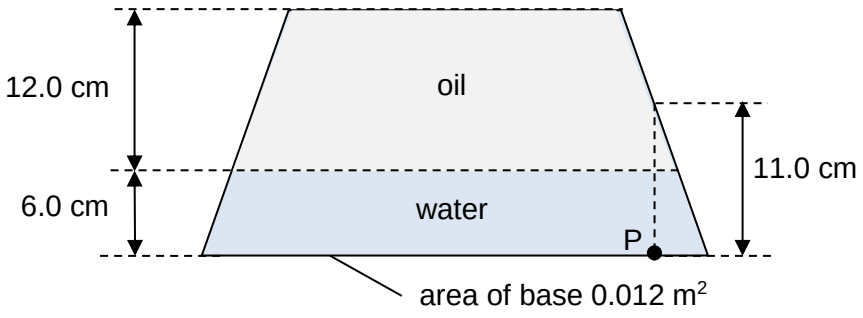
D Its acceleration will increase from zero to a maximum and then decrease.

4 A uniform bar PQ is hinged at a vertical wall at end P and tied to a string at end Q.

Which arrow best represents the direction of the force exerted by the wall on the bar?



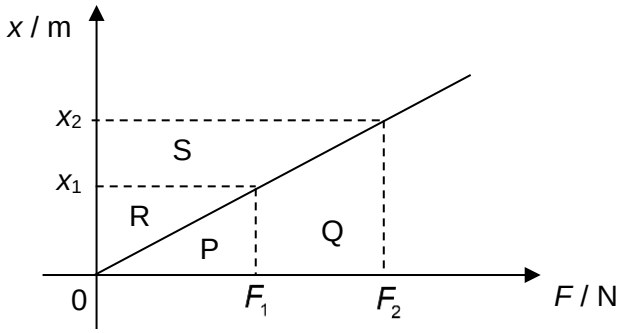
5 A container is filled with oil and water. The oil has a mass of 0.40 kg and density 750 kg m^{-3}. The water has a mass of 0.30 kg and density 1000 kg m^{-3}.



What is the pressure exerted by the oil and water at point P on the base of the container?

A 5.7×10^2 Pa **B** 9.6×10^2 Pa **C** 1.5×10^3 Pa **D** 1.0×10^5 Pa

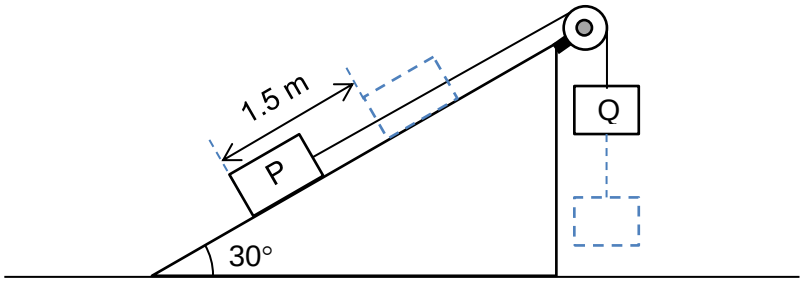
6 The variation with force F of the extension x of a spring is shown in the figure below.



Which area represents the work done in stretching the spring from x_1 to x_2?

A P + Q **B** Q **C** R + S **D** S

7 Two bodies, P and Q, of masses 3.0 kg and 4.0 kg respectively, are connected by a light cord passing over a light, frictionless pulley. P is held at rest on a rough slope inclined at 30° to the horizontal as shown.

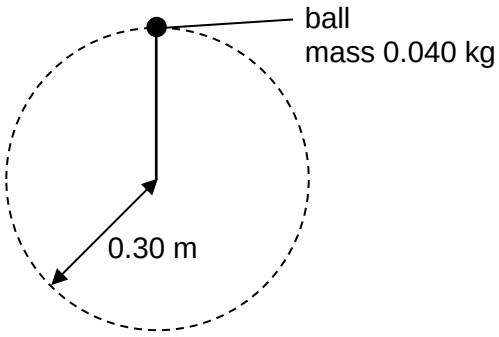


When P and Q are released, P experiences a constant frictional force of 2.5 N.

