EXAM PAPERS PRACTICE

Helping you Achieve Highest Grades in IB

IB Physics HL

Question Paper

Fully in-lined with the First Teaching in 2023 & First Assessment Examinations in 2025 & Beyond

Paper: 1 (Multiple-Choice Questions)

Topic: All Topics

- **A - Space, Time and Motion**
- **B - The Particulate Nature of Matter**
- **C - Wave Behaviour**
- **D - Fields**
- **E - Nuclear and Quantum Physics**

Marks: 165

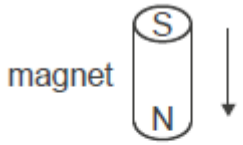
Total Marks: / 165

Suitable for HL Students sitting the 2025 exams onwards
However, SL students may also find these resources useful

Questions

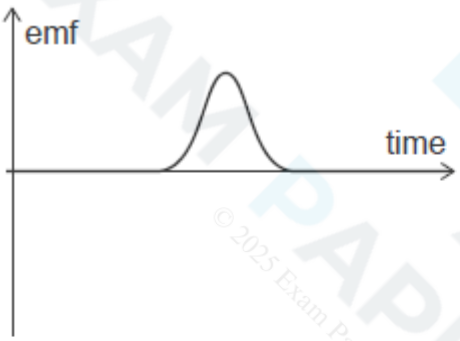
21N.1A.HL.TZ0.33

A small magnet is released from rest to drop through a stationary horizontal conducting ring.

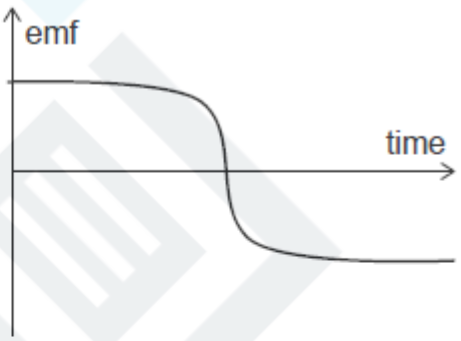


What is the variation with time of the emf induced in the ring?

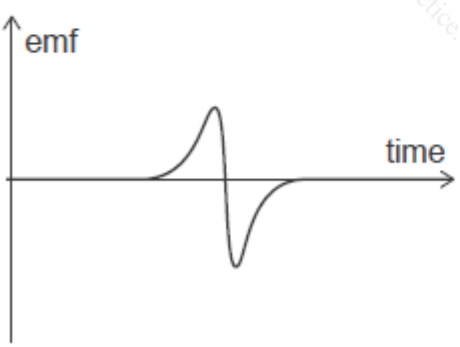
A.



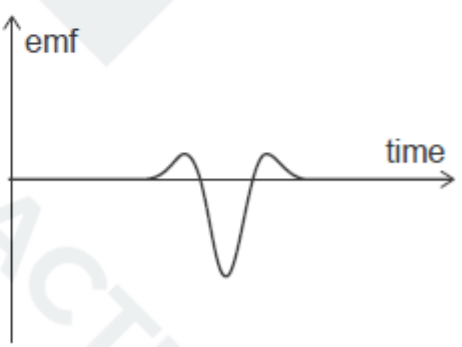
B.



C.



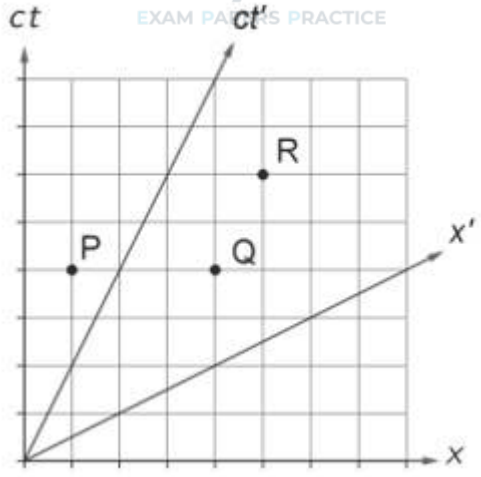
D.



[1]

EXE.1A.HL.TZ0.12

The spacetime diagram shows coordinate axes of reference frames of Earth (x , ct) and of a spaceship (x' , ct'). Three events P, Q and R are plotted.



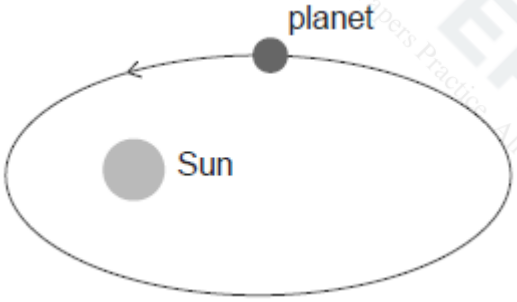
Which statement is correct about the order of the events according to an observer **on the spaceship** ?

A. P and Q are simultaneous, R happens later.
B. Q and R are simultaneous, P happens earlier.
C. Q and R are simultaneous, P happens later.
D. P and R are simultaneous, Q happens earlier.

[1]

SPM.1A.HL.TZ0.25

A planet orbits the Sun in an elliptical orbit moving in the direction shown. [1]

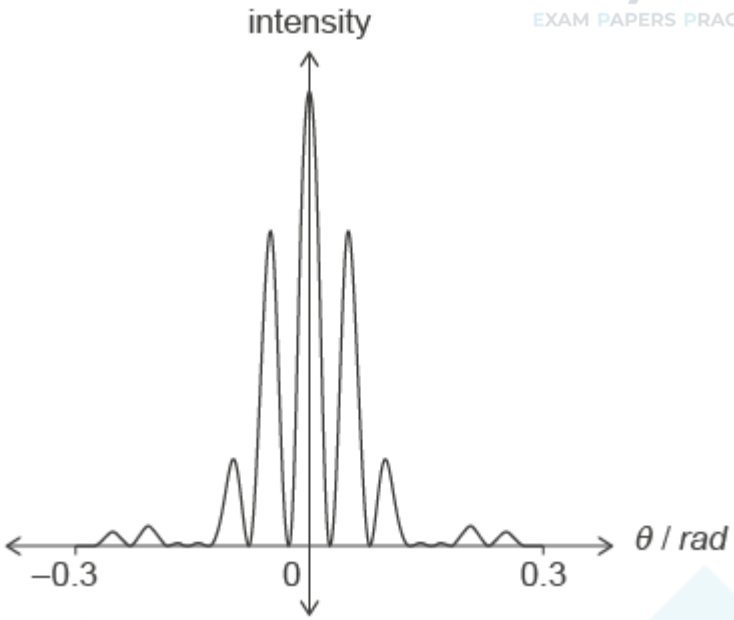


At the position shown, which quantity is decreasing for the planet?

A. Acceleration
B. Angular momentum
C. Kinetic energy
D. Gravitational potential energy

23M.1A.HL.TZ1.27

The intensity pattern of monochromatic light of wavelength λ, is projected onto a screen.



What combination produces this pattern?

	Number of slits	Width of slits
A.	1	smaller than λ
B.	1	greater than λ
C.	2	smaller than λ
D.	2	greater than λ

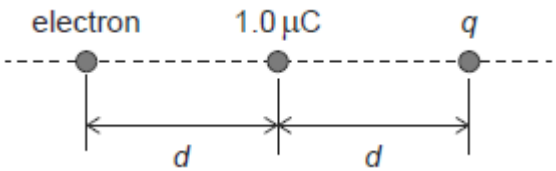
[1]

21M.1A.HL.TZ1.31

Which is a correct unit for gravitational potential? [1]
A. $m^2 s^{-2}$
B. J kg
C. $m s^{-2}$
D. $N m^{-1} kg^{-1}$

SPM.1A.HL.TZ0.32

A positive point charge of magnitude 1.0 μC and a point charge q are separated by a distance d.



An electron is placed at a distance d from the +1.0 μC charge. The electric force on the electron is zero.
What is q?

A. −4.0 μC

B. −2.0 μC
C. 2.0 μC
D. 4.0 μC

[1]

EXE.1A.HL.TZ0.14

A spaceship is travelling at 0.60 *c* from Earth when it launches a probe at 0.10 *c* relative to the spaceship and away from Earth.
What is the speed of the probe relative to Earth?

A. 0.50 *c*
B. 0.66 *c*
C. 0.75 *c*
D. 0.90 *c*

[1]

SPM.1A.HL.TZ0.20

Diagram 1 shows the variation with position of the displacement of a standing wave formed on a string.
Diagram 2 shows the variation with position of the displacement of a travelling wave moving to the right along a string.

Diagram 1

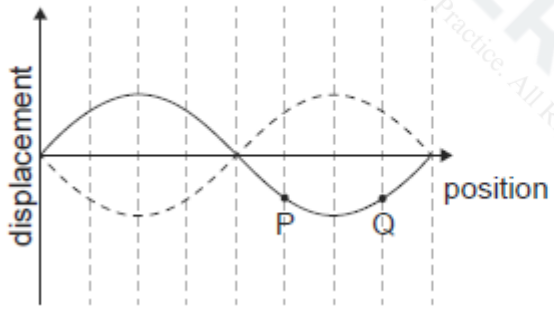
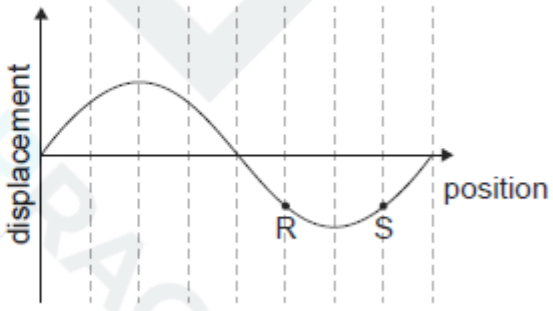


Diagram 2



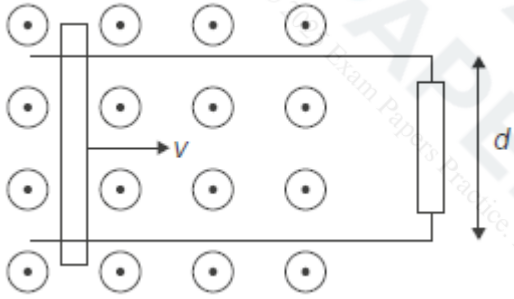
Points P, Q, R and S are points on the string.
What is the phase difference between P and Q and the phase difference between R and S?

	Phase difference between P and Q	Phase difference between R and S
A.	0	0
B.	$\frac{\pi}{2}$	0
C.	0	$\frac{\pi}{2}$
D.	$\frac{\pi}{2}$	$\frac{\pi}{2}$

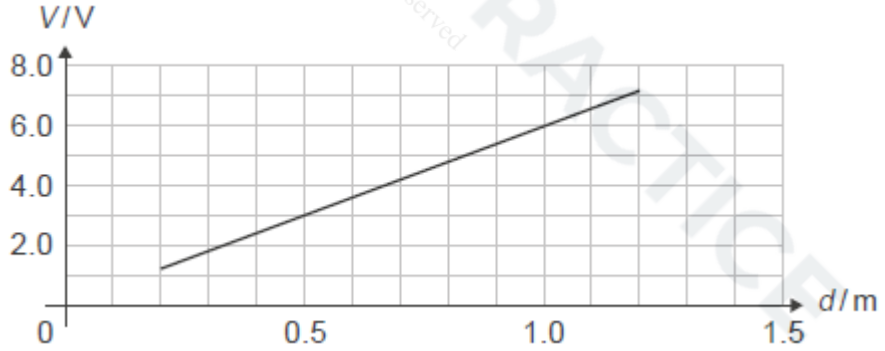
[1]

22N.1A.HL.TZ0.33

A resistor connects two parallel conducting rails a distance d apart. A conducting bar rolls along the rails at a constant velocity v through a uniform magnetic field of 2.0 T perpendicular to the rails as shown.
The voltage V across the resistor is measured.



The graph shows the variation of V with d.



What is v?

A. 0.33 m s $^{-1}$
B. 3.0 m s $^{-1}$
C. 6.0 m s $^{-1}$
D. 12.0 m s $^{-1}$

[1]

20N.1A.HL.TZ0.38

The diameter of a nucleus of a particular nuclide X is $12\ \text{fm}$. What is the nucleon number of X?

A. 5
B. 10
C. 125
D. 155

[1]

22M.1A.HL.TZ1.33

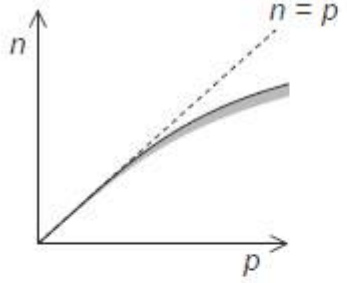
An object of mass m is launched from the surface of the Earth. The Earth has a mass M and radius r. The acceleration due to gravity at the surface of the Earth is g. What is the escape speed of the object from the surface of the Earth?

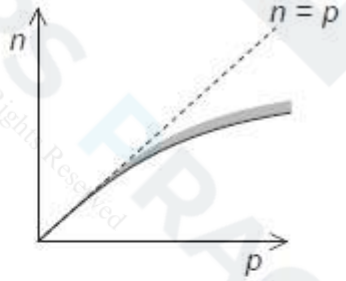
A. $\sqrt{\text{gr}}$
B. $\sqrt{2\text{gr}}$
C. $\sqrt{2\text{Mgr}}$
D. $\sqrt{2\text{mgr}}$

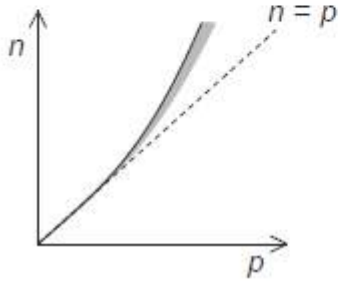
[1]

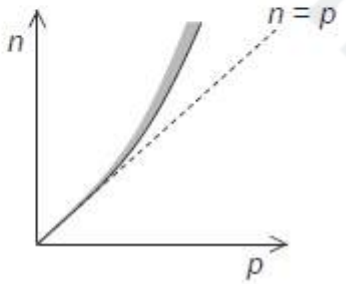
19M.1A.HL.TZ2.25

The positions of stable nuclei are plotted by neutron number *n* and proton number *p*. The graph indicates a dotted line for which $n = p$. Which graph shows the line of stable nuclides and the shaded region where unstable nuclei emit beta minus (β^-) particles?

A.


B.


C.


D.


[1]

21M.1A.HL.TZ2.20

A sample of a pure radioactive nuclide initially contains N_0 atoms. The initial activity of the sample is A_0.

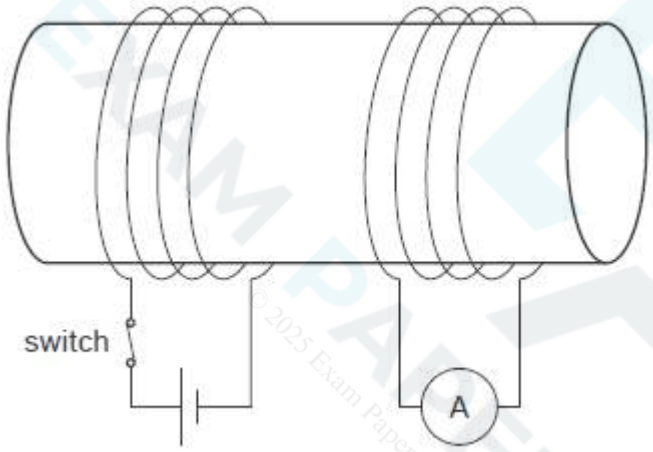
A second sample of the same nuclide initially contains $2N_0$ atoms.
What is the activity of the second sample after three half lives?

A. $\frac{A_0}{2}$
B. $\frac{A_0}{4}$
C. $\frac{A_0}{6}$
D. $\frac{A_0}{8}$

[1]

22N.1A.HL.TZ0.34

Two coils of wire are wound around an iron cylinder. One coil is connected in a circuit with a cell and a switch that is initially closed. The other coil is connected to an ammeter. The switch is opened at time t_0.



What is the ammeter reading before t_0 and what is the ammeter reading after t_0?

	Ammeter reading before t_0	Ammeter reading after t_0
A.	zero	a peak of current falling to zero
B.	zero	zero
C.	non–zero	a peak of current falling to zero
D.	non–zero	zero

[1]

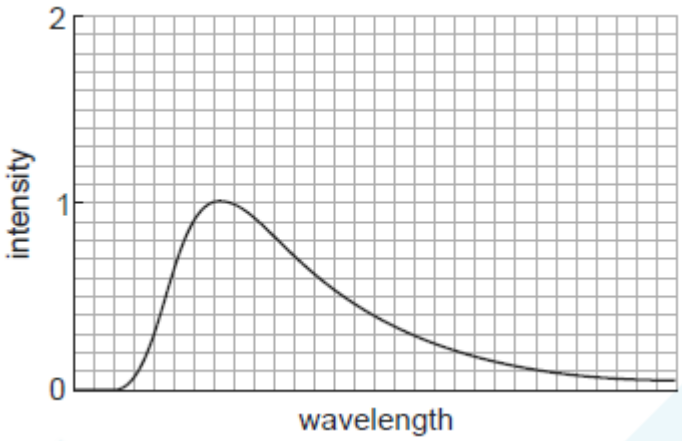
23M.1A.HL.TZ1.39

Which statement about atomic nuclei is correct? [1]
The density is...

A. directly proportional to mass number.
B. inversely proportional to nuclear radius.
C. inversely proportional to volume.
D. constant for all nuclei.

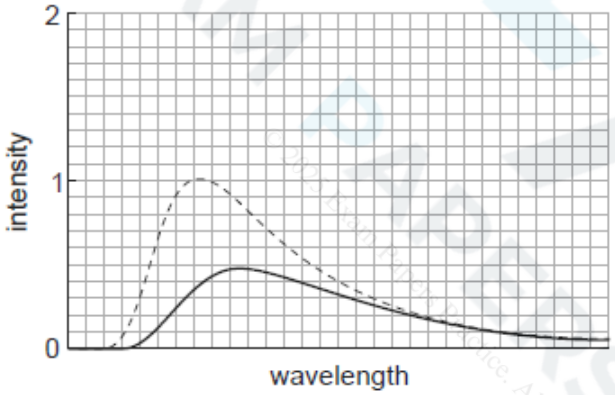
SPM.1A.HL.TZ0.13

The black-body radiation curve of an object at 600 K is shown. The intensity units are arbitrary.

