Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 1

25 April 2024

Zone A afternoon | **Zone B** afternoon | **Zone C** afternoon

1 hour

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[40 marks]**.

2224 – 6707

24 pages

1. A cart accelerates from $(20 \pm 1)\,\mathrm{m\,s^{-1}}$ to $(30 \pm 1)\,\mathrm{m\,s^{-1}}$.

What is the percentage uncertainty in the change of speed of the cart?

A. 2 %

B. 4 %

C. 8 %

D. 20 %

2. Jim runs with a constant velocity *v* past Sally who is at rest. At this instant, Sally begins to chase Jim with constant acceleration *a*.

Which expression gives the time Sally will catch Jim?

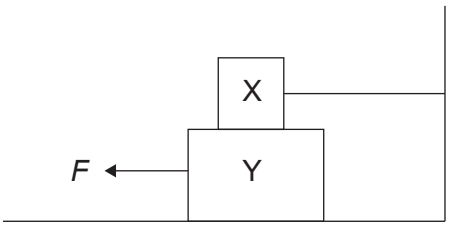
A. $\frac{v}{2a}$

B. $\frac{v}{a}$

C. $\frac{2v}{a}$

D. $\frac{4v}{a}$

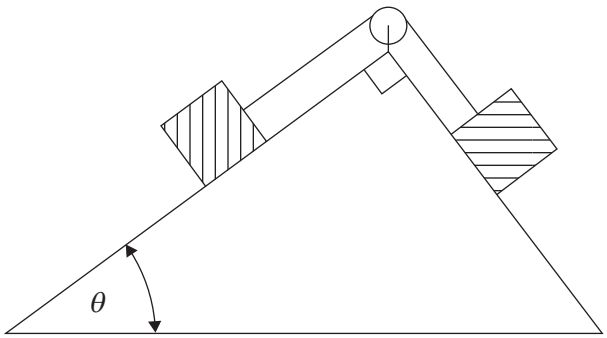
3. A block X of weight 10 N is stacked on a block Y of weight 20 N. Block X is fixed to a wall with a light string. The coefficients of static friction between the blocks and between block Y and the ground are both 0.2.



What is the value of the minimum force *F* required to move block Y and what is the tension *T* in the string immediately before block Y begins to move?

	Minimum force *F* / N	**Tension in string *T* / N**
A.	8	2
B.	8	6
C.	6	2
D.	6	6

4. Two blocks of equal mass are connected by a light string that passes over a frictionless pulley. The blocks slide at a constant velocity on inclined planes that are at right angles to each other. One of the inclined planes makes an angle θ to the horizontal such that $\theta < 45°$.



Which of the following statements is correct?

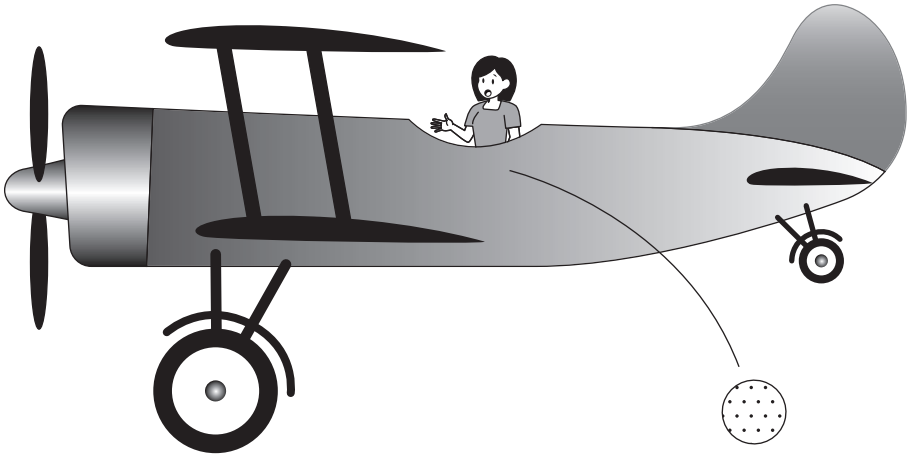
A. The net force acting on each block is the same.