What is the total kinetic energy of P and Q when P has travelled 1.5 m up the slope?

A 11 J **B** 18 J **C** 33 J **D** 41 J

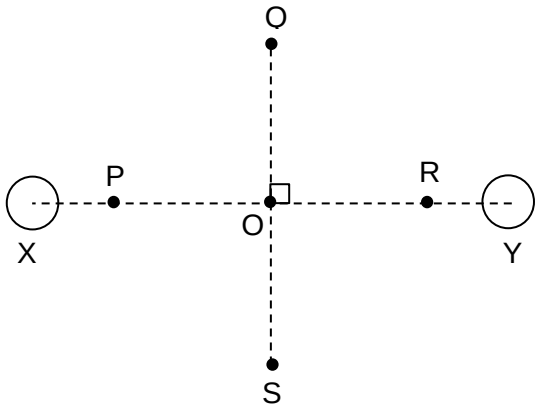
8 A small ball of mass 0.040 kg is attached to a light string and rotates in a vertical circle of radius 0.30 m. When the ball is vertically above the centre of the circle, the tension in the string is 1.2 N.



What is the centripetal acceleration of the ball when it is vertically below the centre of the circle?

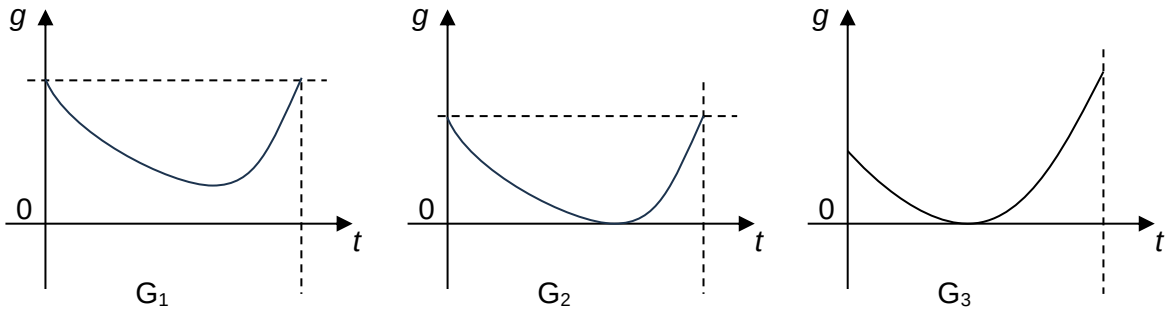
A 40 m s^{-2} **B** 59 m s^{-2} **C** 69 m s^{-2} **D** 79 m s^{-2}

9 The diagram shows two stars, X and Y and 5 points, O, P, Q, R and S.
O is the midpoint of the line joining the centres of X and Y.
P and R are on the line joining the centres of X and Y and are at the same distance from the centres of X and Y respectively.
Q and S are on the perpendicular bisector of the line joining P and R and are at the same distance from O.



A spacecraft travels with constant acceleration in its direction of travel between 2 points.

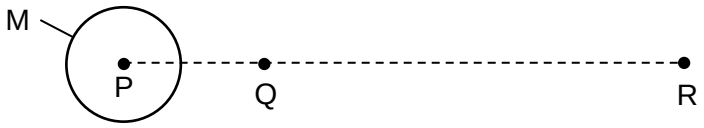
Graphs G_1, G_2 and G_3 show the possible variations in the magnitude of the resultant gravitational field strength g due to the stars at the position of the spacecraft with time t.



Which graphs correspond to the motions of the spacecraft from S to Q and P to R?

	S to Q	P to R
A	G_1	G_2
B	G_1	G_3
C	G_2	G_1
D	G_2	G_3

10 Point P is at the centre of a uniform sphere M. The work done by an external force in bringing a mass of 1.0 kg from infinity to point Q is −2.0 J.