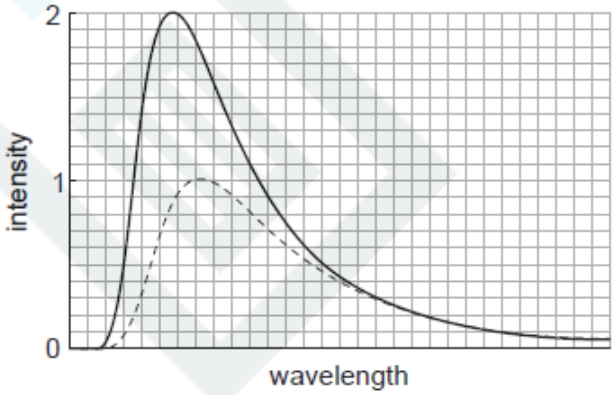


What is the radiation curve of the same object at 450 K?
The original curve is shown with a dashed line.

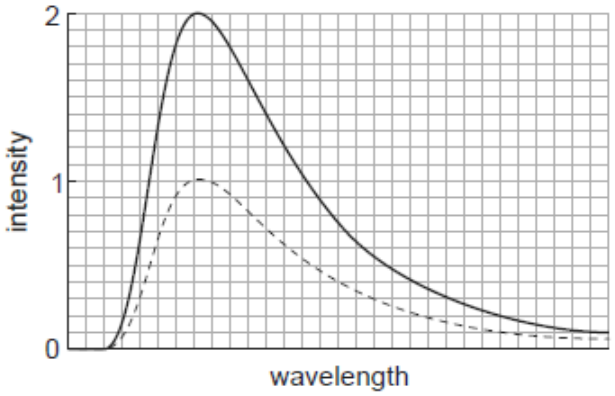
A.



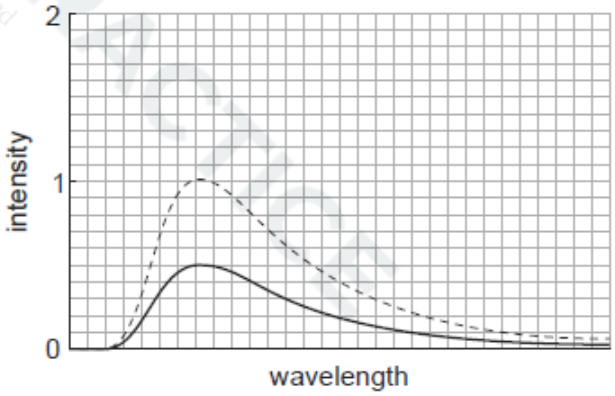
B.



C.



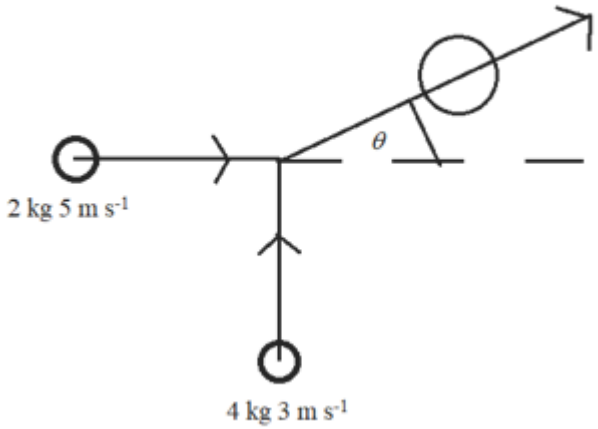
D.



[1]

EXE.1A.HL.TZ0.4

Diagram not to scale



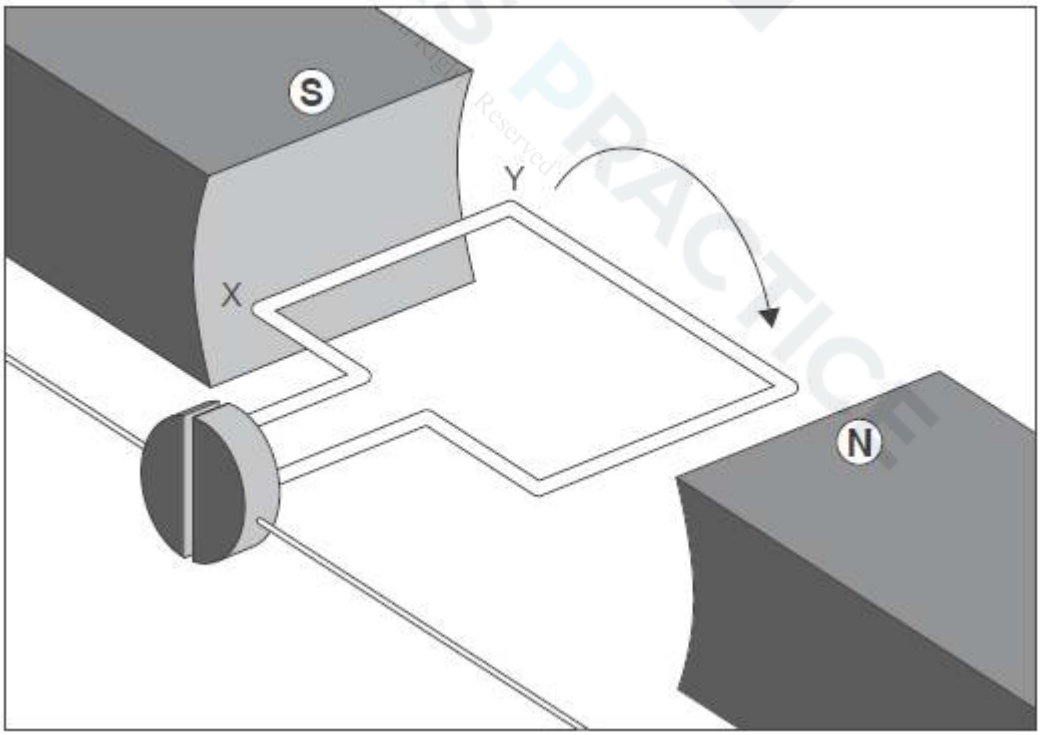
A mass of 2.0 kg travelling at 5.0 m s $^{-1}$ collides with a mass of 4.0 kg travelling at 3.0 m s $^{-1}$. The masses collide at right angles. They join and move together after the collision at θ to the original direction of the 2.0 kg mass.
What is θ ?

A. 34°
B. 37°
C. 50°
D. 56°

[1]

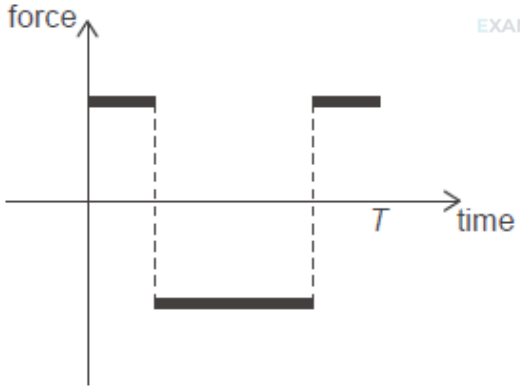
22M.1A.HL.TZ2.19

The coil of a direct current electric motor is turning with a period T. At t = 0 the coil is in the position shown in the diagram. Assume the magnetic field is uniform across the coil.

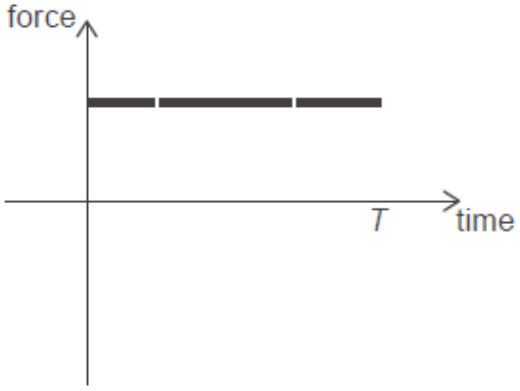


Which graph shows the variation with time of the force exerted on section XY of the coil during one complete turn?

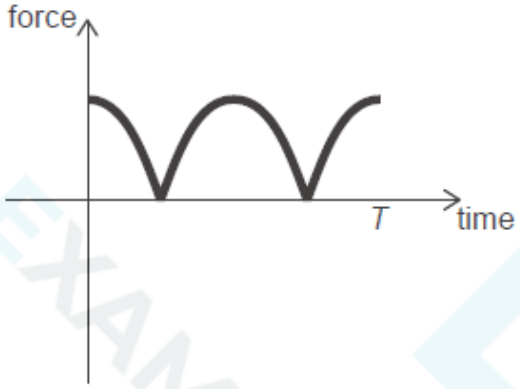
A. force



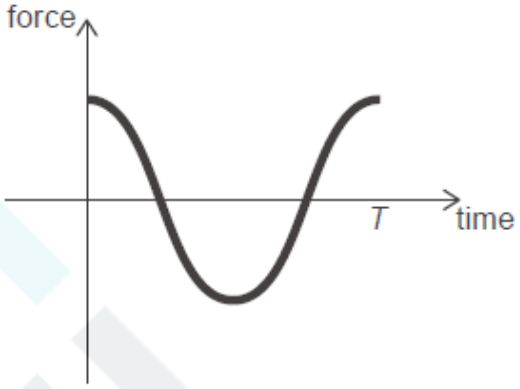
B. force



C. force



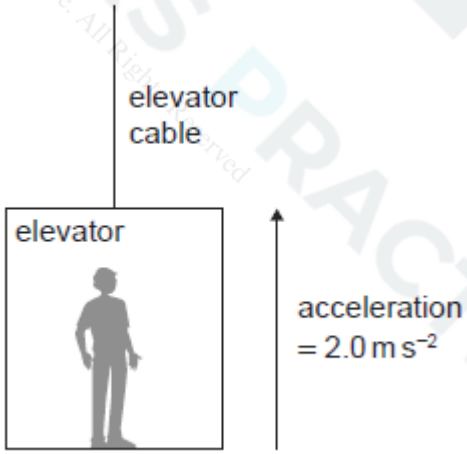
D. force



[1]

SPM.1A.HL.TZ0.5

A person stands in an elevator (lift). The total mass of the person and the elevator is 800 kg. The elevator accelerates upward at 2.0 m s $^{-2}$.



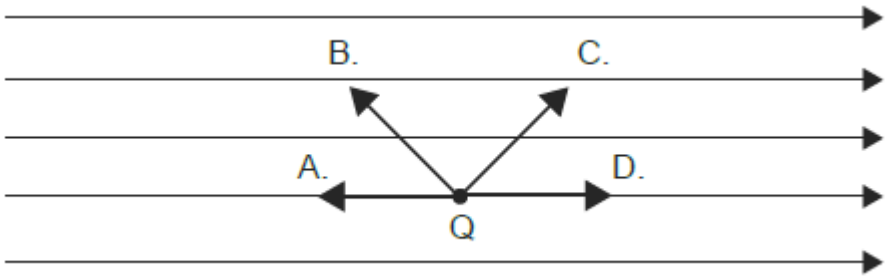
What is the tension in the cable?

A. 1.6 kN
B. 6.4 kN
C. 8.0 kN
D. 9.6 kN

[1]

19M.1A.HL.TZ1.32

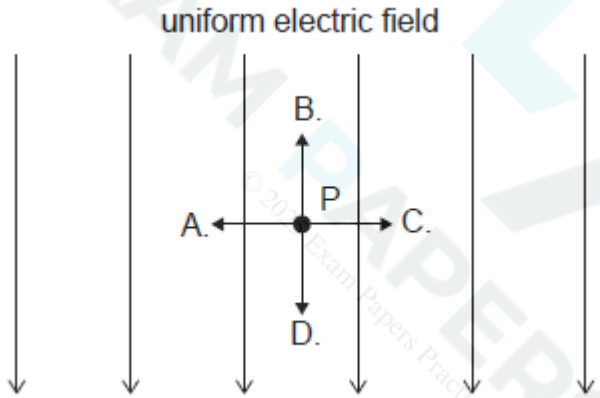
A negative charge Q is to be moved within an electric field E, to equidistant points from its position, as shown.
Which path requires the most work done?



[1]

SPM.1A.HL.TZ0.27

P is a point in a uniform electric field. [1]
What is the direction in which the electric potential increases at P?



19M.1A.HL.TZ1.14

A particle performs simple harmonic motion (shm). What is the phase difference between the displacement and the acceleration of the particle?

A. 0
B. $\frac{\pi}{2}$
C. π
D. $\frac{3\pi}{2}$

[1]

SPM.1A.HL.TZ0.17

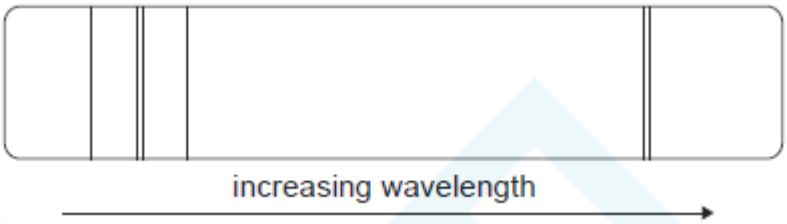
Two containers, X and Y , are filled with an ideal gas at the same pressure.
The volume of X is four times the volume of Y . The temperature of X is 327 °C and the temperature of Y is 27 °C.
What is $\frac{\text{amount of substance in X}}{\text{amount of substance in Y}}$?

A. $\frac{1}{8}$
B. $\frac{1}{2}$
C. 2
D. 8

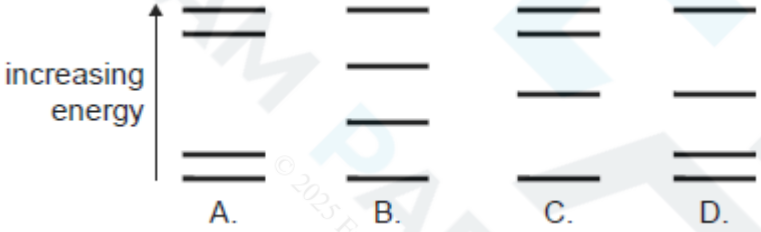
[1]

SPM.1A.HL.TZ0.34

The diagram shows the emission spectrum of an atom. [1]



Which of the following atomic energy level models can produce this spectrum?



EXE.1A.HL.TZ0.26

What is the escape speed from the surface of a planet of radius r that has an acceleration of gravity g at its surface?

A. $\sqrt{\frac{g}{r}}$
B. $\sqrt{gr}$
C. $\sqrt{\frac{2g}{r}}$
D. $\sqrt{2gr}$

[1]

19M.1A.HL.TZ2.18

A particle with a charge *ne* is accelerated through a potential difference *V* . [1]
What is the magnitude of the work done on the particle?
A. eV
B. neV
C. $\frac{nV}{e}$
D. $\frac{eV}{n}$

EXE.1A.HL.TZ0.29

An atom of hydrogen (${}^{1}_{1}\mathrm{H}$) and an atom of helium (${}^{4}_{2}\mathrm{He}$) are moving with the same kinetic energy.
The de Broglie wavelength of the hydrogen atom is λ_{H} and the de Broglie wavelength of the helium atom is λ_{He} .
What is $\frac{\lambda_{\mathrm{H}}}{\lambda_{\mathrm{He}}}$?

A. $\frac{1}{2}$
B. 1
C. 2
D. 4

[1]

23M.1A.HL.TZ1.30

Two isolated point masses, P of mass *m* and Q of mass 2 *m* , are separated by a distance 3 *d* . X is a point a distance *d* from P and 2 *d* from Q.

What is the net gravitational field strength at X and the net gravitational potential at X?

	Net gravitational field strength at X	Net gravitational potential at X
A.	$\frac{Gm}{d^2}$	0
B.	$\frac{Gm}{d^2}$	$-\frac{Gm}{d}$
C.	$\frac{Gm}{2d^2}$	0
D.	$\frac{Gm}{2d^2}$	$-\frac{2Gm}{d}$

[1]

EXE.1A.HL.TZ0.28

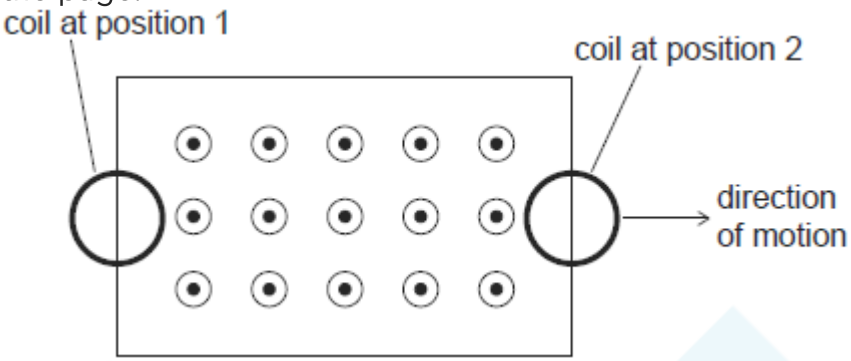
A proton and an alpha particle are accelerated by the same electric potential difference. The kinetic energy of the proton is *E* and its de Broglie wavelength is *λ* . What is the kinetic energy and the de Broglie wavelength of the alpha particle?

	Kinetic energy of alpha particle	De Broglie wavelength of alpha particle
A.	*E*	less than *λ*
B.	*E*	greater than *λ*
C.	greater than *E*	less than *λ*
D.	greater than *E*	greater than *λ*

[1]

19M.1A.HL.TZ2.29

A circular coil of wire moves through a region of uniform magnetic field directed out of the page.



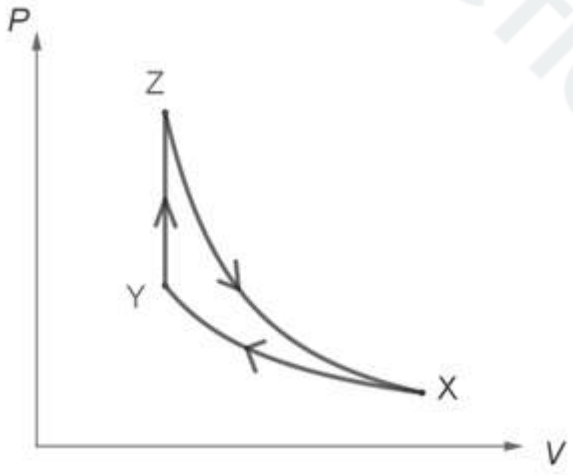
What is the direction of the induced conventional current in the coil for the marked positions?