B. The weight force acting on each block is different.

C. The magnitude of the normal force acting on each block is the same.

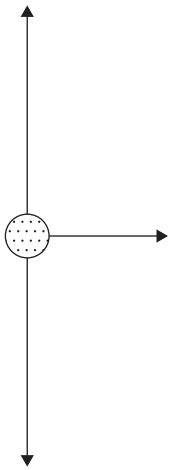
D. The magnitude of the force exerted by the string on each block is different.

5. A ball is thrown from an aircraft in flight.



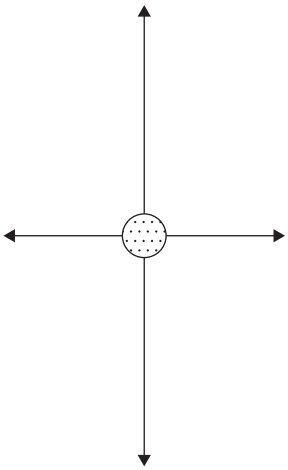
Which of the following shows the correct free-body diagram for the forces acting on the ball when terminal velocity is reached?

A.

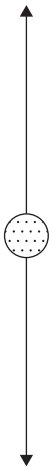


B.

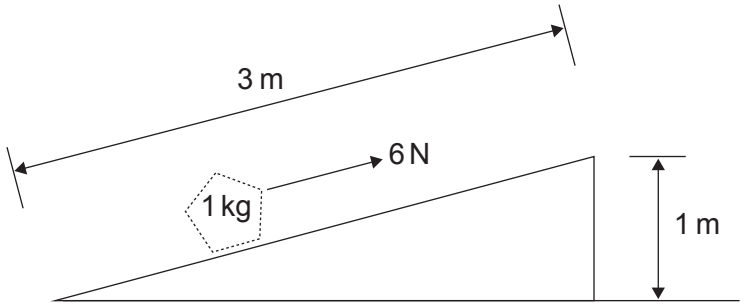
C.



D.



6. A stationary mass of 1 kg is pulled along a frictionless 3 m inclined plane by a constant force of 6 N. At the top of the plane the mass has been displaced 1 m vertically.



What is the speed of the mass at the top of the incline?

A. $3\,m\,s^{-1}$

B. $4\,m\,s^{-1}$

C. $6\,m\,s^{-1}$

D. $18\,m\,s^{-1}$

7. A firework rocket launched vertically explodes into two pieces X and Y when it reaches its maximum height. The mass of X is greater than that of Y.

Three statements are made about the pieces immediately after the explosion:

I. The kinetic energy of X is less than that of Y.

II. The magnitude of the momentum of X is equal to that of Y.

III. The total momentum after the explosion has increased.

Which of these statements are correct?

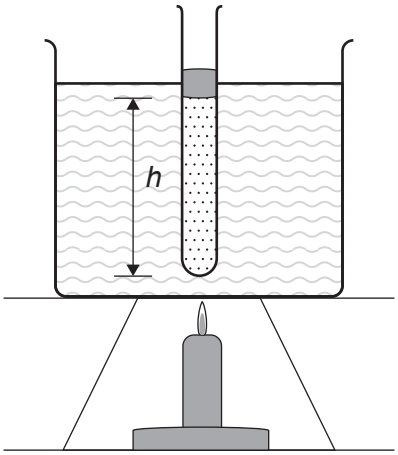
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

8. A layer of mercury traps a volume of gas in a tube. The tube is placed in a water bath and slowly heated. When the temperature of the water is 300 K the height of gas *h* in the tube is 150 mm.



What is *h* when the temperature of the water is 360 K?

A. 120 mm

B. 180 mm

C. 300 mm

D. 360 mm

9. A container is filled with equal mass of helium $^{4}_{2}He$ gas and neon $^{20}_{10}Ne$ gas at the same temperature.

Which statement is correct?

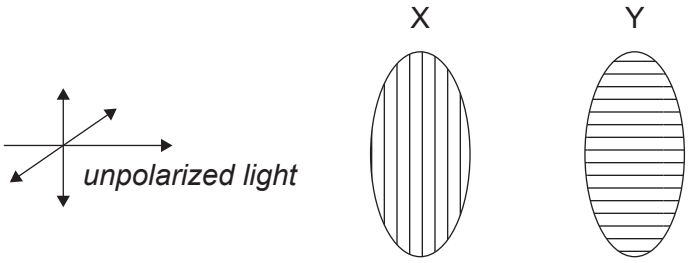
A. The average kinetic energy of the helium particles is equal to the average kinetic energy of the neon particles.