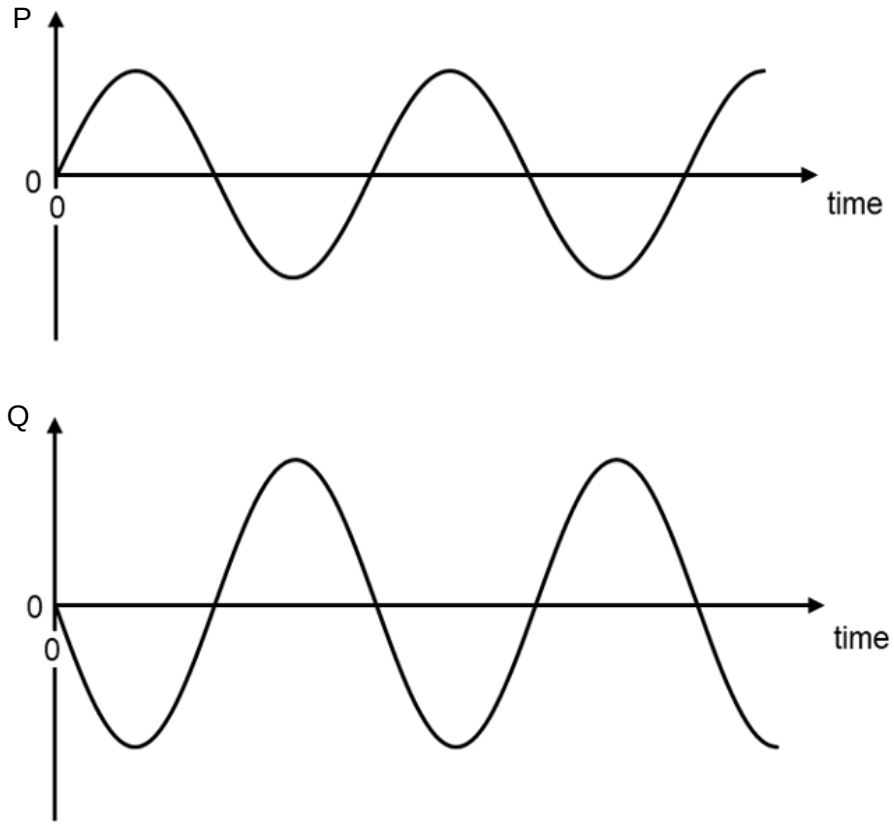


The ratio $\frac{PQ}{QR}$ is $\frac{1}{3}$.

What is the work done by an external force to bring a mass of 3.0 kg from Q to R?

A −18 J **B** −4.5 J **C** 4.5 J **D** 18 J

11 The two graphs below are for the motion of a body undergoing simple harmonic motion.



What could be represented by the quantities P and Q?

	P	Q
A	acceleration	displacement
B	acceleration	velocity
C	displacement	velocity
D	potential energy	velocity

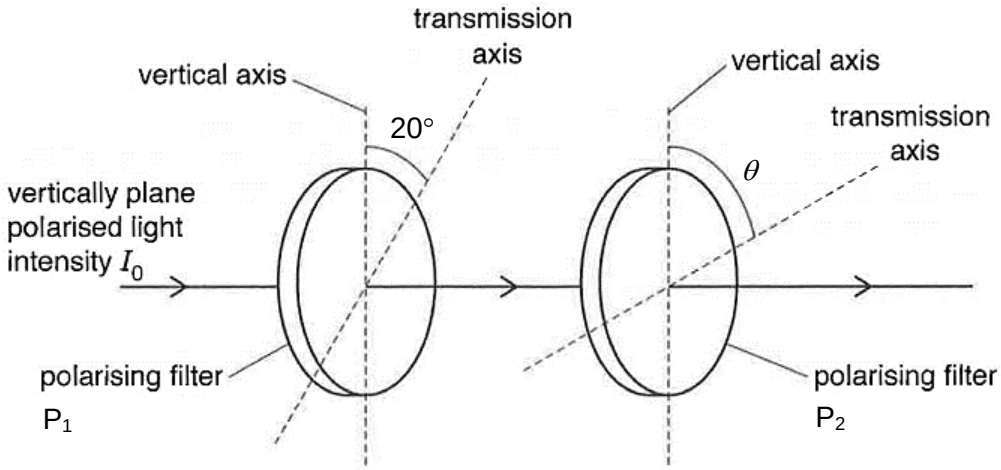
12 The total energy of a mass which undergoes simple harmonic motion on a vibrating platform is 18 mJ.