	Position 1	Position 2
A.	clockwise	clockwise
B.	counterclockwise	clockwise
C.	clockwise	counterclockwise
D.	counterclockwise	counterclockwise

[1]

EXE.1A.HL.TZ0.17

A thermodynamic cycle consisting of an adiabatic, isovolumetric and isothermal processes is shown.



Which of the following correctly identifies the processes of the cycle?

Adiabatic **Isovolumetric** **Isothermal**

A.	X→Y	Y→Z	Z→X
B.	Z→X	X→Y	Y→Z
C.	Z→X	Y→Z	X→Y
D.	Y→Z	Z→X	X→Y

[1]

23M.1A.HL.TZ1.31

A negatively charged particle is stationary halfway between two horizontal charged plates. The plates are separated by a distance *d* with potential difference *V* between them.

What is the magnitude of the electric field and direction of the electric field at the position of the particle?

	Magnitude of electric field	Direction of electric field
A.	$\frac{2V}{d}$	up
B.	$\frac{V}{d}$	up
C.	$\frac{2V}{d}$	down
D.	$\frac{V}{d}$	down

[1]

21N.1A.HL.TZ0.32

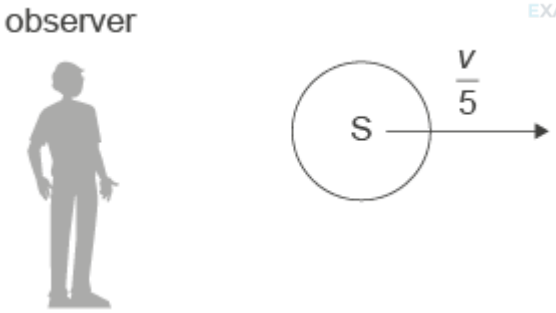
A satellite of mass m orbits a planet of mass M in a circular orbit of radius r. What is the work that must be done on the satellite to increase its orbital radius to $2r$?

A. $\frac{GMm}{r}$
B. $\frac{GMm}{2r}$
C. $\frac{GMm}{4r}$
D. $\frac{GMm}{8r}$

[1]

23M.1A.HL.TZ1.29

Source S produces sound waves of speed *v* and frequency f. S moves with constant velocity $\frac{v}{5}$ away from a stationary observer.



What is the frequency measured by the observer?

A. $\frac{4}{5}$f
B. $\frac{5}{6}$f
C. $\frac{6}{5}$f
D. $\frac{5}{4}$f

[1]

SPM.1A.HL.TZ0.10

The internal energy of a real gas is

A. zero.
B. equal to the intermolecular potential energy of the particles.
C. equal to the total kinetic energy of the particles.
D. equal to the sum of the intermolecular potential energy and the total kinetic energy of the particles.

[1]

23M.1A.HL.TZ1.38

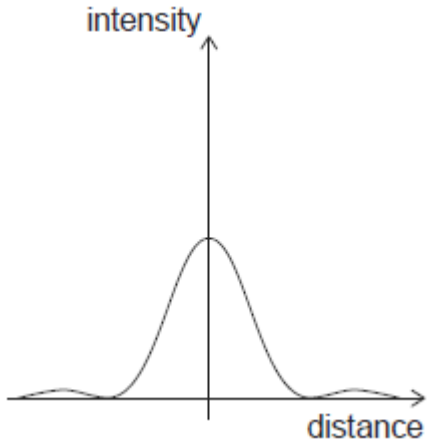
In the Bohr model for hydrogen, the radius of the electron orbit in the n = 2 state is four times that of the radius in the n = 1 state.
What is $\frac{\text{speed of the electron in the n = 2 state}}{\text{speed of the electron in the n = 1 state}}$?

A. $\frac{1}{4}$
B. $\frac{1}{2}$
C. 2
D. 4

[1]

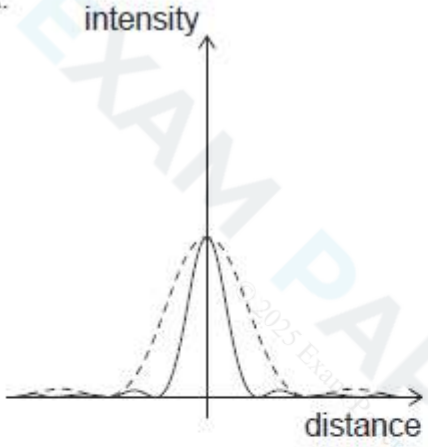
SPM.1A.HL.TZ0.22

Light from a monochromatic source is incident on a single slit and the resulting diffraction pattern is viewed on a screen. The graph shows the variation of intensity with distance on the screen.

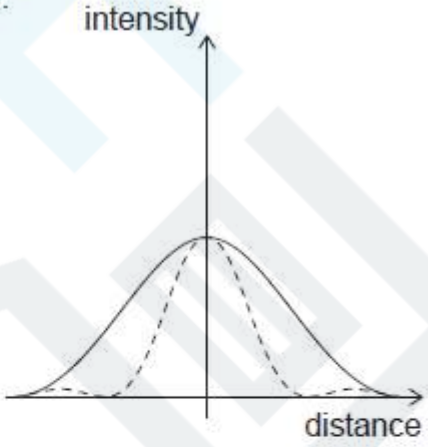


The intensity of the source remains the same. The width of the slit is increased. Which graph correctly shows the variation of intensity after the change? The original curve is shown with a dashed line.

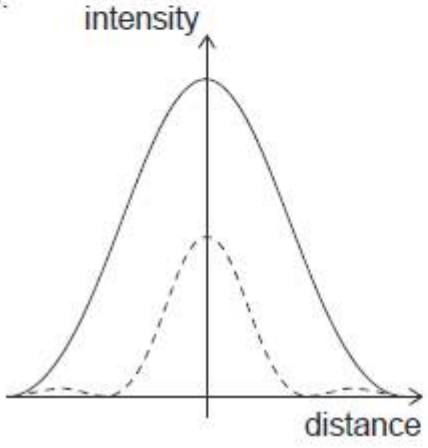
A.



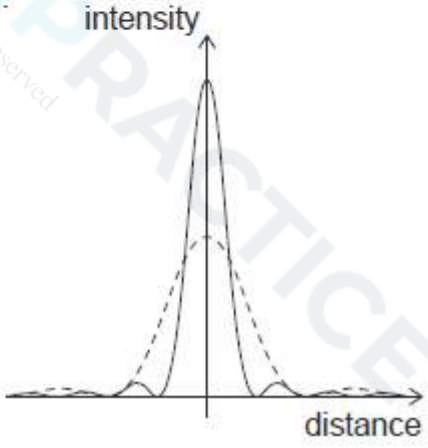
B.



C.



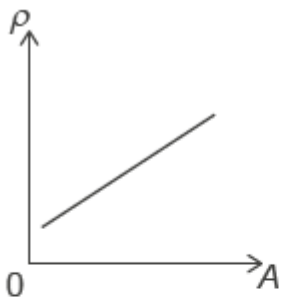
D.

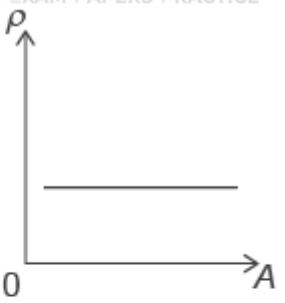


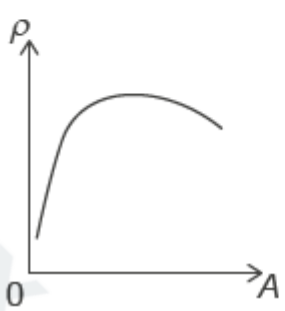
[1]

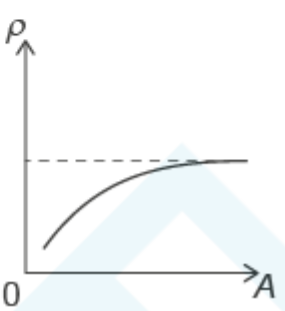
23M.1A.HL.TZ2.38

What is the variation of nuclear density ρ with nucleon number A? [1]

A. 

B. 

C. 

D. 

19N.1A.HL.TZ0.40

A pure sample of a radioactive nuclide contains N_0 atoms at time $t = 0$. At time t, there are N atoms of the nuclide remaining in the sample. The half-life of the nuclide is $t_{\frac{1}{2}}$.

What is the decay rate of this sample proportional to?

A. N

B. $N_0 - N$

C. t

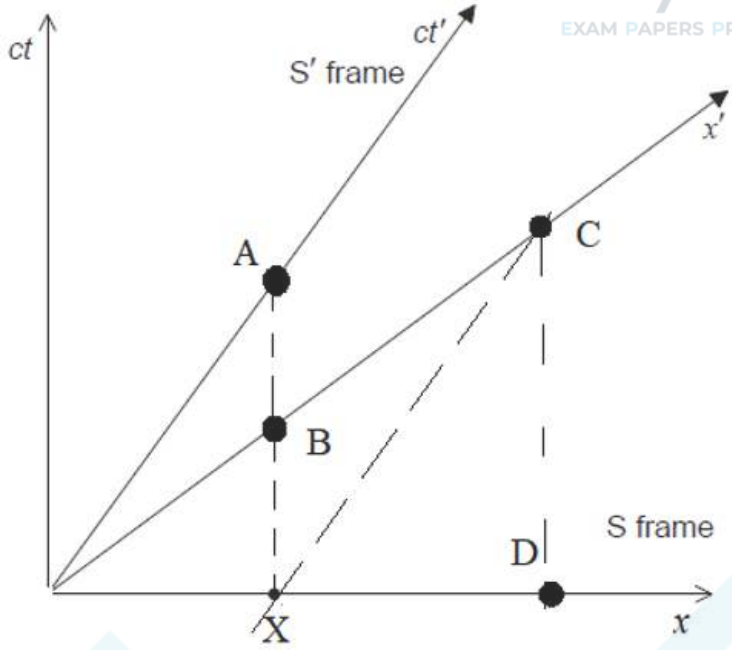
D. $t_{\frac{1}{2}}$

[1]

EXE.1A.HL.TZ0.15

The spacetime diagram shows an inertial reference frame S and a second inertial frame S' that is moving relative to S.

The origins of the frames coincide when the clocks in both frames show zero.



Event X is shown for the S reference frame.
Which event occurs at the same position in the S′ reference frame as X ?

[1]

SPM.1A.HL.TZ0.18

An electromagnetic wave has a wavelength that is about the size of the diameter of an atom.
What region of the electromagnetic spectrum does the wave belong to?

A. Infrared
B. Visible light
C. Ultraviolet
D. X-ray

[1]

22N.1A.HL.TZ0.39

Which emission shows a continuous energy spectrum? [1]

A. Photons during energy transitions between atomic energy states
B. Gamma photons from the nuclei of radioactive isotopes
C. Beta particles from the nuclei of radioactive isotopes
D. Alpha particles from the nuclei of radioactive isotopes

21M.1A.HL.TZ1.30

A particle with charge -2.5×10^{-6} C moves from point X to point Y due to a uniform electrostatic field. The diagram shows some equipotential lines of the field.

What is correct about the motion of the particle from X to Y and the magnitude of the work done by the field on the particle?

	Motion of the particle from X to Y	Magnitude of the work done by the field on the particle
A.	uniform linear	0 J
B.	uniform linear	1 J
C.	uniformly accelerated	0 J
D.	uniformly accelerated	1 J

[1]

EXE.1A.HL.TZ0.5

What are the fundamental SI units for angular impulse? [1]

A. $kg\ m\ s^{-1}$
B. $kg\ m^{2}\ s^{-1}$
C. $kg\ m\ s^{-2}$
D. $kg\ m^{2}\ s^{-2}$

EXE.1A.HL.TZ0.23

Three statements about the Carnot cycle are:

I. The Carnot cycle is reversible.
II. The net entropy change of the surroundings of the gas over one cycle is positive.
III. Heat transfer takes place in only two stages of the cycle

Which statements are correct?

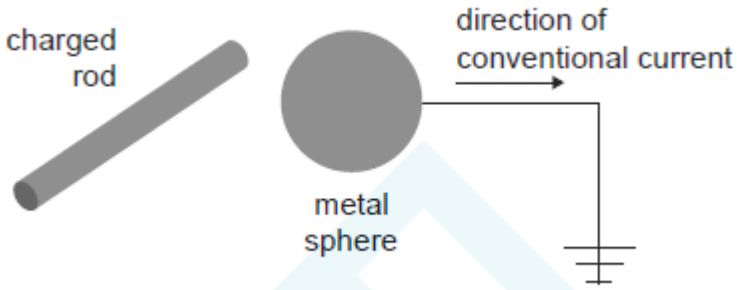
A. I and II
B. I and III

C. II and III
D. I, II and III

[1]

SPM.1A.HL.TZ0.31

A charged rod is brought near an initially neutral metal sphere without touching it.
When the sphere is grounded (earthed), there is an electric current for a short time from the sphere to the ground.



The ground connection is then removed.
What are the charge on the rod and the charge induced on the sphere when the connection is removed?

	Charge on the rod	Charge induced on the sphere
A.	negative	negative
B.	negative	positive
C.	positive	negative
D.	positive	positive

[1]

EXE.1A.HL.TZ0.24

For a thermodynamic process, the entropy of the universe [1]

A. always increases during the process
B. depends only on energy transferred during the process
C. is zero during the process
D. never decreases during the process

SPM.1A.HL.TZ0.28

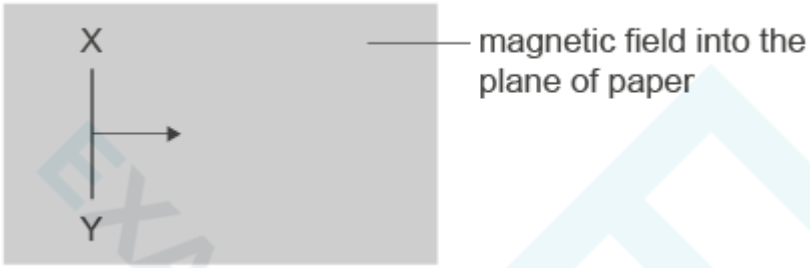
Planets X and Y orbit the same star.
The average distance between planet X and the star is five times greater than the average distance between planet Y and the star.
What is $\frac{\text{orbital period of planet X}}{\text{orbital period of planet Y}}$?

A. $\sqrt[3]{5}$
B. $\sqrt{5}$
C. $\sqrt[3]{5^2}$
D. $\sqrt{5^3}$

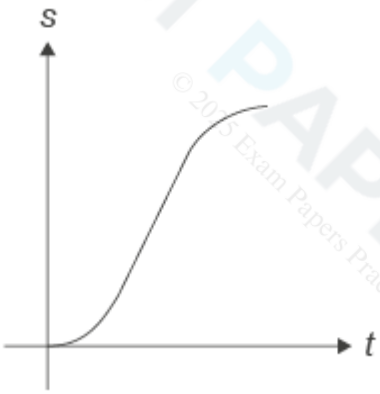
[1]

23M.1A.HL.TZ1.34

Wire XY moves perpendicular to a magnetic field in the direction shown.

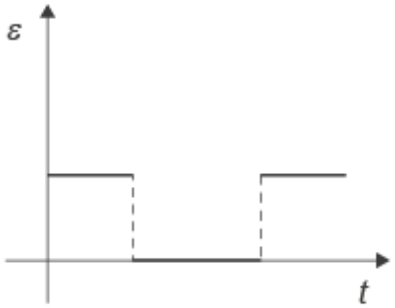


The graph shows the variation with time of the displacement of XY.

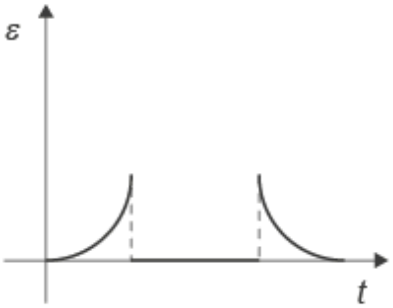


What is the graph of the electromotive force (emf) ε induced across XY?

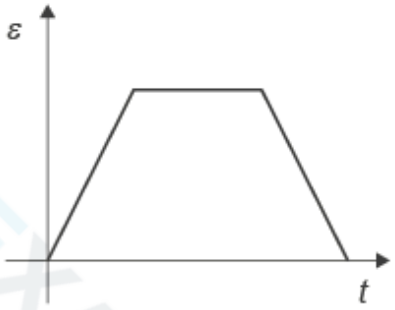
A.



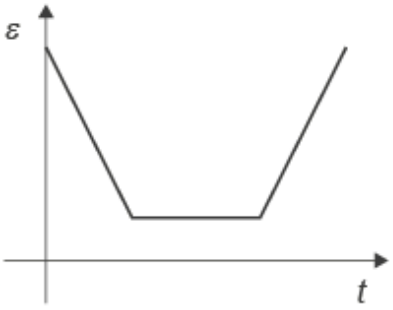
B.



C.



D.



[1]

20N.1A.HL.TZ0.37

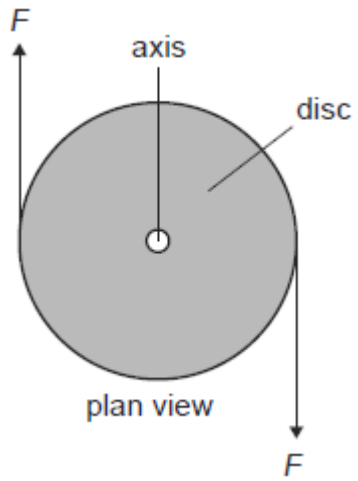
Monochromatic light is incident on a metal surface and electrons are released. The intensity of the incident light is increased. What changes, if any, occur to the rate of emission of electrons and to the kinetic energy of the emitted electrons?

	Rate of emission of electrons	Kinetic energy of the emitted electrons
A.	increase	increase
B.	decrease	no change
C.	decrease	increase
D.	increase	no change

[1]

SPM.1A.HL.TZ0.4

A disc of mass M and radius R is on a horizontal frictionless table. Two equal and opposite forces, each of magnitude F , act on the disc. The moment of inertia of the disc about its axis is $\frac{1}{2}MR^2$.