B. Helium particles collide less frequently with the container walls compared to neon.

C. The container has equal numbers of helium and neon particles.

D. The internal energy of helium gas is equal to the internal energy of neon gas.

10. Unpolarized light is incident on two polarizers X and Y. The transmission axis of X is vertical and that of Y is horizontal.



Polarizer Z can be placed

I. before polarizer X.

II. between polarizer X and Y.

III. after polarizer Y.

The transmission axis of Z makes an angle of 45° with those of X and Y.

At which positions for Z will no light be transmitted?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. Radio waves are emitted spherically from a source. At a distance *d* from the source the amplitude of the waves is *X*.

What is the amplitude at a distance 2*d* from the source?

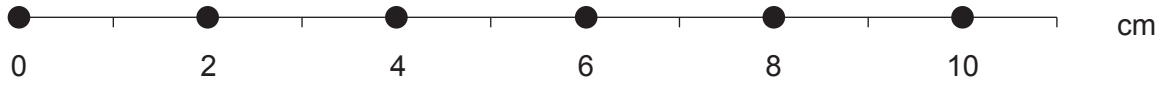
A. $\frac{X}{8}$

B. $\frac{X}{2}$

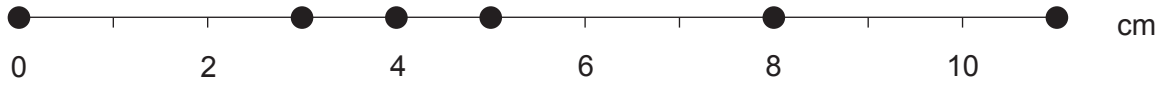
C. $\frac{X}{\sqrt{2}}$

D. X

12. The equilibrium positions of six particles in a medium are separated by a distance of 2 cm as shown.



The positions of these particles, when a longitudinal wave is transmitted through the medium, are now shown.



What is the wavelength of the wave?

A. 2 cm

B. 4 cm

C. 6 cm

D. 8 cm

13. Light passes from a medium into air. The critical angle is θ_c.

Which expression gives the speed of light in the medium?

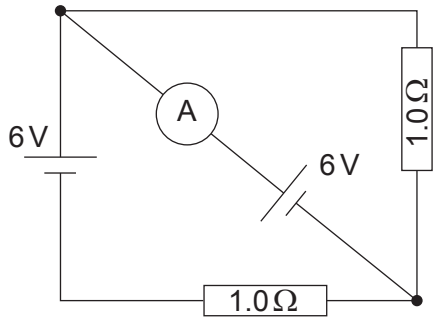
A. $\dfrac{1}{c \sin\theta_c}$

B. $\dfrac{\sin\theta_c}{c}$

C. $\dfrac{c}{\sin\theta_c}$

D. $c \sin\theta_c$

14. Two 1.0 Ω resistors are placed in a circuit with two 6 V cells of negligible internal resistance as shown.



What is the reading on the ideal ammeter?

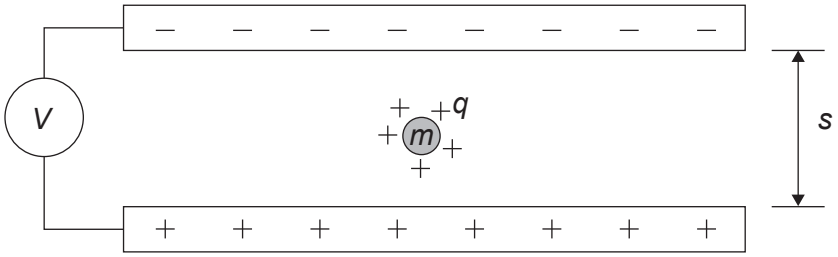
A. 2.0 A

B. 3.0 A

C. 6.0 A

D. 12.0 A

15. A sphere of mass *m* and positive charge *q* is at rest midway between two horizontal parallel plates separated by a distance *s*. The potential difference across the plates is *V*.



What is *q*?