The amplitude of the oscillation is now doubled and the period of oscillation is tripled.

What is the new total energy of the mass?

A 0.89 mJ **B** 8.0 mJ **C** 72 mJ **D** 650 mJ

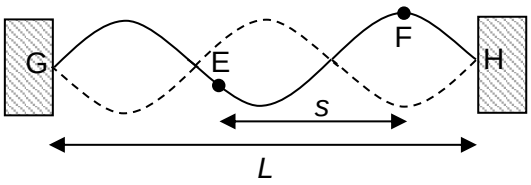
13 A beam of vertically polarised light of intensity I_0 is transmitted through two polarising filters P_1 and P_2 as shown. The axes of polarisation of P_1 and P_2 are at 20° and θ relative to the direction of polarisation of the incident light. The intensity of the light after passing through P_2 is 0.25 I_0.



What is the value of θ?

A 38° **B** 58° **C** 78° **D** 95°

14 A string of length L is stretched between two fixed points G and H and made to vibrate transversely as shown below.

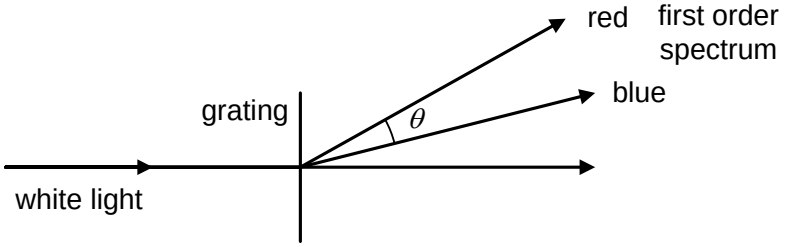


Two particles E and F on the string are separated by a distance s. The maximum kinetic energies of particles E and F are K_E and K_F respectively.

Which of the following gives the correct phase difference and relationship between maximum kinetic energies of the particles?

	phase difference / rad	maximum kinetic energy
A	$\frac{3s}{2L} \times 2\pi$	same
B	$\frac{3s}{2L} \times 2\pi$	$K_E < K_F$
C	π	same
D	π	$K_E < K_F$

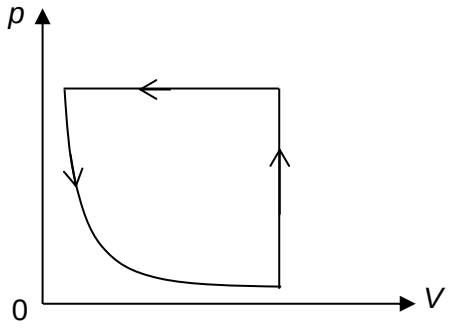
15 White light covers the range of wavelength from 400 nm to 700 nm. A diffraction grating with 5.0×10^5 lines per metre is placed perpendicular to a ray of white light and produces the first order spectrum as shown.



What is the angle θ between the red and blue ends of the spectrum?

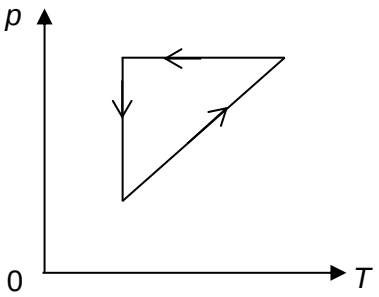
A 9.0 ° **B** 12 ° **C** 20 ° **D** 32 °

16 A fixed mass of ideal gas undergoes a thermodynamic cycle that comprises a constant pressure process, a constant temperature process and a constant volume process. The variation with volume V of pressure p of the ideal gas is shown.

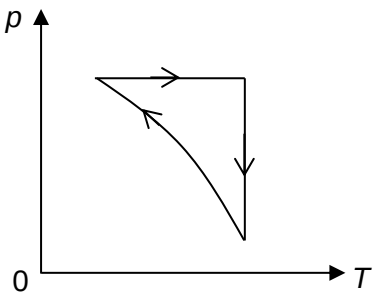


Which of the following shows the same cycle on a graph of pressure p against the thermodynamic temperature T?