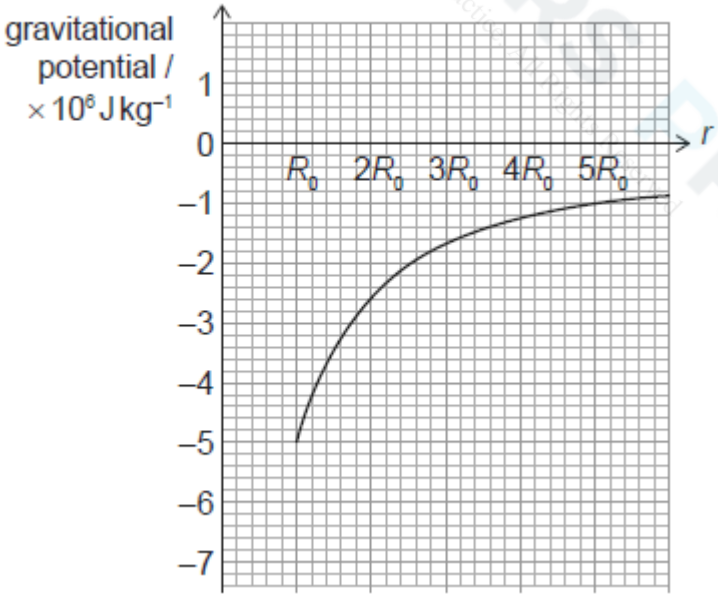
What is the angular acceleration of the disc?

A. 0
B. $\frac{F}{MR}$
C. $\frac{2F}{MR}$
D. $\frac{4F}{MR}$

[1]

SPM.1A.HL.TZ0.30

A spherical planet has a radius R_0.
The graph shows the variation of the gravitational potential due to the planet with distance r from the centre of the planet.



What is the escape speed from the surface of the planet?

A. $1.6 \times 10^3\ m\ s^{-1}$
B. $2.2 \times 10^3\ m\ s^{-1}$
C. $3.2 \times 10^3\ m\ s^{-1}$
D. $4.5 \times 10^3\ m\ s^{-1}$

[1]

21M.1A.HL.TZ2.29

Monochromatic light of wavelength λ passes through a single-slit of width b and produces a diffraction pattern on a screen. Which combination of changes to b and λ will cause the greatest decrease in the width of the central maximum?

	Slit width	Wavelength of light
A.	$\frac{1}{2}b$	$\frac{1}{2}\lambda$
B.	$\frac{1}{2}b$	2λ
C.	$2b$	$\frac{1}{2}\lambda$
D.	$2b$	2λ

[1]

23M.1A.HL.TZ2.37

Light of frequency f is incident on a metallic surface of work function W. Photoelectrons with a maximum kinetic energy E_{max} are emitted. The frequency of the incident light is changed to 2 f.
What is true about the maximum kinetic energy and the work function?

	Maximum kinetic energy	Work function
A.	less than $2E_{max}$	unchanged
B.	less than $2E_{max}$	greater than W
C.	greater than $2E_{max}$	unchanged
D.	greater than $2E_{max}$	greater than W

[1]

21M.1A.HL.TZ1.33

A conducting ring encloses an area of 2.0 cm^2 and is perpendicular to a magnetic field of strength 5.0 mT. The direction of the magnetic field is reversed in a time 4.0 s. What is the average emf induced in the ring?
A. 0
B. 0.25 μV
C. 0.40 μV
D. 0.50 μV

[1]

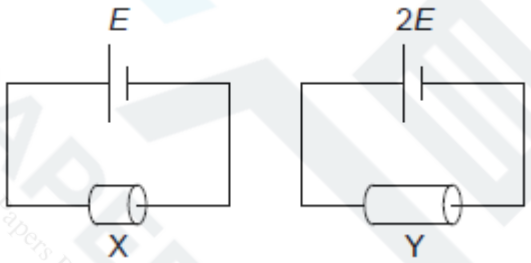
SPM.1A.HL.TZ0.3

A net force of 8.0 N accelerates a 4.0 kg body from rest to a speed of 5.0 m s^{-1}. [1]
What is the work done by the force?

A. 50 J
B. 40 J
C. 32 J
D. 20 J

SPM.1A.HL.TZ0.16

Conductor X is connected to a cell of emf E. A power of 16 W is dissipated in X.
Conductor Y is made from the same material with the same diameter as X but is twice as long. A cell of emf 2 E is connected to Y.
Both cells have negligible internal resistance.
What power is dissipated in Y?



A. 8.0 W
B. 16 W
C. 32 W
D. 64 W

[1]

21M.1A.HL.TZ1.32

A planet has radius R. The escape speed from the surface of the planet is v. At what distance from the surface of the planet is the orbital speed 0.5 v?
A. 0.5 R
B. R
C. 2 R
D. 4 R

[1]

SPM.1A.HL.TZ0.38

The energy of the *n* th level of hydrogen is given by $-\frac{E_0}{n^2}$. What is the frequency of the photon emitted in the transition from $n = 4$ to $n = 2$?

A. $\frac{1}{16} \times \frac{E_0}{h}$
B. $\frac{3}{16} \times \frac{E_0}{h}$
C. $\frac{1}{4} \times \frac{E_0}{h}$
D. $\frac{3}{4} \times \frac{E_0}{h}$

[1]

SPM.1A.HL.TZ0.12

A working refrigerator with the door open is placed in a sealed room. [1]
The entropy of the room

A. is zero.
B. decreases.
C. remains unchanged.
D. increases.

EXE.1A.HL.TZ0.21

An energy of 200 J is transferred isothermally to an ideal gas. The temperature of the gas is 27 °C.
The entropy change of the gas is

A. $0.67\ \text{J K}^{-1}$
B. $0.14\ \text{J K}^{-1}$
C. $1.5\ \text{J K}^{-1}$
D. $7.4\ \text{J K}^{-1}$

[1]

SPM.1A.HL.TZ0.9

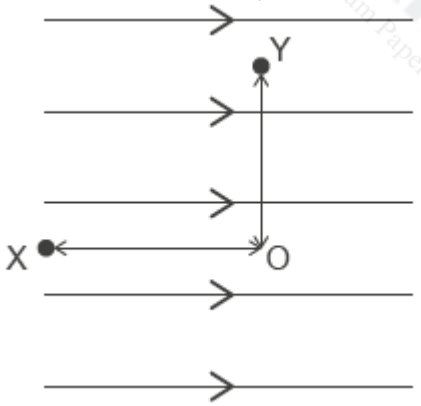
A spacecraft, moving with speed *v* relative to Earth, passes Earth on its way to a planet.
As the spacecraft passes Earth, clocks on Earth and in the spacecraft show zero.
The planet is a distance *D* from Earth, according to an observer on Earth.
What are the readings on the Earth clock and on the spacecraft clock when the spacecraft arrives at the planet?

	Earth clock reading	Spacecraft clock reading
A.	$\frac{D}{v}$	$\frac{D}{v}\sqrt{1-\frac{v^2}{c^2}}$
B.	$\frac{D}{v}$	$\frac{D}{v\sqrt{1-\frac{v^2}{c^2}}}$
C.	$\frac{D}{v\sqrt{1-\frac{v^2}{c^2}}}$	$\frac{D}{v}$
D.	$\frac{D}{v}\sqrt{1-\frac{v^2}{c^2}}$	$\frac{D}{v}$

[1]

21M.1A.HL.TZ2.31

The points X and Y are in a uniform electric field of strength E . The distance OX is x and the distance OY is y .



What is the magnitude of the change in electric potential between X and Y?

A. Ex

B. Ey

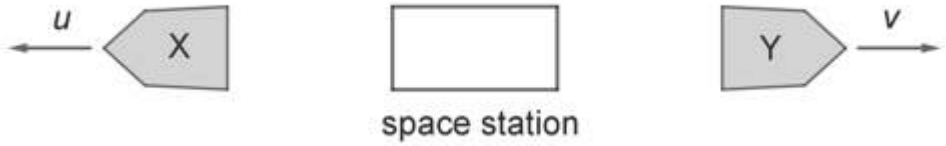
C. $E(x + y)$

D. $E\sqrt{x^2 + y^2}$

[1]

EXE.1A.HL.TZ0.13

Two spaceships, X and Y move in opposite directions away from a space station. The speeds of the spaceships relative to the space station are u and v .



What is the speed of Y in the reference frame of X?

A. $\frac{u - v}{1 - \frac{uv}{c^2}}$

B. $\frac{u - v}{1 + \frac{uv}{c^2}}$

C. $\frac{u + v}{1 - \frac{uv}{c^2}}$

D. $\frac{u + v}{1 + \frac{uv}{c^2}}$

[1]

SPM.1A.HL.TZ0.6

An object is released from rest in a vacuum at a height H above the Earth's surface. [1]
As the object falls it passes a point at a height of 0.75 H above the surface.
What is $\frac{\text{kinetic energy of the object at a height of } 0.75H}{\text{gravitational potential energy of the object at a height of } H}$?

A. $\frac{1}{16}$

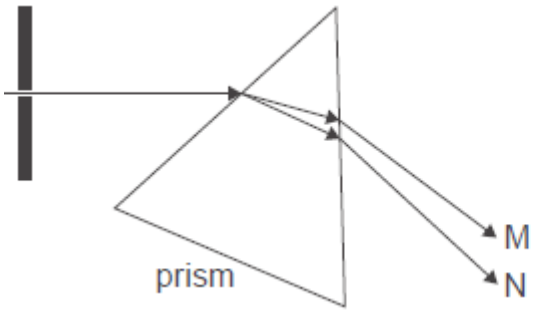
B. $\frac{1}{4}$

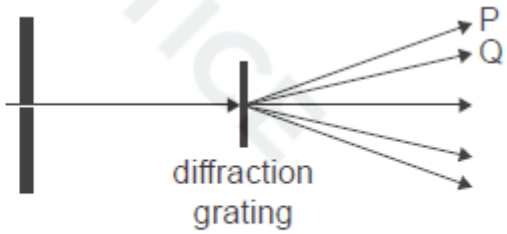
C. $\frac{9}{16}$

D. $\frac{3}{4}$

22M.1A.HL.TZ2.30

In two different experiments, white light is passed through a single slit and then is either refracted through a prism or diffracted with a diffraction grating. The prism produces a band of colours from M to N. The diffraction grating produces a first order spectrum P to Q.





What are the colours observed at M and P?

	M	P
A.	red	red
B.	red	violet
C.	violet	red
D.	violet	violet

[1]

SPM.1A.HL.TZ0.39

Monochromatic light of frequency f_1 is incident on the surface of a metal. The stopping voltage for this light is V_1 . When the frequency of the radiation is changed to f_2 , the stopping voltage is V_2 .
What is the quantity $\frac{V_2 - V_1}{f_2 - f_1}$ equal to?

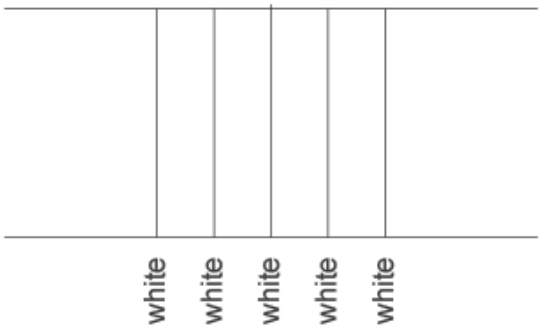
A. h
B. $\frac{h}{e}$
C. $\frac{h}{c}$
D. $\frac{hc}{e}$

[1]

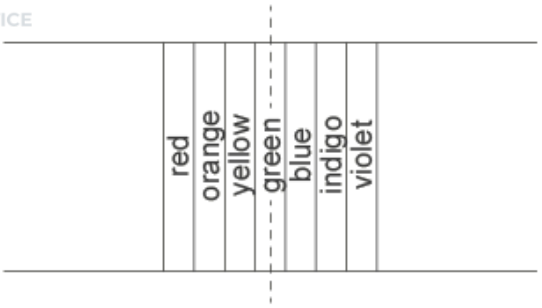
23M.1A.HL.TZ1.28

What is the pattern observed when white light passes through a diffraction grating?

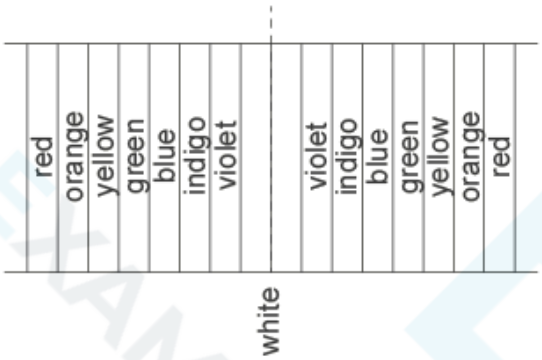
A.



B.



C.

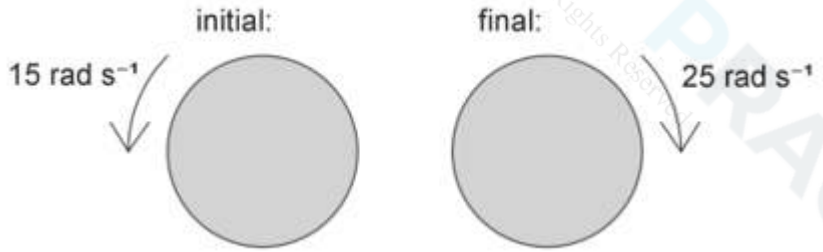


D.

[1]

EXE.1A.HL.TZ0.6

A flywheel of moment of inertia 0.50 kg m ^{2} rotates anti-clockwise with an initial angular velocity of 15 rad s $^{-1}$. A torque is applied to the flywheel and its angular velocity changes to 25 rad s $^{-1}$, rotating clockwise.



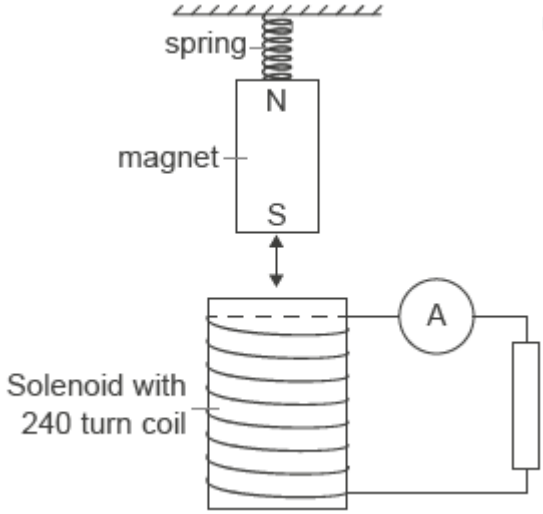
What is the angular impulse delivered to the flywheel?

A. 5.0 N m s
B. 10 N m s
C. 20 N m s
D. 40 N m s

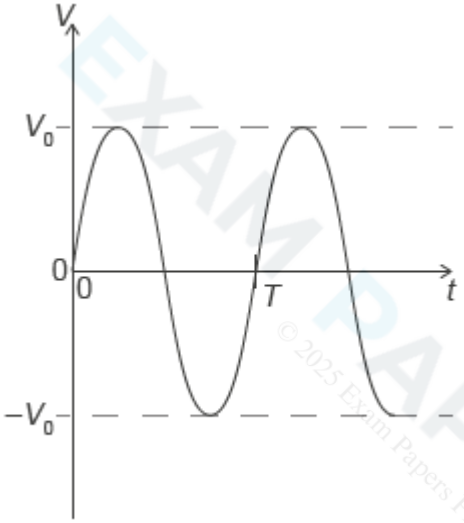
[1]

21M.1A.HL.TZ2.35

A magnet connected to a spring oscillates above a solenoid with a 240 turn coil as shown.

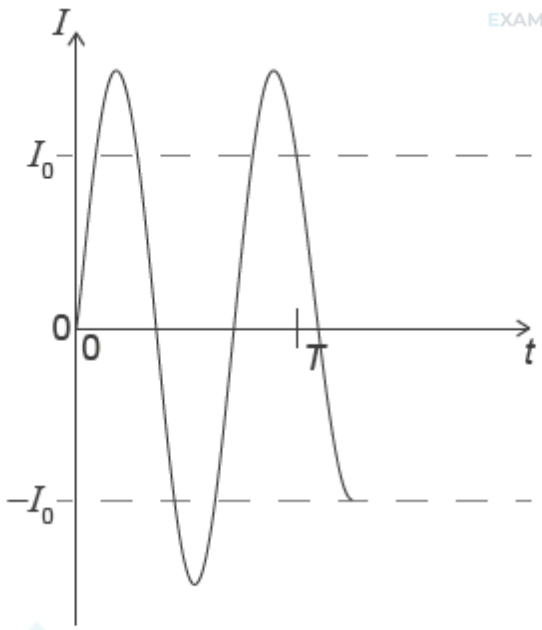


The graph below shows the variation with time t of the emf across the solenoid with the period, T , of the system shown.

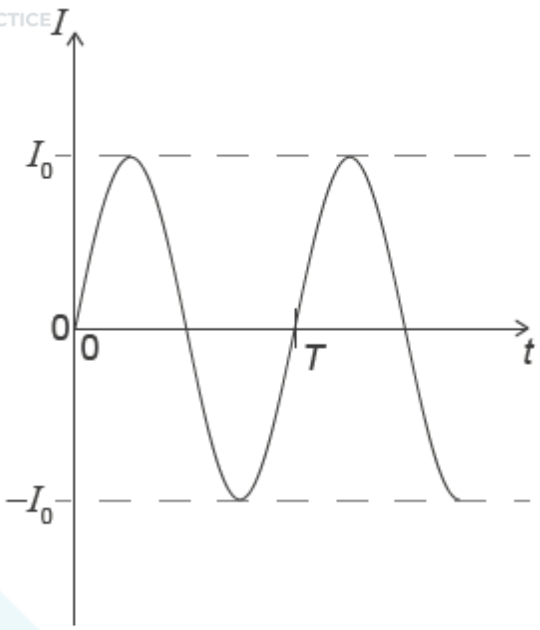


The spring is replaced with one that allows the magnet to oscillate with a higher frequency. Which graph shows the new variation with time t of the current I in the resistor for this new set-up?