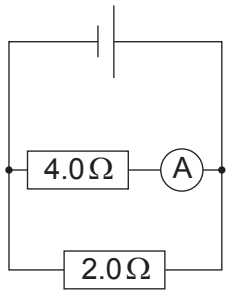
A. $\frac{s}{mgV}$

B. $\frac{V}{mgs}$

C. $\frac{mgV}{s}$

D. $\frac{mgs}{V}$

16. A 2.0 Ω and a 4.0 Ω resistor are connected in parallel to a cell with negligible internal resistance. An ammeter placed in the circuit as shown measures a current of 1.0 A.



What is the current passing through the 2.0 Ω resistor?

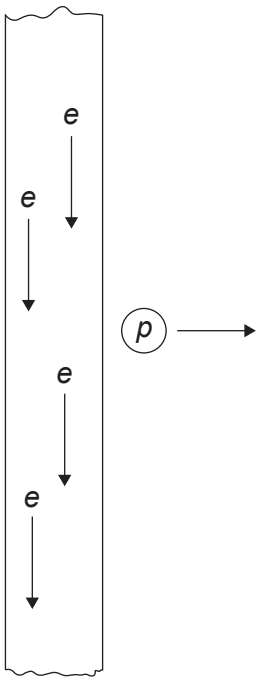
A. 0.5 A

B. 1.0 A

C. 2.0 A

D. 4.0 A

17. Electrons in a conductor are moving down the page. A proton outside the wire is moving to the right.



What is the direction of the magnetic force acting on the proton?

A. Down the page

B. Up the page

C. Out of the page

D. Into the page

18. An asteroid falling towards a planet has a speed of $20.0\,\text{km}\,\text{s}^{-1}$ at point P.

10 minutes later the asteroid is at point Q and its speed is $20.6\,\text{km}\,\text{s}^{-1}$.

What is the average gravitational field strength between P and Q?

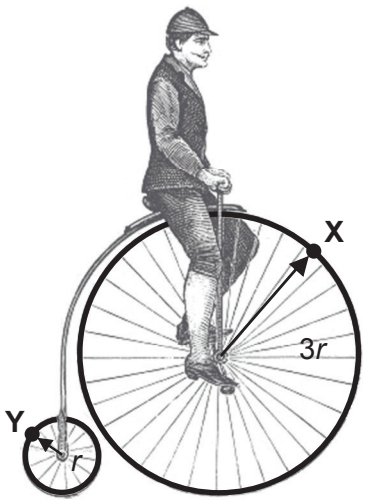
A. $0.001\,\text{N}\,\text{kg}^{-1}$

B. $0.006\,\text{N}\,\text{kg}^{-1}$

C. $1\,\text{N}\,\text{kg}^{-1}$

D. $6\,\text{N}\,\text{kg}^{-1}$

19. An old-fashioned bicycle is moving with a constant speed v. The front wheel has a radius 3 times that of the rear wheel. Points X and Y are positioned on the front and rear wheel as shown.



What is $\frac{\text{acceleration of X}}{\text{acceleration of Y}}$?

A. $\frac{1}{9}$

B. $\frac{1}{3}$

C. 3

D. 9

20. A nucleus of uranium undergoes fission.

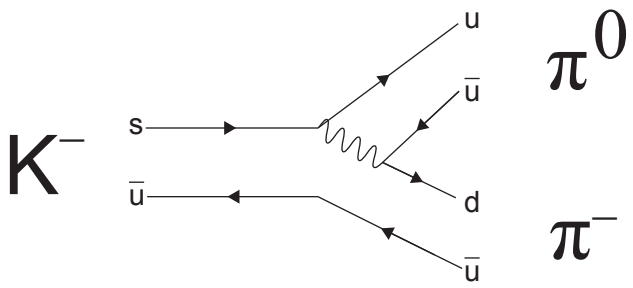
$$ {}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{x}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} $$

What is correct about the number of nucleons x in the Kr nucleus and the ratio

$$ \frac{\text{binding energy per nucleon of Kr}}{\text{binding energy per nucleon of Ba}} \; ? $$

	Number of nucleons x in Kr nucleus	**$\frac{\text{binding energy per nucleon of Kr}}{\text{binding energy per nucleon of Ba}}$**
A.	92	Greater than 1
B.	92	Less than 1
C.	94	Greater than 1
D.	94	Less than 1

21. The Feynman diagram shows a possible decay of a K^- meson.



Which particle is represented by the wavy line?