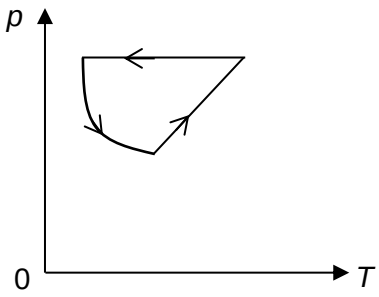
A



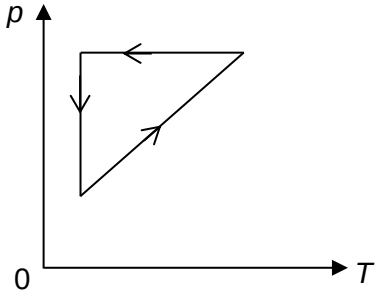
B



C



D

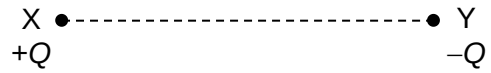


17 A 500 W electric kettle is used to boil water and is left on even after the water begins to boil. After 5 minutes, the temperature of its heating coil reaches a constant value.

When the first law of thermodynamics is used to quantitatively describe the heating coil after this time, which row correctly describes the application of the first law?

	rate of increase of internal energy / W	rate of heat supplied to the coil / W	rate of work done on the coil / W
A	+500	+500	0
B	+500	0	+500
C	0	+500	−500
D	0	−500	+500

18 A point charge of $+Q$ is placed at X and a point charge of $-Q$ is placed at Y.



What happens to the electric force acting on an electron as it moves in a straight line from X to Y?

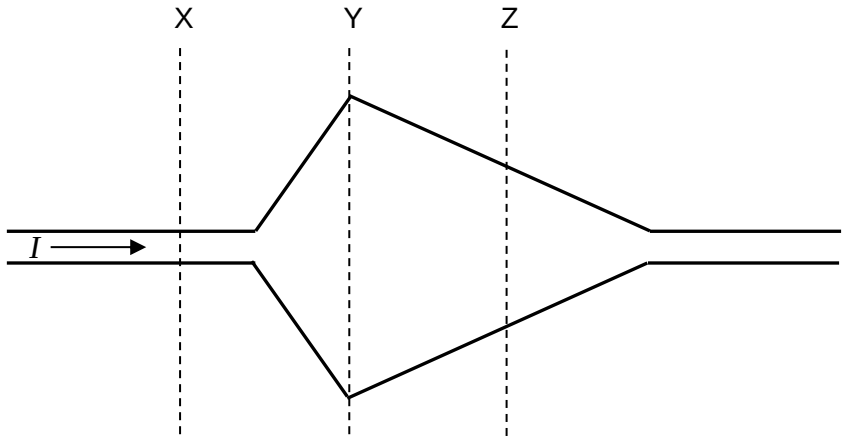
	magnitude of force	direction of force
A	decreases to a minimum at midpoint of XY and increases	always towards the left
B	decreases to a minimum at midpoint of XY and increases	always towards the right
C	increases to a maximum at midpoint of XY and decreases	always towards the left
D	increases to a maximum at midpoint of XY and decreases	always towards the right

19 An oil drop, carrying a charge of -3.2×10^{-19} C, is stationary in the region between two horizontal plates when the potential difference between the two plates is 5.0×10^{3} V. The separation of the plates is 16 mm.

What is the initial acceleration of the oil drop when the potential difference is decreased to 4.0×10^{3} V?

A 0.20 m s^{-2} **B** 2.0 m s^{-2} **C** 7.8 m s^{-2} **D** 18 m s^{-2}

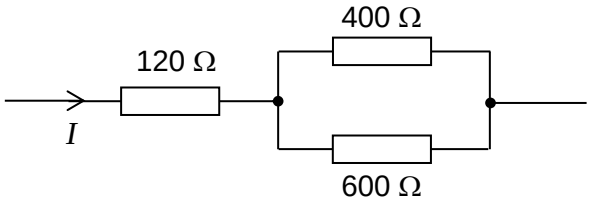
20 An electric current I in a flat metal specimen of uniform thickness and of the shape shown.



Which of the following correctly describes the magnitude of the current I and drift velocity v at sections X, Y and Z?