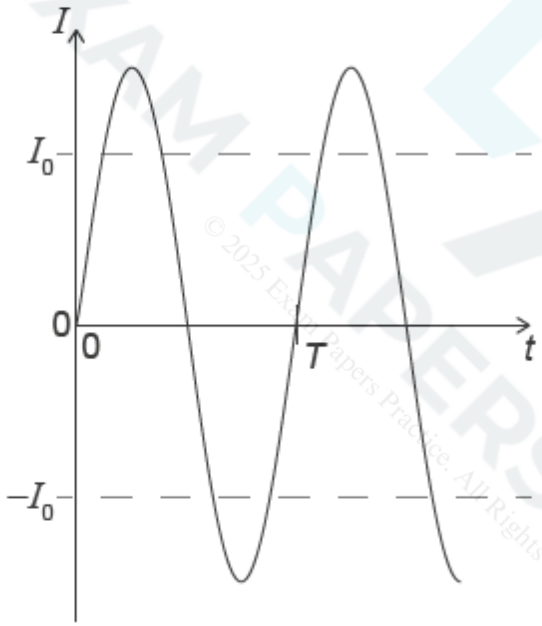
A.



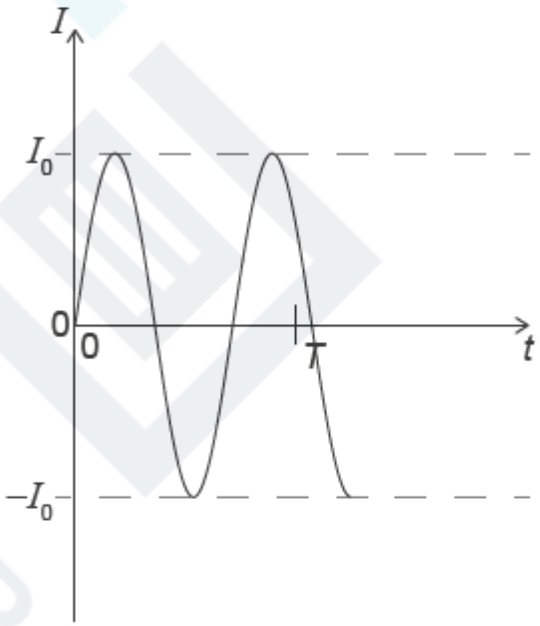
B.



C.



D.



[1]

19M.1A.HL.TZ1.16

Two parallel plates are a distance apart with a potential difference between them. A point charge moves from the negatively charged plate to the positively charged plate. The charge gains kinetic energy W. The distance between the plates is doubled and the potential difference between them is halved. What is the kinetic energy gained by an identical charge moving between these plates?

A. $\frac{W}{2}$

B. W

C. $2\ W$

D. $4\ W$

[1]

EXE.1A.HL.TZ0.10

An object with a moment of inertia of 12 kg m ^{2} is rotating about its axis of rotation with an angular speed of 15 rad s $^{-1}$. A torque is applied to the object so that its angular speed increases to 50 rad s $^{-1}$.
What angular impulse acted on the object?

A. 420 kg m s $^{-1}$
B. 780 kg m s $^{-1}$
C. 390 kg m s $^{-1}$
D. 210 kg m s $^{-1}$

[1]

EXE.1A.HL.TZ0.18

An ideal gas expands isothermally. The work done by the gas is 100 J. What is the change in the internal energy of the gas?

A. −100 J
B. 0
C. +50 J
D. +100 J

[1]

23M.1A.HL.TZ2.28

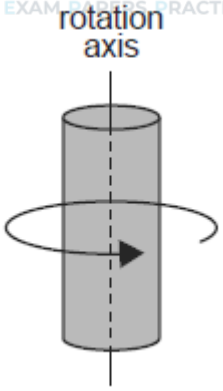
A mass oscillating in simple harmonic motion on the end of a spring has an amplitude x_0 and a total energy E_T. The mass on the spring is doubled and made to oscillate with the same amplitude x_0.
What is the total energy of the oscillating system after the change?

A. E_T
B. $\sqrt{2}\,E_T$
C. $2\,E_T$
D. $4\,E_T$

[1]

SPM.1A.HL.TZ0.7

A cylinder of mass M and radius R rotates at constant angular speed ω about an axis through its centre. The rotational kinetic energy of the cylinder is K.
The moment of inertia of the cylinder is $\frac{1}{2}MR^2$.



A second cylinder has mass $2M$, radius $2R$ and rotates with angular speed 2ω .
What is the rotational kinetic energy of the second cylinder?

A. $8K$
B. $16K$
C. $32K$
D. $64K$

[1]

SPM.1A.HL.TZ0.35

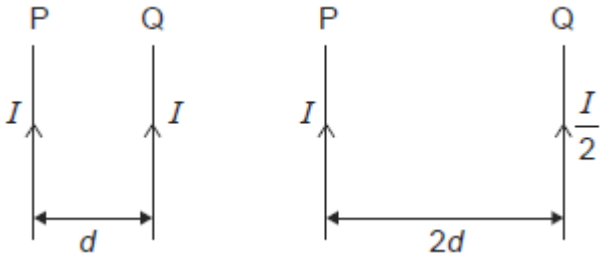
A photon of wavelength λ scatters off an electron at rest. The scattered photon has wavelength λ' .
What is the fraction of the incident photon energy that gets transferred to the electron?

A. $\frac{\lambda}{\lambda'}$
B. $\frac{\lambda'}{\lambda}$
C. $\frac{\lambda' - \lambda}{\lambda'}$
D. $\frac{\lambda' - \lambda}{\lambda}$

[1]

SPM.1A.HL.TZ0.26

Two long parallel wires P and Q are a distance d apart. They each carry a current.
A magnetic force per unit length F acts on P due to Q.
The distance between the wires is increased to $2d$ and the current in Q is decreased to $\frac{I}{2}$.



What is the magnetic force per unit length that acts on P due to Q after the changes?

A. $\frac{F}{8}$
B. $\frac{F}{4}$
C. $\frac{F}{2}$
D. F

[1]

22M.1A.HL.TZ1.30

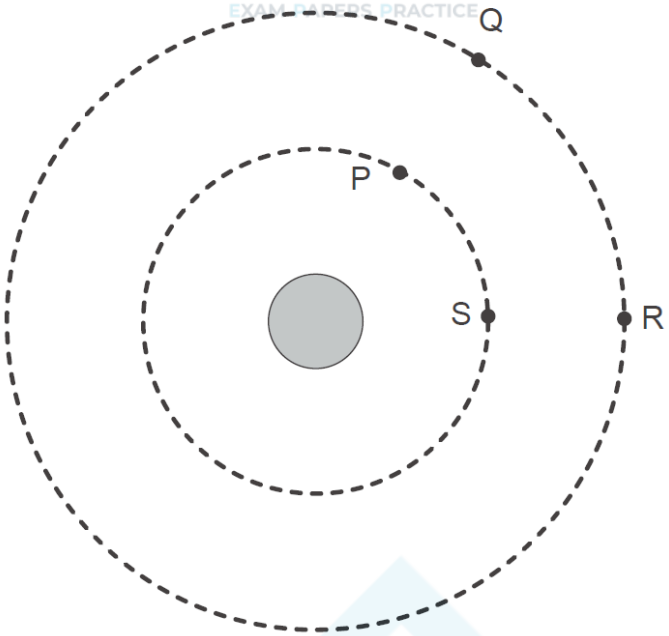
Light of wavelength λ is diffracted after passing through a very narrow single slit of width x . The intensity of the central maximum of the diffracted light is I_0 . The slit width is doubled.
What is the intensity of central maximum and the angular position of the first minimum?

	Intensity	Angular position of first minimum
A.	$2I_0$	$\frac{\lambda}{x}$
B.	$2I_0$	$\frac{\lambda}{2x}$
C.	$4I_0$	$\frac{\lambda}{x}$
D.	$4I_0$	$\frac{\lambda}{2x}$

[1]

20N.1A.HL.TZ0.31

P and S are two points on a gravitational equipotential surface around a planet. Q and R are two points on a different gravitational equipotential surface at a greater distance from the planet.



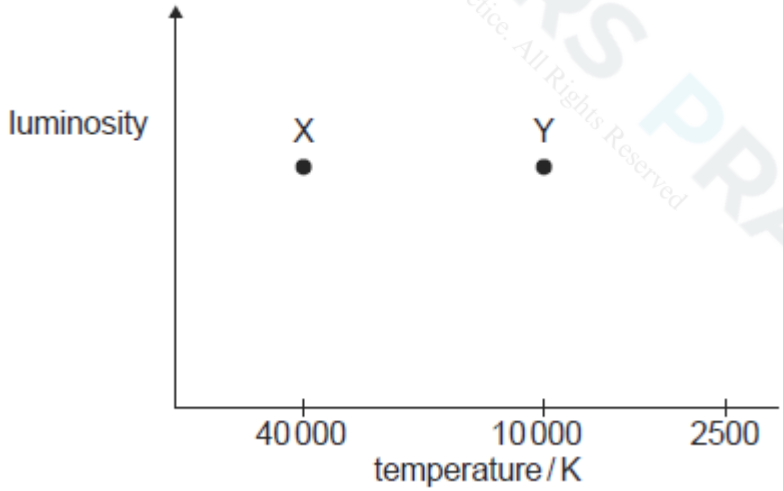
The greatest work done by the gravitational force is when moving a mass from

A. P to S.
B. Q to R.
C. R to P.
D. S to R.

[1]

SPM.1A.HL.TZ0.37

The Hertzsprung–Russell diagram shows two stars, X and Y . [1]



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

A. $\frac{1}{16}$
B. $\frac{1}{4}$
C. 4
D. 16

22M.1A.HL.TZ1.25

Three statements about radioactive decay are: [1]

I. The rate of decay is exponential.
II. It is unaffected by temperature and pressure.
III. The decay of individual nuclei cannot be predicted.

Which statements are correct?

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

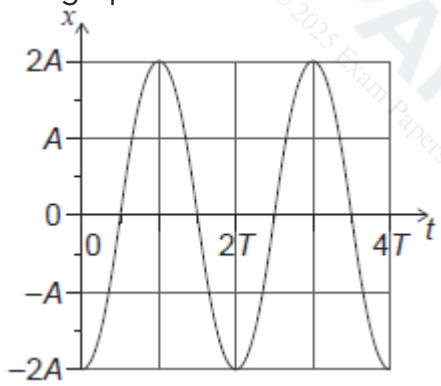
21M.1A.HL.TZ1.40

What was a reason to postulate the existence of neutrinos? [1]

A. Nuclear energy levels had a continuous spectrum.
B. The photon emission spectrum only contained specific wavelengths.
C. Some particles were indistinguishable from their antiparticle.
D. The energy of emitted beta particles had a continuous spectrum.

19M.1A.HL.TZ2.16

An object at the end of a spring oscillates vertically with simple harmonic motion (shm). The graph shows the variation with time t of the displacement x of the object.



What is the velocity of the object?

A. $-\frac{2\pi A}{T}\sin\left(\frac{\pi t}{T}\right)$
B. $\frac{2\pi A}{T}\sin\left(\frac{\pi t}{T}\right)$
C. $-\frac{2\pi A}{T}\cos\left(\frac{\pi t}{T}\right)$
D. $\frac{2\pi A}{T}\cos\left(\frac{\pi t}{T}\right)$

[1]

SPM.1A.HL.TZ0.36

Three statements about a nuclear fission reactor are: [1]

I. The heat exchanger transfers energy from the fuel rods to the moderator.
II. The control rods must be good absorbers of neutrons.
III. The moderator must slow neutrons down.

Which statements about the reactor are correct?

A. I and II only

B. I and III only
C. II and III only
D. I, II and III

EXE.1A.HL.TZ0.25

A space probe moves in a circular orbit around Earth. The kinetic energy of the probe is E.
The probe will reach the escape speed when its **kinetic** energy is increased at least to:

A. $\sqrt{2}E$
B. $2E$
C. $2\sqrt{2}E$
D. $4E$

[1]

19N.1A.HL.TZ0.28

Light of wavelength λ is normally incident on a diffraction grating of spacing 3λ. What is the angle between the two second-order maxima?
A. $\sin^{-1}\frac{2}{3}$
B. $\sin^{-1}\frac{4}{3}$
C. $2\sin^{-1}\frac{2}{3}$
D. >90° so no second orders appear

[1]

EXE.1A.HL.TZ0.19

A thermodynamic process taking place in an isolated system is irreversible when the final state of the system has a:

A. greater number of microstates than the initial state
B. smaller number of microstates than the initial state
C. greater internal energy than the initial state
D. smaller internal energy than the initial state

[1]

22N.1A.HL.TZ0.32

Two satellites are in circular orbits around the Earth. Both satellites have the same mass and satellite X is closer to Earth than satellite Y.
What is correct for the orbital periods of X and Y and the total energies of X and Y?

	Orbital periods	Total energies
A.	X greater than Y	X greater than Y
B.	X greater than Y	Y greater than X
C.	Y greater than X	X greater than Y
D.	Y greater than X	Y greater than X

[1]

22M.1A.HL.TZ1.39

What is evidence for wave–particle duality? [1]
A. Line spectra of elements
B. Electron-diffraction experiments
C. Rutherford alpha-scattering experiments
D. Gamma-ray spectra

EXE.1A.HL.TZ0.22

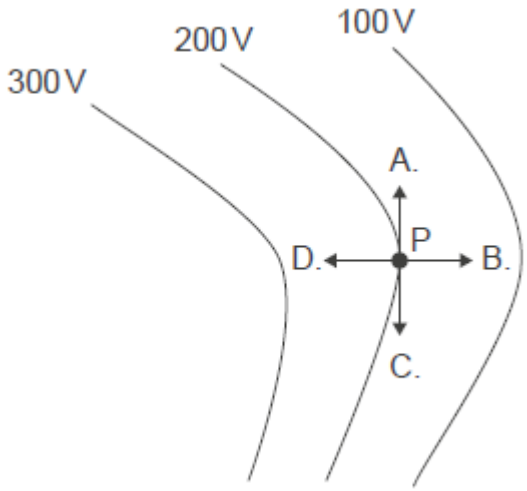
Energy is transferred very slowly to ice of mass 0.050 kg at its melting point so that the ice melts completely. The melted water remains at 0 °C.
The specific latent heat of fusion of ice = 335 kJ kg^{-1}
What is the entropy change of the ice?

A. 0.041 kJ k^{-1}
B. 0.061 kJ k^{-1}
C. 0.041 J k^{-1}
D. 0.061 J k^{-1}

[1]

21N.1A.HL.TZ0.30

The diagram shows equipotential lines for an electric field. Which arrow represents the acceleration of an electron at point P?



[1]

21M.1A.HL.TZ2.32

A satellite orbits planet X with a speed v_X at a distance r from the centre of planet X. Another satellite orbits planet Y at a speed of v_y at a distance r from the centre of planet Y. The mass of planet X is M and the mass of planet Y is $4M$. What is the ratio of $\frac{v_X}{v_y}$?

A. 0.25
B. 0.5
C. 2.0
D. 4.0

[1]

SPM.1A.HL.TZ0.23

Monochromatic light is incident on a diffraction grating. The diffraction pattern from the diffraction grating is then formed on a screen.
Only the central maximum and the first-order maxima can be observed on the screen.
What change will allow the second-order maxima to be observed on the screen?

A. Decrease the distance between the diffraction grating and the source of light
B. Increase the distance between the diffraction grating and the screen
C. Increase the wavelength of the monochromatic light
D. Reduce the number of lines per unit length of the diffraction grating

[1]

SPM.1A.HL.TZ0.21

A mass of 0.25 kg hangs from a spring of spring constant 4.0 N m $^{-1}$. [1]
What is the natural frequency of oscillation for this system?

A. 0.50 Hz

B. 0.64 Hz
C. 1.6 Hz
D. 2.0 Hz

22M.1A.HL.TZ2.32

Two positive and two negative charges are located at the corners of a square as shown. Point X is the centre of the square. What is the value of the electric field E and the electric potential V at X due to the four charges?

	Electric field E at X	Electric potential V at X
A.	$E = 0$	$V = 0$
B.	$E \neq 0$	$V = 0$
C.	$E = 0$	$V \neq 0$
D.	$E \neq 0$	$V \neq 0$

[1]

19M.1A.HL.TZ2.10

Satellite X is in orbit around the Earth. An identical satellite Y is in a higher orbit. What is correct for the total energy and the kinetic energy of the satellite Y compared with satellite X?

	Total energy of satellite X	Kinetic energy of satellite X
A.	larger	larger
B.	smaller	larger
C.	larger	smaller
D.	smaller	smaller

[1]

EXE.1A.HL.TZ0.30

An electron is accelerated from rest through a potential difference of 3.8 kV. [1]
The de Broglie wavelength of the electron after acceleration is

A. 0.021 mm
B. 0.021 μm
C. 0.021 nm
D. 0.021 pm

20N.1A.HL.TZ0.29

White light is incident normally on separate diffraction gratings X and Y. Y has a greater number of lines per metre than X. Three statements about differences between X and Y are

I. adjacent slits in the gratings are further apart for X than for Y
II. the angle between red and blue light in a spectral order is greater in X than in Y
III. the total number of visible orders is greater for X than for Y.

Which statements are correct?
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

[1]

SPM.1A.HL.TZ0.2

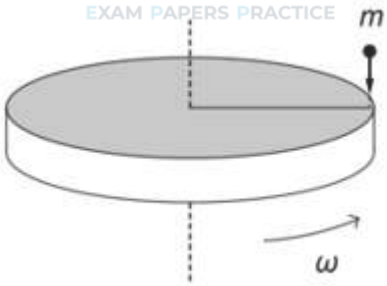
A block of mass 2.0 kg accelerates from a speed of 15 m s^{-1} to a speed of 20 m s^{-1} without changing its direction.
What impulse acts on the block?

A. 2.5 N s
B. 5.0 N s
C. 10 N s
D. 17.5 N s

[1]

EXE.1A.HL.TZ0.9

A turntable of mass M and radius R spins freely about the vertical axis at an initial angular velocity ω . The moment of inertia of the turntable about the axis of rotation is $\frac{1}{2}MR^2$. A small body of mass m is dropped close to the edge of the turntable with a negligible initial velocity.