A. Gluon

B. Z^0

C. Photon

D. W^-

22. A 1000 kg car accelerates from rest to a speed of $20\,m\,s^{-1}$. The car has an efficiency of $\frac{1}{3}$ and uses fuel of specific energy of $50\,MJ\,kg^{-1}$.

What mass of fuel is used to accelerate the car?

A. 4 g

B. 6 g

C. 12 g

D. 36 g

23. The wind generator equation can be used to estimate the power produced by a wind turbine from a given set of conditions.

Which assumption is **not** used in the derivation of this equation?

A. The number of blades on the turbine is a constant.

B. Speed of air particles after passing through the turbine is zero.

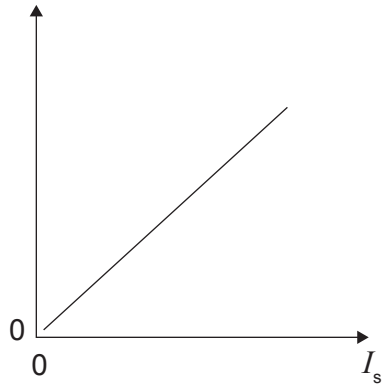
C. Speed of air particles approaching the turbine cross-sectional area is constant.

D. Turbulence created by the spinning turbine is negligible.

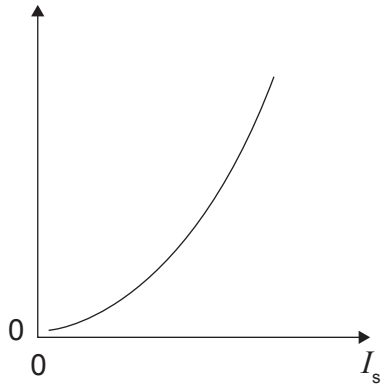
24. A planet has a known albedo and emissivity. The average intensity received at the surface is I_s.

Which graph describes the variation of surface temperature *T* with I_s?

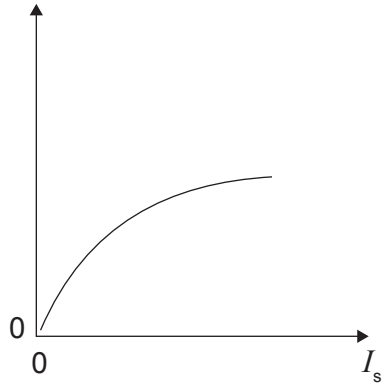
A.



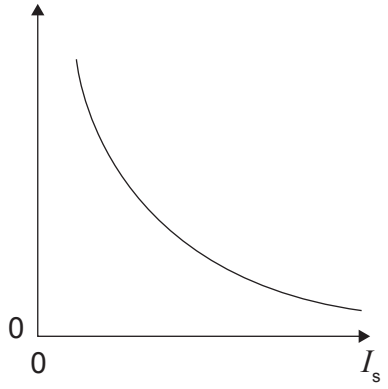
B.



C.



D.



25. In the fusion reaction ${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H}$ an energy of 4 MeV is released.

What is the specific energy of deuterium ${}^{2}_{1}\mathrm{H}$?

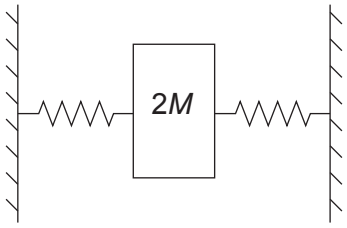
A. $10^{2}\,\mathrm{MJ\,kg^{-1}}$

B. $10^{8}\,\mathrm{MJ\,kg^{-1}}$

C. $10^{14}\,\mathrm{MJ\,kg^{-1}}$

D. $10^{27}\,\mathrm{MJ\,kg^{-1}}$

26. A mass M oscillates with a period T when connected to a spring with spring stiffness constant k. A mass of $2M$ is connected to 2 identical springs, each with spring stiffness constant k.



What is the period of the system?