	I	v
A	$I_X = I_Y = I_Z$	$v_X = v_Y = v_Z$
B	$I_X = I_Y = I_Z$	$v_X > v_Z > v_Y$
C	$I_X > I_Z > I_Y$	$v_X = v_Y = v_Z$
D	$I_X > I_Z = I_Y$	$v_X > v_Z > v_Y$

21 Three resistors are arranged in a part of a circuit, and the resistance of each resistor is labelled as shown.

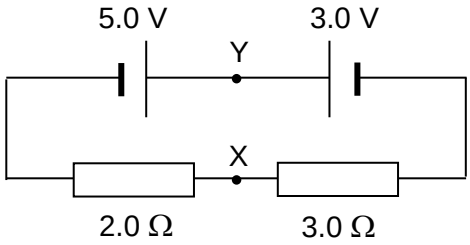


The current through the 120 Ω resistor is I.

What is the value of $\frac{\text{power dissipated in the 120 Ω resistor}}{\text{power dissipated in the 600 Ω resistor}}$?

A 0.20 **B** 0.50 **C** 1.3 **D** 5.0

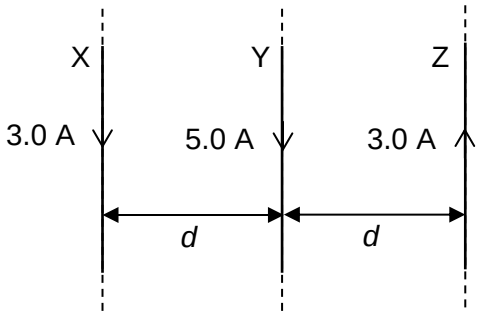
22 A circuit is connected as shown below. The internal resistance of each cell is negligible.



What is the potential difference between point X and point Y?

A 0.80 V **B** 1.2 V **C** 3.0 V **D** 4.2 V

23 Three long, parallel wires X, Y and Z carry currents of 3.0 A, 5.0 A and 3.0 A respectively in the directions shown. X and Z are at distance *d* from Y. Wire Y exerts a force per unit length of 8.0×10^{-6} N m^{-1} on wire Z.



What is the resultant force per unit length acting on wire X?

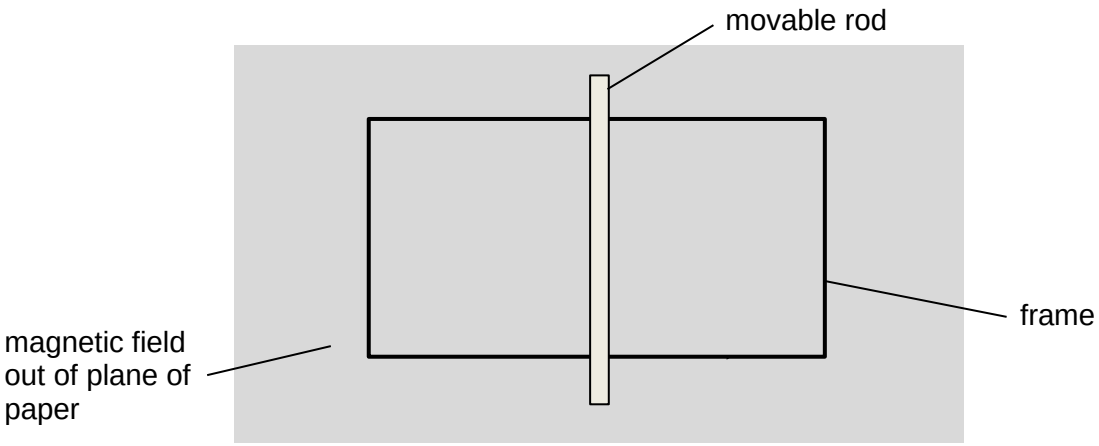
A 5.6×10^{-6} N m^{-1} to the right

B 5.6×10^{-6} N m^{-1} to the left

C 8.0×10^{-6} N m^{-1} to the right

D 8.0×10^{-6} N m^{-1} to the left

24 A movable metal rod is placed in the middle of a rectangular metal frame. A uniform magnetic field directed out of the plane of the paper acts perpendicular to the frame.



Which of the following actions will induce a clockwise current in the frame?

A Sliding the rod to the left while maintaining contact with the frame.