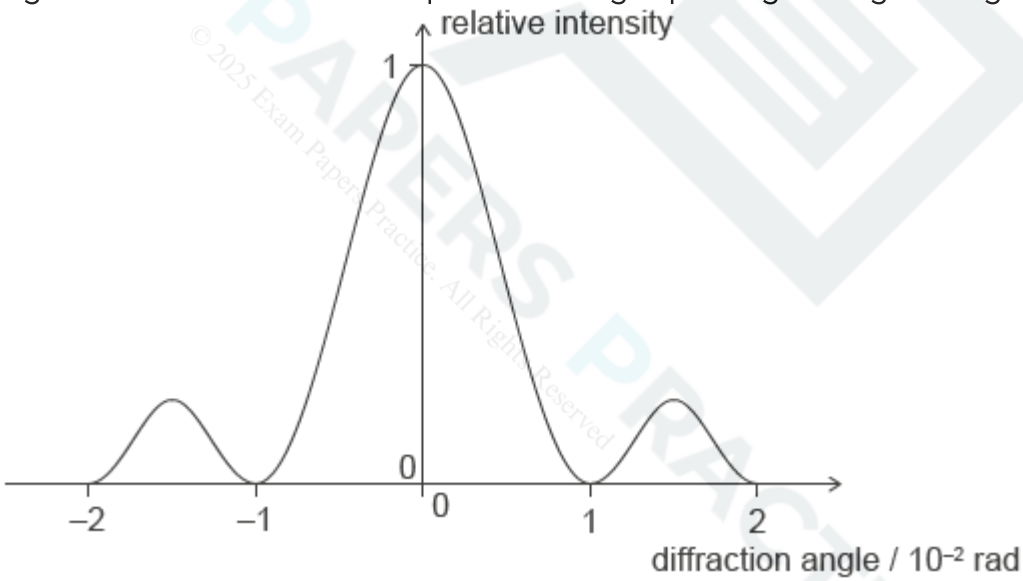
The body comes to rest relative to the turntable. What is the final angular velocity of the turntable?

A. $\frac{M}{M+2m}\omega$
B. $\frac{M}{M+m}\omega$
C. $\frac{M}{2M+m}\omega$
D. $\frac{2M}{M+m}\omega$

[1]

21M.1A.HL.TZ1.27

The diagram shows the diffraction pattern for light passing through a single slit. [1]

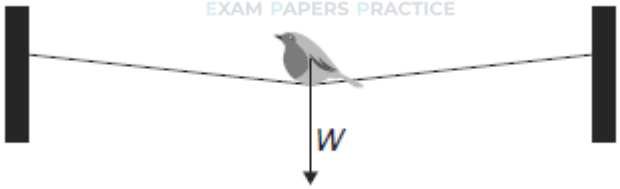


What is $\frac{\text{wavelength of light}}{\text{width of slit}}$

A. 0.01
B. 0.02
C. 1
D. 2

SPM.1A.HL.TZ0.8

A bird of weight W sits on a thin rope at its midpoint. The rope is almost horizontal and has negligible mass.



The tension in the rope is

A. less than $\frac{W}{2}$
B. equal to $\frac{W}{2}$
C. between $\frac{W}{2}$ and W
D. greater than W

[1]

SPM.1A.HL.TZ0.11

A gas undergoes one cycle of a cyclic process. [1]
The net change in internal energy of the gas is

A. zero.
B. positive.
C. negative.
D. determined by the initial temperature of the gas.

19N.1A.HL.TZ0.39

Three observations of the behaviour of electrons are [1]

I. electron emission as a result of the photoelectric effect
II. electron diffraction as an electron interacts with an atom
III. emission of radio waves as a result of electrons oscillating in a conductor.

Which observations are evidence that the electron behaves as a particle?

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

SPM.1A.HL.TZ0.33

What is the sequence for the evolution of a main sequence star of about 2 solar masses?

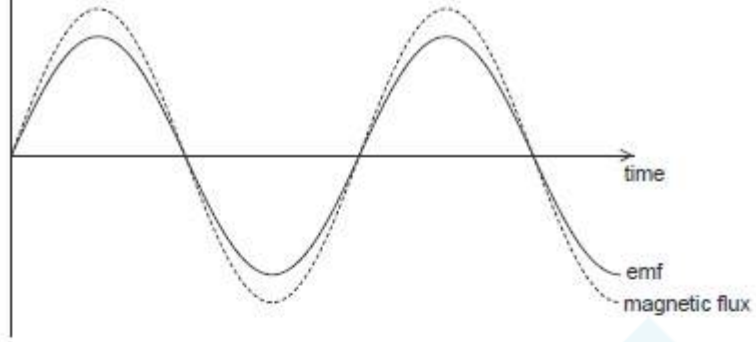
A. Red super giant → supernova → neutron star
B. Red giant → planetary nebula → white dwarf
C. Red giant → supernova → white dwarf
D. Red super giant → planetary nebula → neutron star

[1]

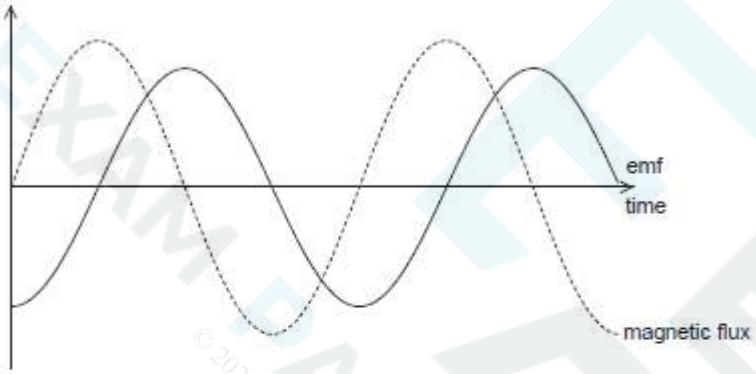
19N.1A.HL.TZ0.34

A coil is rotated in a uniform magnetic field. An alternating emf is induced in the coil. What is a possible phase relationship between the magnetic flux through the coil and the induced emf in the coil when the variations of both quantities are plotted with time?

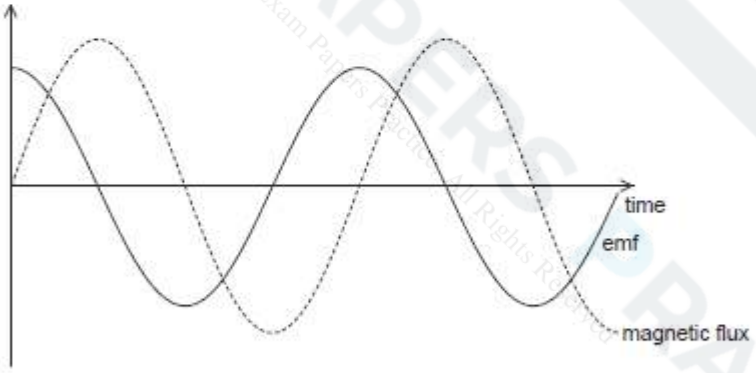
A.



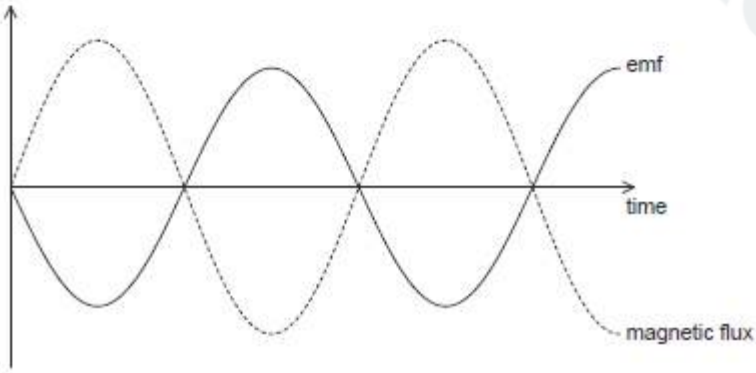
B.



C.



D.



[1]

20N.1A.HL.TZ0.30

Two satellites W and X have the same mass. They have circular orbits around the same planet. W is closer to the surface than X. What quantity is smaller for W than for X?
A. Gravitational force from the planet
B. Angular velocity
C. Orbital speed
D. Orbital period

[1]

SPM.1A.HL.TZ0.24

A solid metallic sphere is positively charged and isolated from all other charges. [1]
The electric potential due to the sphere

A. is constant inside the sphere.
B. is constant outside the sphere.
C. is smallest at the surface of the sphere.
D. increases with distance from the sphere.

SPM.1A.HL.TZ0.1

A car has an initial speed of 16 m s $^{-1}$. It decelerates at 4.0 m s $^{-2}$ until it stops. [1]
What is the distance travelled by the car?

A. 4 m
B. 16 m
C. 32 m
D. 64 m

19M.1A.HL.TZ1.34

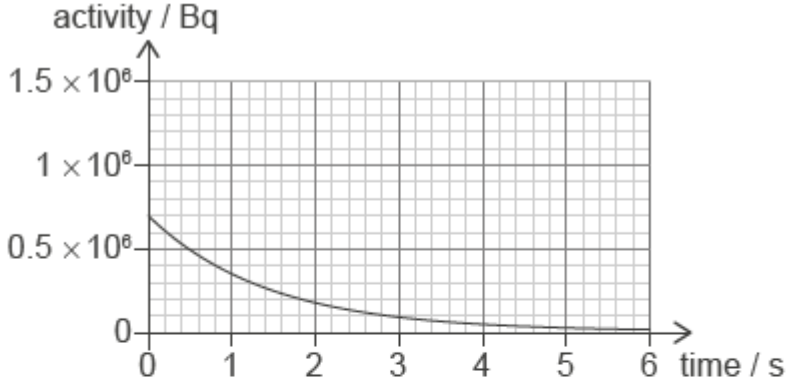
A satellite in a circular orbit around the Earth needs to reduce its orbital radius.
What is the work done by the satellite rocket engine and the change in kinetic energy resulting from this shift in orbital height?

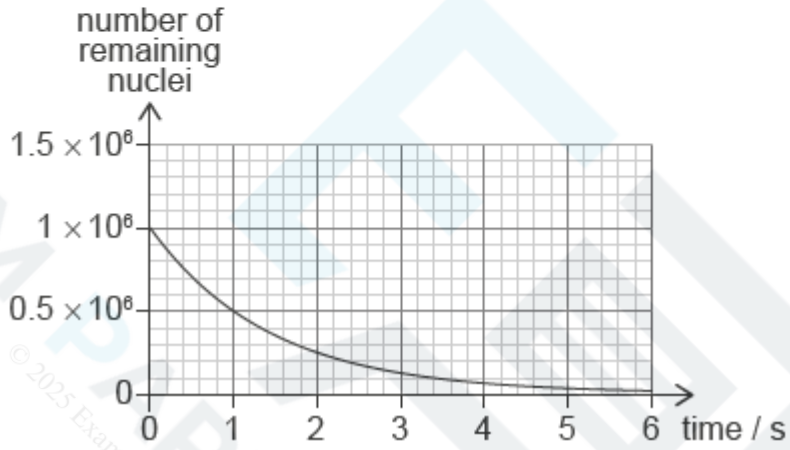
	Work done by the satellite rocket engine	Kinetic energy
A.	positive	increase
B.	positive	decrease
C.	negative	increase
D.	negative	decrease

[1]

21M.1A.HL.TZ1.39

The graphs show the variation with time of the activity and the number of remaining nuclei for a sample of a radioactive nuclide.





What is the decay constant of the nuclide?

A. $0.7\,s^{-1}$

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

C. $\frac{1}{0.7}s^{-1}$

D. $1.5\,s^{-1}$

[1]

23M.1A.HL.TZ2.31

The mass of Mars is about ten times that of the Moon. The radius of Mars is about twice that of the Moon.

What is the $\frac{\text{escape speed from Mars}}{\text{Moon}}$?

A. $\sqrt{5}$

B. $2\sqrt{5}$

C. 5

D. 25

[1]

23M.1A.HL.TZ2.29

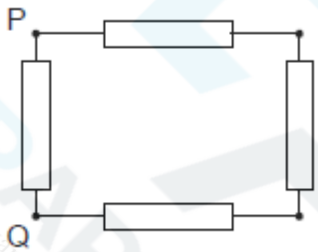
Monochromatic light is incident on a single slit to form a diffraction pattern on a screen. The width of the single slit is then halved.
What are the change in the width of the central maximum and the change in the maximum intensity of the pattern?

	Change in width of central maximum	Change in maximum intensity of pattern
A.	decrease	increase
B.	decrease	decrease
C.	increase	decrease
D.	increase	increase

[1]

SPM.1A.HL.TZ0.15

Four identical resistors, each of resistance R , are connected as shown. [1]

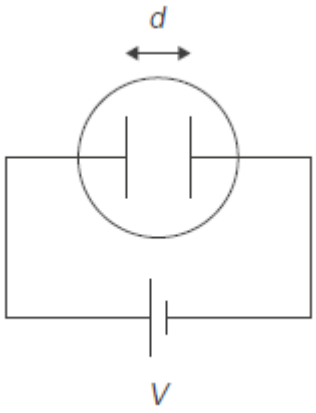


What is the effective resistance between P and Q?

A. $\frac{3R}{4}$
B. R
C. $\frac{4R}{3}$
D. $4R$

22N.1A.HL.TZ0.31

An electric field is established between two electrodes separated by distance d , held at a potential difference of V . A charged particle in this field experiences a force F .



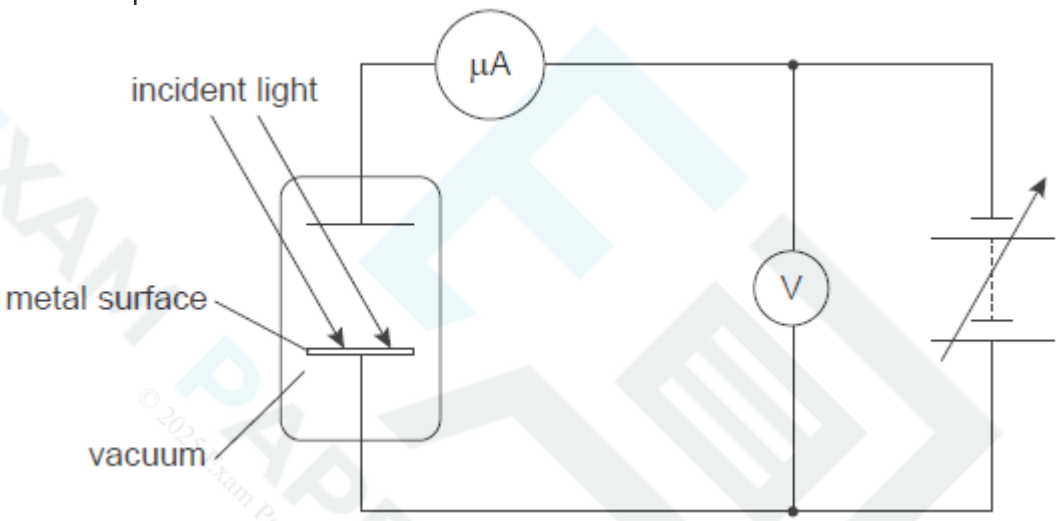
What is the charge on the particle?

A. $\frac{d}{FV}$
B. $\frac{FV}{d}$
C. $\frac{V}{Fd}$
D. $\frac{Fd}{V}$

[1]

22M.1A.HL.TZ1.38

Light with photons of energy 8.0×10^{-20} J are incident on a metal surface in a photoelectric experiment.



The work function of the metal surface is 4.8×10^{-20} J. What minimum voltage is required for the ammeter reading to fall to zero?
A. 0.2 V
B. 0.3 V
C. 0.5 V
D. 0.8 V

[1]

19N.1A.HL.TZ0.26

An object undergoes simple harmonic motion (shm) of amplitude x_0. When the displacement of the object is $\frac{x_0}{3}$, the speed of the object is v. What is the speed when the displacement is x_0?
A. 0
B. $\frac{v}{3}$
C. $\frac{\sqrt{2}}{3}v$
D. $3v$

[1]

SPM.1A.HL.TZ0.40

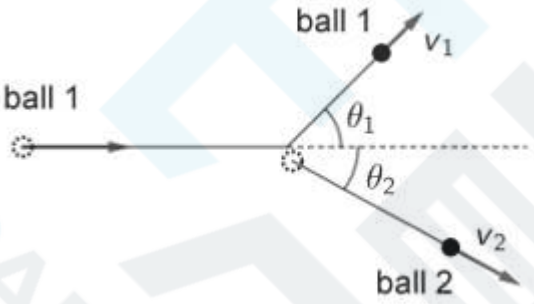
An alpha particle ($^{4}_{2}\mathrm{He}$) of initial energy 5.5 MeV moves towards the centre of a nucleus of gold-197 ($^{197}_{79}\mathrm{Au}$).
What is the distance of closest approach of the alpha particle?

A. 1.0×10^{-13} m
B. 4.1×10^{-14} m
C. 2.1×10^{-14} m
D. 6.6×10^{-33} m

[1]

EXE.1A.HL.TZ0.2

Ball 1 collides with an initially stationary ball 2 of the same mass. After the collision, the balls move with speeds v_1 and v_2 . Their velocities make angles θ_1 and θ_2 with the original direction of motion of ball 1.



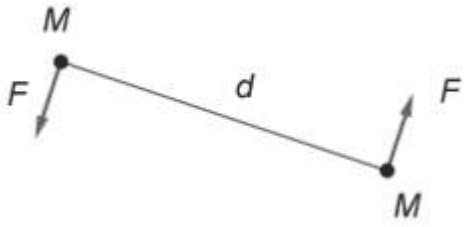
What is $\frac{v_1}{v_2}$

A. $\frac{\sin\ \theta_2}{\sin\ \theta_1}$
B. $\frac{\sin\ \theta_1}{\sin\ \theta_2}$
C. $\frac{\cos\ \theta_2}{\cos\ \theta_1}$
D. $\frac{\cos\ \theta_1}{\cos\ \theta_2}$

[1]

EXE.1A.HL.TZ0.8

Two objects of mass M each are connected by a weightless rod of length d . A force F is applied to each of the objects, at right angles to the rod as shown.



What is the torque acting on the system about the midpoint of the rod and what is the angular acceleration of the system?