A. T

B. $\frac{T}{\sqrt{2}}$

C. $\frac{T}{2}$

D. $\frac{T}{4}$

27. White light is incident on a diffraction grating. The second order maximum of wavelength 600 nm falls directly onto the third order maximum of a wavelength λ.

What is λ?

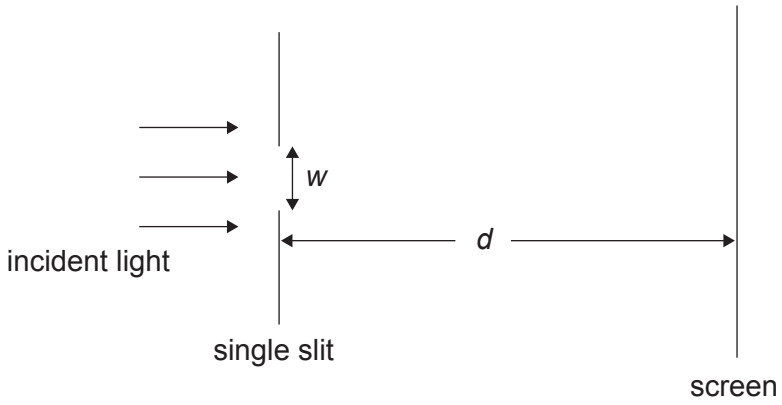
A. 250 nm

B. 400 nm

C. 900 nm

D. 1200 nm

28. Light of intensity I and wavelength λ is incident on a single slit of width *w*. An interference pattern is formed on a screen located a distance *d* from the slits.



What change will increase the width of the central maximum?

A. Decrease λ

B. Decrease I

C. Decrease *d*

D. Decrease *w*

29. A radar detector is used to measure the speed of a car. The car is moving with a speed v towards the detector.

The detector emits microwaves of frequency f and speed c. Which of the following is the change in frequency of the microwaves measured at the detector after reflection by the car?

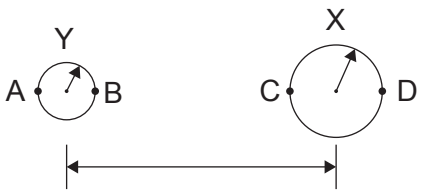
A. $\frac{-2vf}{c}$

B. $\frac{-vf}{c}$

C. $\frac{vf}{c}$

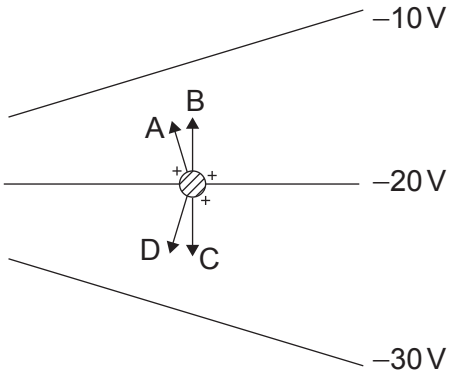
D. $\frac{2vf}{c}$

30. Two planets X and Y have equal density. Planet X has a larger radius than planet Y.



At which position is the gravitational potential most negative?

31. A positively charged particle is positioned in an electric field. Three equipotential lines are shown. The particle is released.



What is the initial direction of the velocity of the particle?