B Sliding the rod to the right while maintaining contact with the frame.

C Decreasing the magnitude of the magnetic flux density of the field.

D Increasing the magnitude of the magnetic flux density of the field.

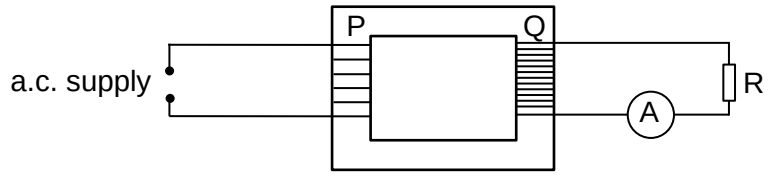
25 In a region where the magnetic flux density of the Earth is 5.6×10^{-5} T, and directed at 72° to the horizontal, a ceiling fan with four horizontal blades rotates about a vertical axis at a frequency of 1.6 Hz. The length of each blade is 0.55 m.

What is the e.m.f. induced between the axle of the fan and the tips of the blades?

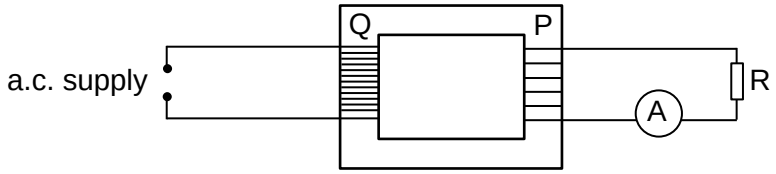
A 26 μV **B** 81 μV **C** 85 μV **D** 150 μV

26 The diagram shows an ideal iron-cored transformer. The ratio of the number of turns of P to the number of turns of Q is 1:20.

P is connected to an a.c. supply and Q is connected to a resistor R. The reading on the ammeter is 2.0 A.



The transformer is turned around such that Q is now connected to the same a.c. supply and P is connected to R as shown below.



What is the new reading on the ammeter?

A 0.0050 A **B** 0.10 A **C** 2.0 A **D** 40 A

27 In an evacuated chamber, particles are accelerated from rest through a potential difference of the same magnitude.

Which of the following has the shortest de Broglie wavelength after the acceleration?

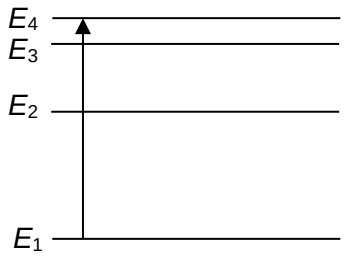
A proton ${}^{1}_{1}\mathrm{p}$

B electron ${}^{0}_{-1}\mathrm{e}$

C deuterium nucleus ${}^{2}_{1}\mathrm{H}$

D helium nucleus ${}^{4}_{2}\mathrm{He}$

28 A beam of electrons of energy E excite atoms of element X from ground state E_1 to an excited state E_4 as shown.



element X

Photons emitted from element X interact with atoms of another element Y at their ground state. Three emission spectral lines are obtained from element Y.

The process is then repeated with atoms of element Y at ground state being excited by the same beam of electrons of energy E. Photons emitted from element Y now interact with atoms of element X at their ground state.

Which of the following is **not** a possible number of emission spectral lines obtained from element X following this interaction?

A 0 **B** 3 **C** 4 **D** 6

29 The rest mass of the deuteron, ${}^{2}_{1}\mathrm{H}$, is equivalent to an energy of 1876 MeV. The rest masses of a proton and a neutron are equivalent to 939 MeV and 940 MeV respectively.

Which of the following occurs when a deuteron disintegrates into a proton and neutron?

A The deuteron emits a γ-ray photon of energy 2 MeV.

B The deuteron captures a γ-ray photon of energy 2 MeV.

C The deuteron emits a γ-ray photon of energy 3 MeV.

D The deuteron captures a γ-ray photon of energy 3 MeV.

30 Which of the following illustrates the random nature of radioactive decay?

A Activity of a radioactive sample decreases with time.

B Fluctuations in the count rate from a radioactive sample.

C Activity of a radioactive sample does not change upon heating.

D Some isotopes of an element are radioactive while others are not.