Torque	Angular acceleration

A. Fd $\frac{2F}{Md}$

B. Fd $\frac{4F}{Md}$

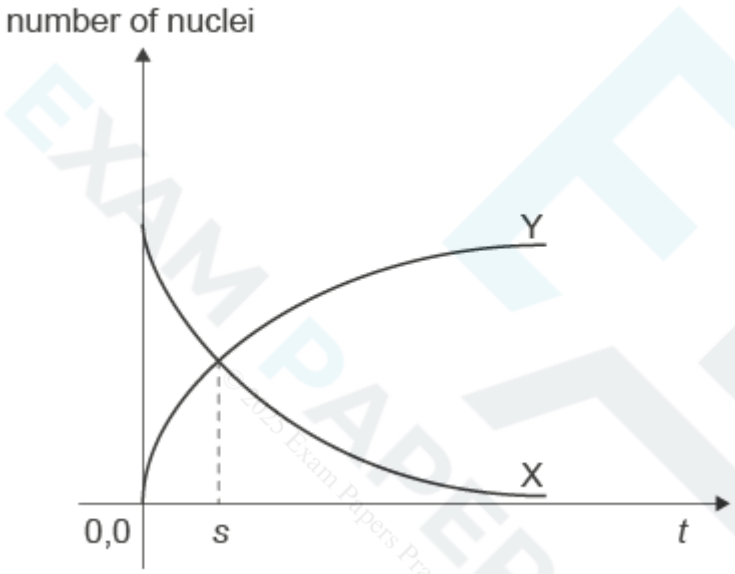
C. 2Fd $\frac{2F}{Md}$

D. 2Fd $\frac{4F}{Md}$

[1]

23M.1A.HL.TZ1.40

Radioactive nuclide X decays into a stable nuclide Y. The decay constant of X is λ. The variation with time *t* of number of nuclei of X and Y are shown on the same axes.



What is the expression for *s* ?

A. $\frac{\ln 2}{\lambda}$

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

C. $\frac{\lambda}{\ln 2}$

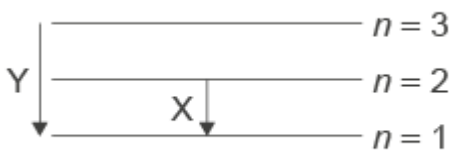
D. $\ln 2$

[1]

23M.1A.HL.TZ2.40

Some energy levels for a hydrogen atom are shown. [1]

diagram not to scale



What is the $\frac{\text{wavelength emitted in transition X}}{\text{wavelength emitted in transition Y}}$?

A. $\frac{1}{2}$
B. $\frac{27}{32}$
C. $\frac{32}{27}$
D. 2

19M.1A.HL.TZ1.38

A metallic surface is first irradiated with infrared radiation and photoelectrons are emitted from the surface. The infrared radiation is replaced by ultraviolet radiation of the same intensity.
What will be the change in the kinetic energy of the photoelectrons and the rate at which they are ejected?

	Kinetic energy of photoelectrons	Rate of ejected photoelectrons
A.	increase	decrease
B.	decrease	decrease
C.	increase	constant
D.	decrease	constant

[1]

21M.1A.HL.TZ1.34

The conservation of which quantity explains Lenz's law? [1]
A. Charge
B. Energy
C. Magnetic field
D. Mass

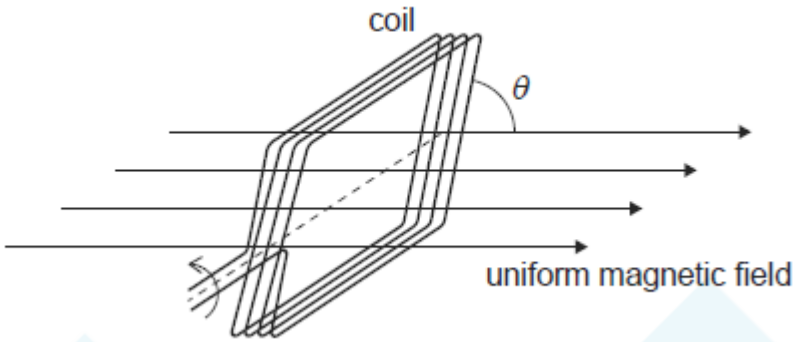
22M.1A.HL.TZ2.38

Samples of two radioactive nuclides X and Y are held in a container. The number of particles of X is half the number of particles of Y. The half-life of X is twice the half-life of Y.
What is the initial value of $\frac{\text{activity of radioisotope X}}{\text{activity of radioisotope Y}}$?
A. $\frac{1}{4}$
B. $\frac{1}{2}$
C. 1
D. 4

[1]

SPM.1A.HL.TZ0.29

A rectangular conducting coil rotates at a constant angular velocity in a uniform magnetic field. The rotation axis of the coil is perpendicular to the field.



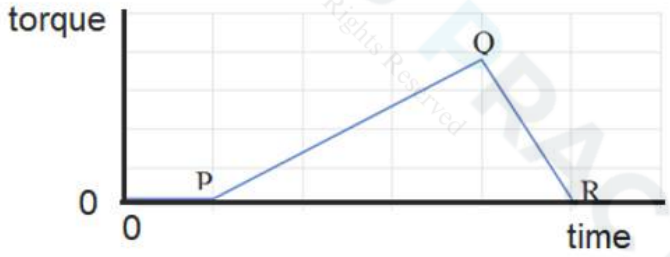
At one instant the plane of the coil is at an angle θ to the direction of the field.
The magnitude of the emf induced in the coil is

A. never zero.
B. at a maximum when $\theta = 0°$ or 180°.
C. at a maximum when $\theta = 45°$ or 225°.
D. at a maximum when $\theta = 90°$ or 270°.

[1]

EXE.1A.HL.TZ0.11

The graph shows the variation of torque with time acting on a rotating object. [1]

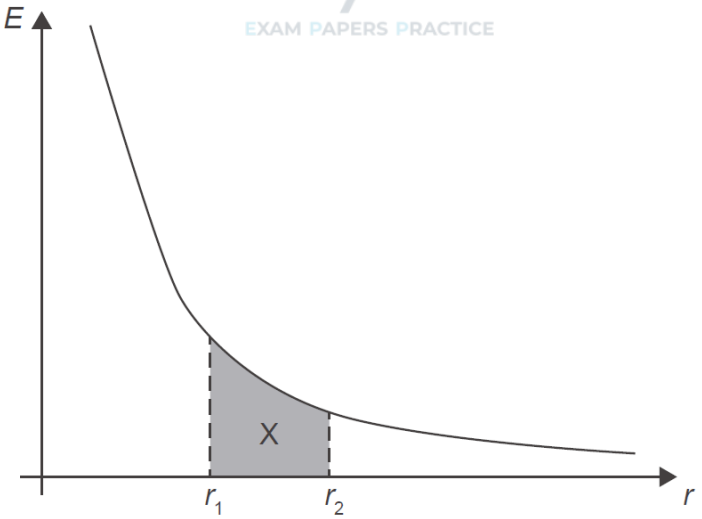


What is the angular impulse acting on the object?

A. The gradient of the line PQ
B. The average gradient of the line PQR
C. The area under the line PQ
D. The area under the line PQR

20N.1A.HL.TZ0.32

The graph shows the variation of electric field strength E with distance r from a point charge.



The shaded area X is the area under the graph between two separations r_1 and r_2 from the charge.
What is X?
A. The electric field average between r_1 and r_2
B. The electric potential difference between r_1 and r_2
C. The work done in moving a charge from r_1 to r_2
D. The work done in moving a charge from r_2 to r_1

[1]

19M.1A.HL.TZ2.11

The escape speed from a planet of radius *R* is v_{esc}. A satellite orbits the planet at a distance *R* from the surface of the planet. What is the orbital speed of the satellite?
A. $\frac{1}{2}v_{esc}$
B. $\frac{\sqrt{2}}{2}v_{esc}$
C. $\sqrt{2}v_{esc}$
D. $2v_{esc}$

[1]

21M.1A.HL.TZ2.28

A train is moving in a straight line away from a stationary observer when the train horn emits a sound of frequency f_0. The speed of the train is $0.10v$ where v is the speed of sound. What is the frequency of the horn as heard by the observer?
A. $\frac{0.9}{1}f_0$
B. $\frac{1}{1.1}f_0$
C. $\frac{1.1}{1}f_0$
D. $\frac{1}{0.9}f_0$

[1]

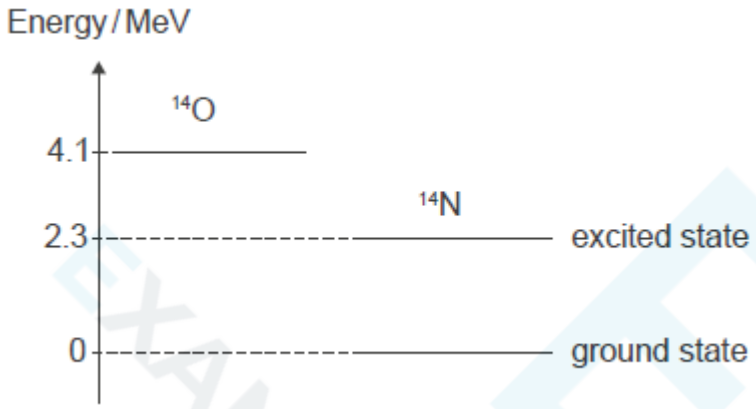
21M.1A.HL.TZ2.39

What is true for the Bohr model for the hydrogen atom? [1]

A. Angular momentum of electrons is quantized.
B. Electrons are described by wave functions.
C. Electrons never exist in fixed orbitals.
D. Electrons will continuously emit radiation.

21N.1A.HL.TZ0.39

Some of the nuclear energy levels of oxygen-14 (^{14}O) and nitrogen-14 (^{14}N) are shown.



A nucleus of ^{14}O decays into a nucleus of ^{14}N with the emission of a positron and a gamma ray. What is the maximum energy of the positron and the energy of the gamma ray?

	Maximum energy of the positron / MeV	Energy of the gamma ray / MeV
A.	1.8	2.3
B.	1.8	4.1
C.	2.3	1.8
D.	4.1	2.3

[1]

SPM.1A.HL.TZ0.19

A particle undergoes simple harmonic motion of period T. At time $t = 0$ the particle is at its equilibrium position.
What is t when the particle is at its greatest distance from the equilibrium position?

A. $\frac{T}{8}$
B. $\frac{T}{2}$
C. $\frac{3T}{4}$
D. T

[1]

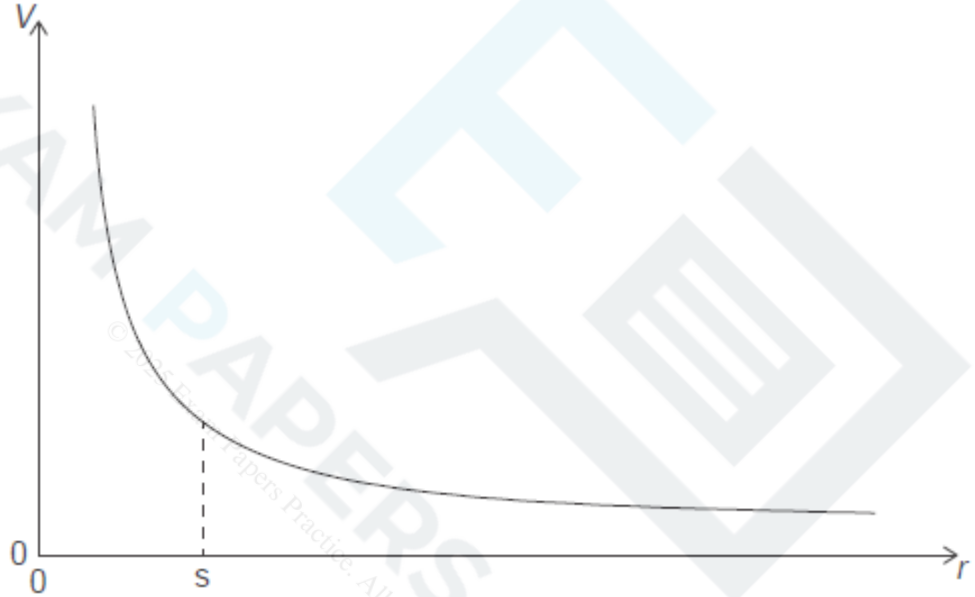
19M.1A.HL.TZ1.39

The half-life of a radioactive nuclide is 8.0 s. The initial activity of a pure sample of the nuclide is 10 000 Bq. What is the approximate activity of the sample after 4.0 s?
A. 2500 Bq
B. 5000 Bq
C. 7100 Bq
D. 7500 Bq

[1]

22M.1A.HL.TZ2.33

The graph shows the variation with distance r of the electric potential V from a charge Q .

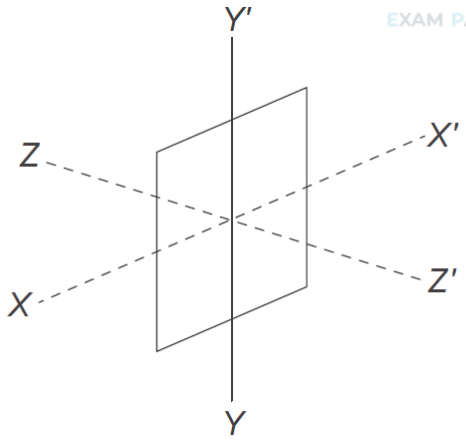


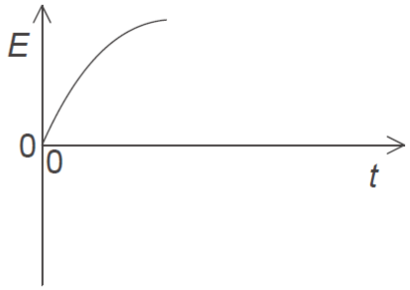
What is the electric field strength at distance s?
A. The area under the graph between s and infinity
B. The area under the graph between 0 and s
C. The gradient of the tangent at s
D. The negative of the gradient of the tangent at s

[1]

20N.1A.HL.TZ0.35

A rectangular coil rotates at a constant angular velocity. At the instant shown, the plane of the coil is at right angles to the line ZZ ' . A uniform magnetic field acts in the direction ZZ ' .





What rotation of the coil about a specified axis will produce the graph of electromotive force (emf) E against time t ?

A. Through $\frac{\pi}{2}$ about ZZ '

B. Through π about YY '

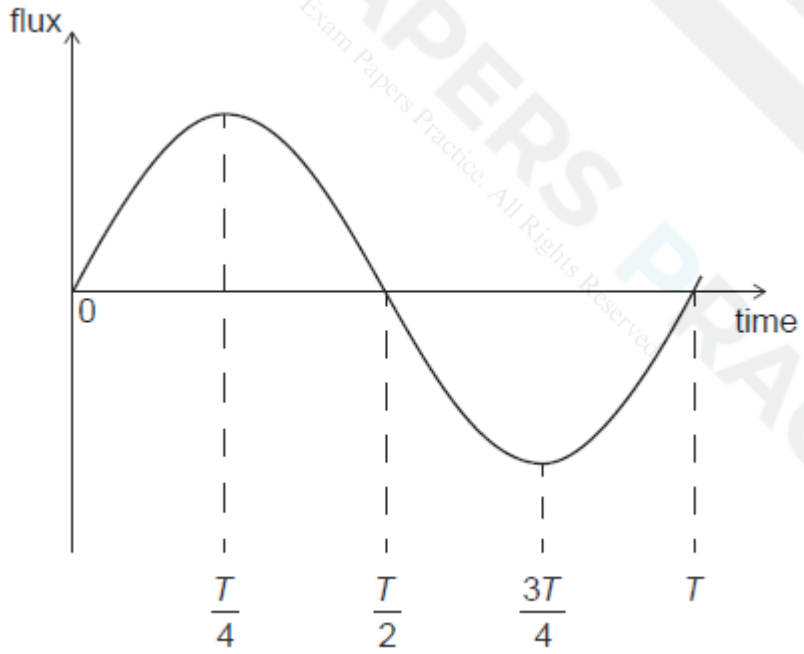
C. Through $\frac{\pi}{2}$ about XX '

D. Through π about XX '

[1]

19M.1A.HL.TZ1.35

The graph below shows the variation with time of the magnetic flux through a coil.



Which of the following gives three times for which the magnitude of the induced emf is a maximum?

A. 0, $\frac{T}{4}$, $\frac{T}{2}$

B. 0, $\frac{T}{2}$, T

C. 0, $\frac{T}{4}$, T

D. $\frac{T}{4}$, $\frac{T}{2}$, $\frac{3T}{4}$

[1]

22M.1A.HL.TZ1.40

The decay constant, λ , of a radioactive sample can be defined as [1]

A. the number of disintegrations in the radioactive sample.
B. the number of disintegrations per unit time in the radioactive sample.
C. the probability that a nucleus decays in the radioactive sample.
D. the probability that a nucleus decays per unit time in the radioactive sample.

23M.1A.HL.TZ1.33

Which law is equivalent to the law of conservation of energy? [1]

A. Coulomb's law
B. Ohm's Law
C. Newton's first law
D. Lenz's law

SPM.1A.HL.TZ0.14

Star X has a luminosity *L* and an apparent brightness *b* . Star X is at a distance d from Earth.
Star Y has the same apparent brightness as X but is four times more luminous.
What is the distance of Star Y from Earth?

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

[1]

EXE.1A.HL.TZ0.32

A beam of X-rays of wavelength 100.00 pm is scattered from a block of carbon. Radiation is observed at right angles to the incident beam.
What is the Compton shift for the observed radiation?

A. 0.1024 pm
B. 2.4322 pm
C. 2.4322 nm
D. 0.1024 nm

[1]

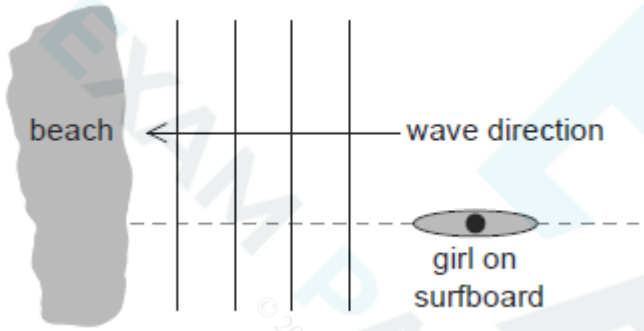
19M.1A.HL.TZ2.39

Three possible features of an atomic model are [1]

I. orbital radius
II. quantized energy
III. quantized angular momentum.
Which of these are features of the Bohr model for hydrogen?
A. I and II only
B. I and III only
C. II and III only
D. I, II, and III

19N.1A.HL.TZ0.29

Sea waves move towards a beach at a constant speed of 2.0 m s^{-1}. They arrive at the beach with a frequency of 0.10 Hz. A girl on a surfboard is moving in the sea at right angles to the wave fronts. She observes that the surfboard crosses the wave fronts with a frequency of 0.40 Hz.