32. Which new concept was required to understand action at a distance?

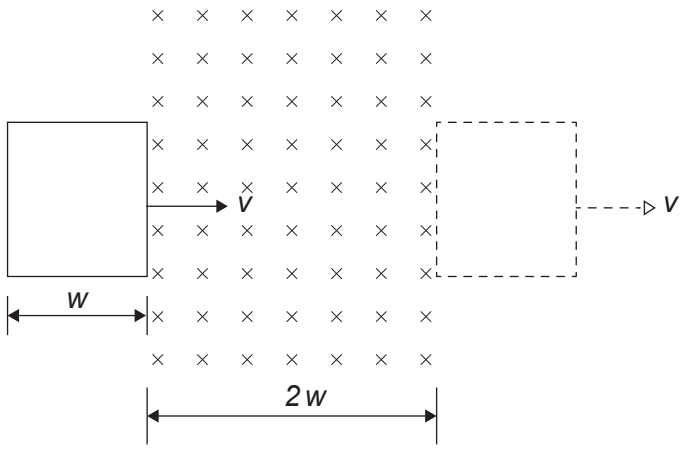
A. Wave motion

B. Atomic theory

C. Tunnelling

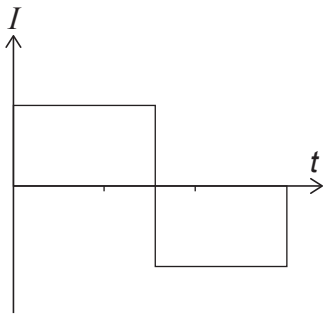
D. Fields

33. A square loop of wire of width w is pulled at a constant velocity v through a magnetic field of width $2w$.

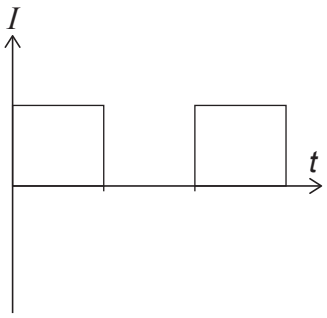


Which of the following shows the variation of current I in the loop with time t?

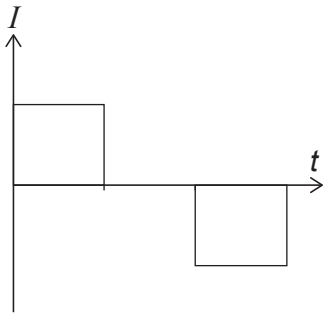
A.



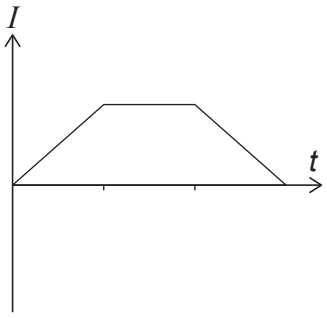
B.



C.



D.



34. An ideal step-up transformer has 500 turns on the primary coil and 2000 turns on the secondary coil. An alternating voltage with peak value of 250 V is supplied to the primary coil.

What is the rms voltage on the secondary coil?

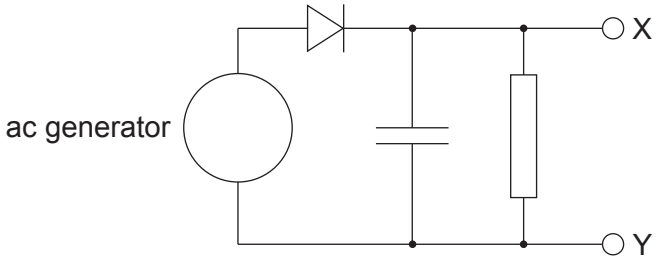
A. 500 V

B. $500\sqrt{2}$ V

C. 1000 V

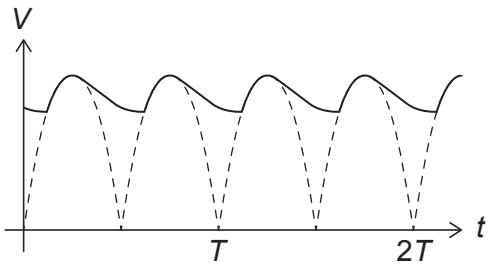
D. $1000\sqrt{2}$ V

35. An ac generator rotating with period T is placed into a circuit with a resistor, a diode, and a capacitor.

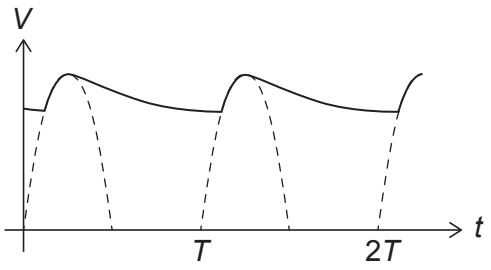


Which graph shows the variation of potential difference V across terminals X and Y with time t?

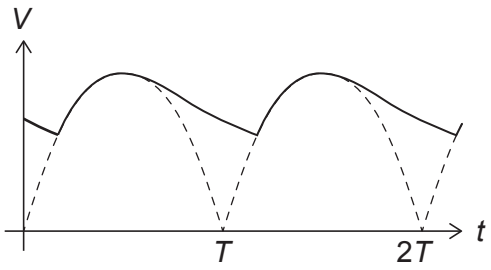
A.