What is the speed of the surfboard and what is the direction of motion of the surfboard relative to the beach?

	Speed of surfboard relative to the beach / m s^{-1}	Direction of motion of surfboard relative to the beach
A.	6.0	towards beach
B.	6.0	away from beach
C.	1.5	towards beach
D.	1.5	away from beach

[1]

21M.1A.HL.TZ2.38

Element X has a nucleon number A_X and a nuclear density ρ_X. Element Y has a nucleon number of $2A_X$. What is an estimate of the nuclear density of element Y?
A. $\frac{1}{2}\rho_X$
B. ρ_X
C. $2\rho_X$
D. $8\rho_X$

[1]

22M.1A.HL.TZ2.37

Three correct statements about the behaviour of electrons are:

I. An electron beam is used to investigate the structure of crystals.

II. An electron beam produces a pattern of fringes when sent through two narrow parallel slits.

III. Electromagnetic radiation ejects electrons from the surface of a metal.

Which statements are explained using the wave-like properties of electrons?

A. I and II only

B. I and III only

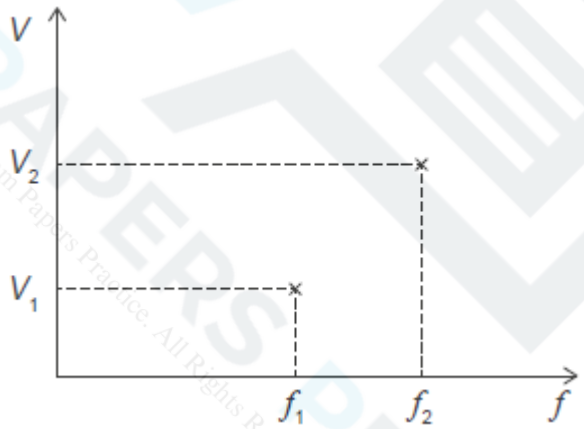
C. II and III only

D. I, II and III

[1]

21N.1A.HL.TZ0.37

In a photoelectric experiment a stopping voltage V required to prevent photoelectrons from flowing across the photoelectric cell is measured for light of two frequencies f_1 and f_2 . The results obtained are shown.



The ratio $\frac{V_2 - V_1}{f_2 - f_1}$ is an estimate of

A. e

B. h

C. $\frac{e}{h}$

D. $\frac{h}{e}$

[1]

23M.1A.HL.TZ1.32

The escape speed from the surface of earth is v_{esc} . The radius of earth is R . A satellite of mass m is in orbit at a height $\frac{R}{4}$ above the surface of the Earth. What is the energy required to move the satellite to infinity?

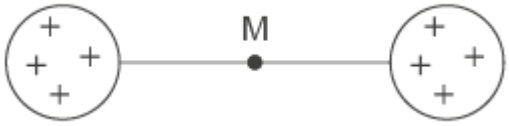
A. $\frac{mv^2_{esc}}{5}$

B. $\frac{2mv^2_{esc}}{5}$
C. mv^2_{esc}
D. $2mv^2_{esc}$

[1]

23M.1A.HL.TZ2.30

Two spheres have the same positive charge. A point M is midway between the two spheres.



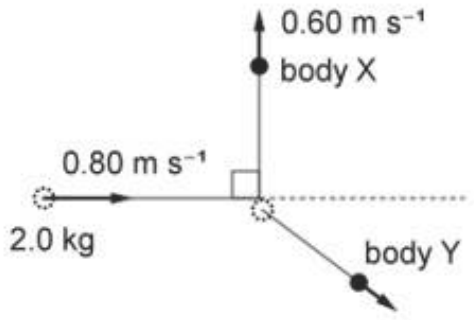
Along the line joining the spheres, what is true about the electrical field and the electric potential at M?

	Electric field	Electric potential
A.	zero	minimum positive value
B.	maximum	minimum positive value
C.	zero	maximum positive value
D.	maximum	maximum positive value

[1]

EXE.1A.HL.TZ0.1

Two bodies collide on a horizontal frictionless surface. Body X, of mass 2.0 kg, moves with an initial speed of 0.80 m s^{-1} and body Y is initially stationary. After the collision, body X moves at an angle of 90° to the initial direction of motion with a speed of 0.60 m s^{-1}.



What is the magnitude of the momentum of body Y after the collision?

A. 0.40 kg m s^{-1}
B. 1.0 kg m s^{-1}
C. 2.0 kg m s^{-1}
D. 2.8 kg m s^{-1}

[1]

EXE.1A.HL.TZ0.27

Which statement is correct about Compton scattering of a photon by an electron? [1]

A. The energy of the photon decreases.
B. The wavelength of the photon decreases.
C. The momentum of the photon is unchanged.
D. The combined momentum of the particles increases.

19N.1A.HL.TZ0.27

Light of frequency 500 THz is incident on a single slit and forms a diffraction pattern. The first diffraction minimum forms at an angle of $2.4\ 10^{-3}$ rad to the central maximum. The frequency of the light is now changed to 750 THz. What is the angle between the first diffraction minimum and the central maximum?

A. 1.6×10^{-3} rad
B. 1.8×10^{-3} rad
C. 2.4×10^{-3} rad
D. 3.6×10^{-3} rad

[1]

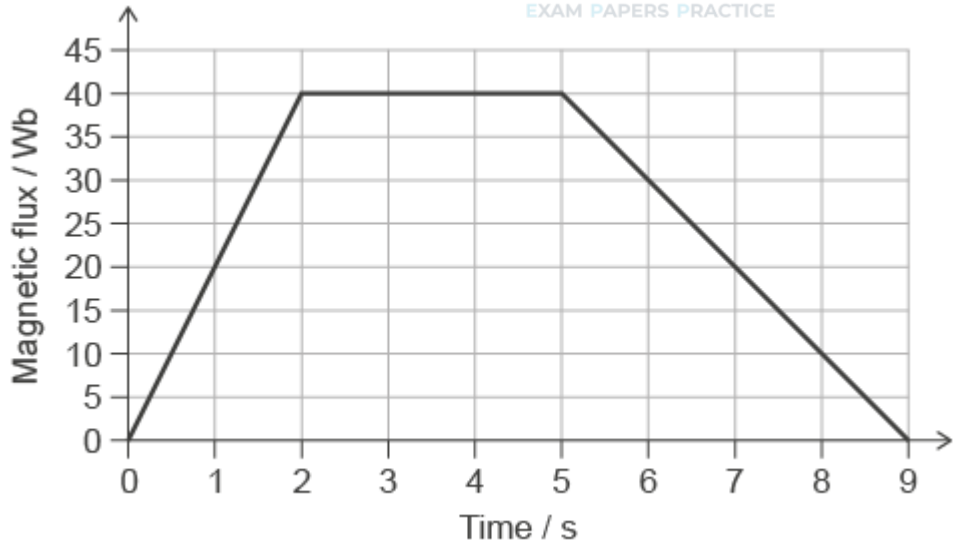
19M.1A.HL.TZ2.40

Photons of discrete energy are emitted during gamma decay. This is evidence for [1]

A. atomic energy levels.
B. nuclear energy levels.
C. pair annihilation.
D. quantum tunneling.

23M.1A.HL.TZ2.32

A single loop of wire of resistance 10 Ω has its plane perpendicular to a changing magnetic field.
The graph shows the variation with time of the magnetic flux linked through the loop of wire.



What is the maximum current in the loop of wire?

A. 1.0 A
B. 2.0 A
C. 4.0 A
D. 20 A

[1]

20N.1A.HL.TZ0.39

A photon has a wavelength λ . What are the energy and momentum of the photon? [1]

	Energy of photon	Momentum of photon
A.	$\frac{hc}{\lambda}$	$\frac{h}{\lambda}$
B.	$\frac{hc}{\lambda}$	$\frac{\lambda}{h}$
C.	$\frac{h\lambda}{c}$	$\frac{h}{\lambda}$
D.	$\frac{h\lambda}{c}$	$\frac{\lambda}{h}$

22N.1A.HL.TZ0.38

A student quotes three equations related to atomic and nuclear physics: [1]

I. $E = \frac{-13.6}{n^2}eV$

II. $N = N_0 e^{-\lambda t}$

III. $mvr = \frac{nh}{2\pi}$

Which equations refer to the Bohr model for hydrogen?

A. I and II only
B. I and III only

C. II and III only
D. I, II and III

21N.1A.HL.TZ0.31

Two charged parallel plates have electric potentials of 10 V and 20 V.

A particle with charge +2.0 μC is moved from the 10 V plate to the 20 V plate. What is the change in the electric potential energy of the particle?

A. −20 μJ
B. −10 μJ
C. 10 μJ
D. 20 μJ

[1]

19M.1A.HL.TZ2.38

Photons of a certain frequency incident on a metal surface cause the emission of electrons from the surface. The intensity of the light is constant and the frequency of photons is increased. What is the effect, if any, on the number of emitted electrons and the energy of emitted electrons?

	Number of emitted electrons	Energy of emitted electrons
A.	no change	no change
B.	decrease	increase
C.	decrease	no change
D.	no change	increase

[1]

22M.1A.HL.TZ2.24

Three statements about Newton's law of gravitation are. [1]

I. It can be used to predict the motion of a satellite.
II. It explains why gravity exists.
III. It is used to derive the expression for gravitational potential energy.

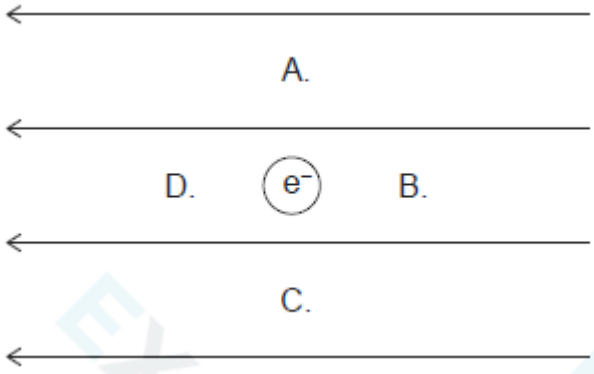
Which combination of statements is correct?

A. I and II only

B. I and III only
C. II and III only
D. I, II and III

19M.1A.HL.TZ2.30

An electron is fixed in position in a uniform electric field. What is the position for which the electrical potential energy of the electron is greatest?



[1]

22N.1A.HL.TZ0.40

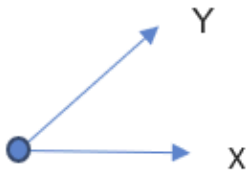
The nucleus of the isotope hydrogen-2 has a radius R and a density ρ. [1]
What are the approximate radius and density of a nucleus of oxygen-16?

	Oxygen-16 radius	Oxygen-16 density
A.	$2R$	ρ
B.	$2R$	2ρ
C.	$8R$	ρ
D.	$8R$	2ρ

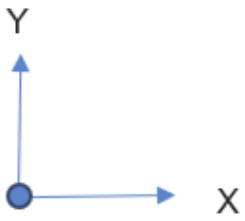
EXE.1A.HL.TZ0.3

Object X collides with object Y. Y is initially stationary. The tracks of the colliding particles after the collision are shown.
Which collision is elastic?

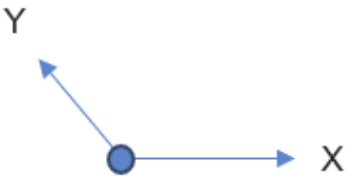
A.



B.



C.



D.

[1]

19N.1A.HL.TZ0.30

The gravitational potential is V at a distance R above the surface of a spherical planet of radius R and uniform density. What is the gravitational potential a distance 2R above the surface of the planet?

A. $\frac{V}{4}$

B. $\frac{4V}{9}$

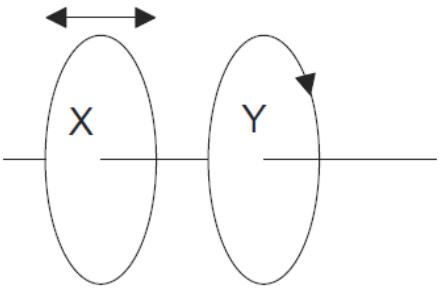
C. $\frac{V}{2}$

D. $\frac{2V}{3}$

[1]

19N.1A.HL.TZ0.33

X and Y are two plane coils parallel to each other that have a common axis. There is a constant direct current in Y.



X is first moved towards Y and later is moved away from Y. What, as X moves, is the direction of the current in X relative to that in Y?

	Current direction in X as X moves towards Y	Current direction in X as X moves away from Y
A.	same direction as in Y	same direction as in Y
B.	same direction as in Y	opposite direction to Y
C.	opposite direction to Y	same direction as in Y
D.	opposite direction to Y	opposite direction to Y

[1]

20N.1A.HL.TZ0.15

A travelling wave has a frequency of $500\ \text{Hz}$. The closest distance between two points on the wave that have a phase difference of $60\ ° \frac{\pi}{3}\text{rad}$ is $0.050\ \text{m}$. What is the speed of the wave?

A. $25\ \text{m s}^{-1}$
B. $75\ \text{m s}^{-1}$
C. $150\ \text{m s}^{-1}$
D. $300\ \text{m s}^{-1}$

[1]

EXE.1A.HL.TZ0.7

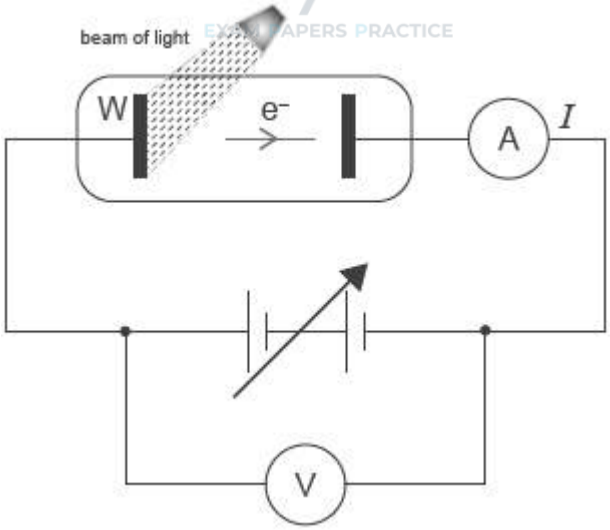
A constant torque acts on a bicycle wheel. The wheel accelerates from rest to a final angular velocity of 16 rad s^{-1} in a time of 4.0 s.
What is the angular displacement of the wheel during the acceleration?

A. 16 rad
B. 32 rad
C. 48 rad
D. 64 rad

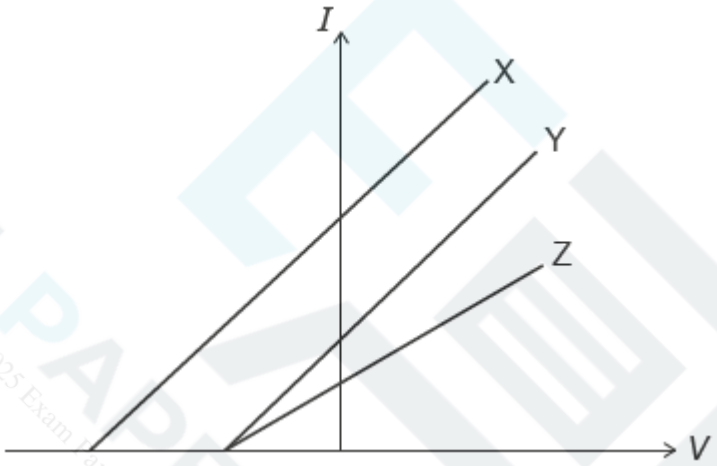
[1]

21M.1A.HL.TZ1.38

In a photoelectric effect experiment, a beam of light is incident on a metallic surface W in a vacuum.



The graph shows how the current I varies with the potential difference *V* when three different beams X, Y, and Z are incident on W at different times.



I. X and Y have the same frequency.
II. Y and Z have different intensity.
III. Y and Z have the same frequency.
Which statements are correct?
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

[1]

21N.1A.HL.TZ0.14

A travelling wave on the surface of a lake has wavelength λ . Two points along the wave oscillate with the phase difference of π . What is the smallest possible distance between these two points?

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

[1]

EXE.1A.HL.TZ0.20

Which statement is correct about the entropy of a non-isolated system? [1]

A. It always increases
B. It always decreases
C. It can only increase if the entropy of the surroundings decreases
D. It can only decrease if the entropy of the surroundings increases

21N.1A.HL.TZ0.27

When monochromatic light is incident on a single slit a diffraction pattern forms on a screen. The width of the slit is decreased.
What are the changes in the width and in the intensity of the central maximum of the diffraction pattern?

	Width of the central maximum	Intensity of the central maximum
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

[1]

EXE.1A.HL.TZ0.31

The Compton effect can be explained using [1]

A. conservation of momentum
B. kinematic equations applied in two dimensions
C. the concept of a photon
D. the wave theory of light

22N.1A.HL.TZ0.37

Monochromatic electromagnetic radiation ejects photoelectrons from a metal surface.
The minimum frequency for which this is possible is f.
When radiation of frequency $2f$ is incident on the surface, the kinetic energy of the photoelectrons is K.
What is the kinetic energy of the photoelectrons when the frequency of the radiation is $4f$?

A. K
B. $2K$

C. 3 *K*
D. 4 *K*

[1]

EXE.1A.HL.TZ0.16

A spaceship leaves Earth and travels at a speed of 0.60 *c* relative to the Earth to a point P. P is 3.0 lightyears from Earth.
The spaceship then returns to Earth. Ignore the time taken to reverse the direction of the spaceship.
What is the time taken for the total journey to and from P as measured by an observer in the spaceship?

A. 6.3 years
B. 5.0 years
C. 8.0 years
D. 10 years

[1]