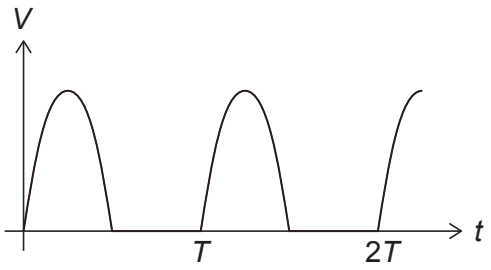
B.



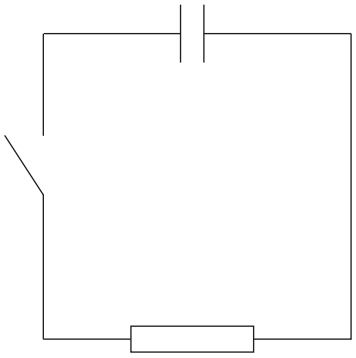
C.



D.



36. A charged capacitor is placed into a circuit with a resistor and an open switch. The time constant of the circuit is τ.



When the switch is closed at time $t = 0$ the initial power dissipated by the resistor is P_0.

What is $\frac{\text{power dissipated by the resistor at } t = \tau}{P_0}$?

A. $\frac{1}{\sqrt{e}}$

B. $\frac{1}{e}$

C. $\frac{1}{e^2}$

D. 0

37. Light of intensity I and frequency f, which is above the threshold frequency, is directed at a polished metal surface. The following three claims are made about electrons ejected from the surface.

I. The ejection is almost instantaneous.

II. The number ejected is proportional to I.

III. Their kinetic energy is equal to Planck's constant multiplied by f.

Which statements are correct?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

38. The uncertainty in an electron's position is x.

What is the uncertainty in the electron's energy?

A. $\frac{h}{16\pi x m_e}$

B. $\frac{h}{16\pi x^2 m_e}$

C. $\frac{h^2}{32\pi^2 x m_e^2}$

D. $\frac{h^2}{32\pi^2 x^2 m_e}$

39. A radioactive substance has a half-life of 5 hours and a decay constant λ. At time $t = 20$ hours N nuclei are present in the sample.

What was the activity of the sample at time $t = 5$ hours?

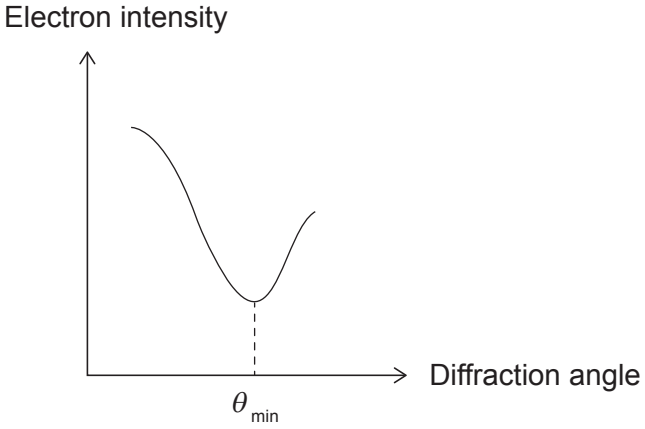
A. $4N\lambda$

B. $8N\lambda$

C. $\frac{4N}{\lambda}$

D. $\frac{8N}{\lambda}$

40. High speed electrons are directed at nuclei X. A graph of the variation of electron intensity with diffraction angle θ is shown for nuclei X. The minimum intensity occurs at $\theta = \theta_{min}$.



Electrons of the same speed are directed at nuclei Y which have double the diameter of nuclei X.

What is correct about the nuclear density of Y and θ_{min} for Y?

	Nuclear density of Y	**θ_{min} for Y**
A.	Same as X	Decrease
B.	Same as X	Increase
C.	More than X	Decrease
D.	More than X	Increase

References:

19. Clu, n.d. *Penny farthing bicycle*. [image online] Available at: https://www.gettyimages.co.uk/detail/illustration/penny-farthing-bicycle-first-exercise-royalty-free-illustration/1179950344 [Accessed 16 May 2023]. Source adapted.