BP~691

VICTORIA JUNIOR COLLEGE

2022 JC2 PRELIMINARY EXAMINATIONS

PHYSICS
Higher 2

9749/01

2.30 pm- 3.30 pm

1 Hour

Paper 1 Multiple Choice

Additional Materials: Multiple Choice Answer Sheet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil (2B or softer).
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, CT group and shade your index number on the Answer Sheet provided.

HOW TO SHADE YOUR INDEX NUMBER:
Eg. If your class is 21S43, index number is 06, then shade 2140306.
Check that you have shaded correctly.

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

Read the instructions on the Answer Sheet very carefully.

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

This document consists of **17** printed pages.

Data

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

Formulae

uniformly accelerated motion,	$s = ut + (½) at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
temperature	$T / K = T / °C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_o \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + ...$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + ...$
electric potential,	$V = Q/4\pi\varepsilon_o r$
alternating current/voltage,	$x = x_o \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_o \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

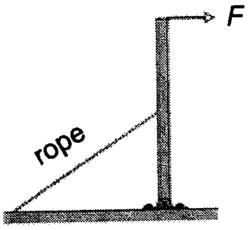
1. For electromagnetic induction, there is a physical quantity called self-induction, which is defined as

$$\text{self inductance} = \frac{\text{e.m.f. induced in coil by a changing current}}{\text{rate of change of current through coil}}$$

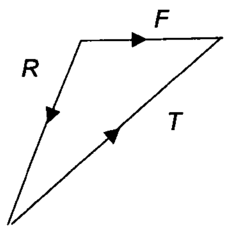
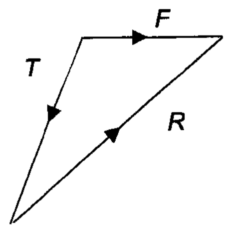
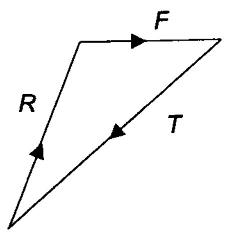
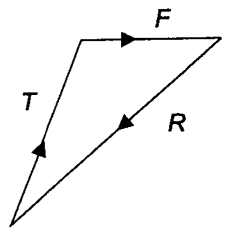
What are the base units of self-inductance?

A	H	B	kg m^2 A s^{-2}
C	J s	D	kg m^2 s^{-2} A^{-2}

2. A light rod, hinged at its lower end, has a horizontal force *F* acting at its upper end and a reaction force *R* acting at its lower end. A tension *T* acts in the rope on the beam.



Which of the vector diagram below showing the forces acting on the beam is correct?

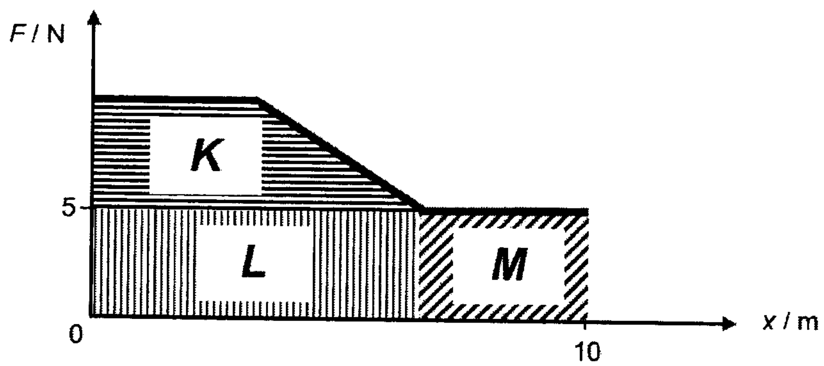
A		C	
B		D	

3. The diagram below shows two spheres undergoing a head-on elastic collision. Sphere A has mass $2M$ while sphere B has mass M. Both are moving with speed v towards each other.

Which of the following statements is incorrect?

A The two spheres cannot come to rest at the same time.
B The total kinetic energy of both spheres is conserved throughout the collision.
C The magnitude of the change in momentum for each sphere is the same after the collision.
D The force exerted by sphere A on B is equal and opposite to the force exerted by B on A during the collision.

4. An object is pushed from rest in a straight line by a variable force F along a rough ground. The ground exerts a constant frictional force of 5 N throughout the motion of the object. The variation with displacement x of the force F is shown below.



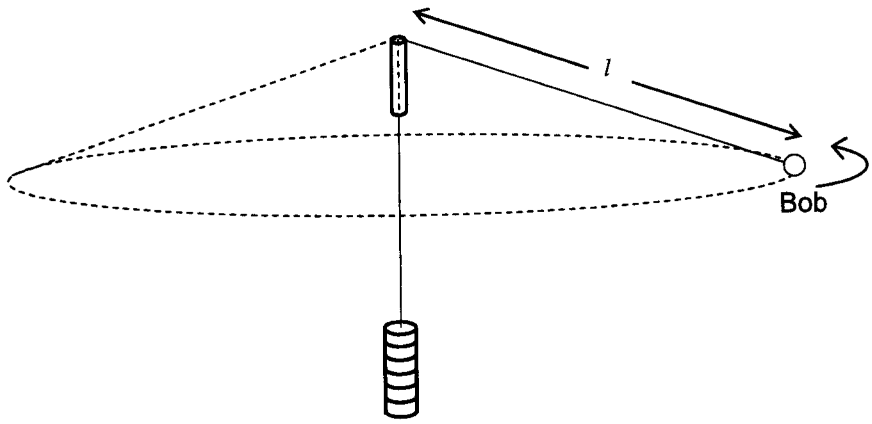
The magnitude of the kinetic energy of the object when it has travelled 10 m is the area

A K B $K + L$ C $K + L + M$ D $L + M$

5. A motor of power 10 W is used to lift a load of 20 N. The efficiency of the motor is 25 %. How long does it take to lift the load through a vertical distance of 0.50 m?

A 0.040 s B 0.25 s C 4.0 s D 39 s

6. A bob is tied using an inelastic string to a fixed set of brass weights. It is then made to execute circular motion in a horizontal plane, so that the string traces out a cone, as shown in the diagram below. The string is passed through a smooth vertical glass tube so that the length l of the string from the top of the glass tube to the bob can vary freely as the speed of the circular oscillation changes. What is the relationship between length l and the frequency f of the circular motion?



A $l \propto f^2$

B $l \propto f$

C $l \propto \frac{1}{f}$

D $l \propto \frac{1}{f^2}$

7. The table below gives the values for the gravitational potential at various points in the gravitational field of a celestial body.

Distance from surface of body / km	Potential / kJ kg^{-1}
0	−784.0
360	−649.6
370	−633.3
380	−617.0
Infinity	0

What is value of the gravitational acceleration at a height of 370 km of this celestial body?

A 9.83 m s^{-2} B 1.63 m s^{-2} C 19.73 m s^{-2} D 6.33 m s^{-2}

8. A satellite is shifted from a stable orbit to another orbit which is higher. Which one of the following quantities increases?

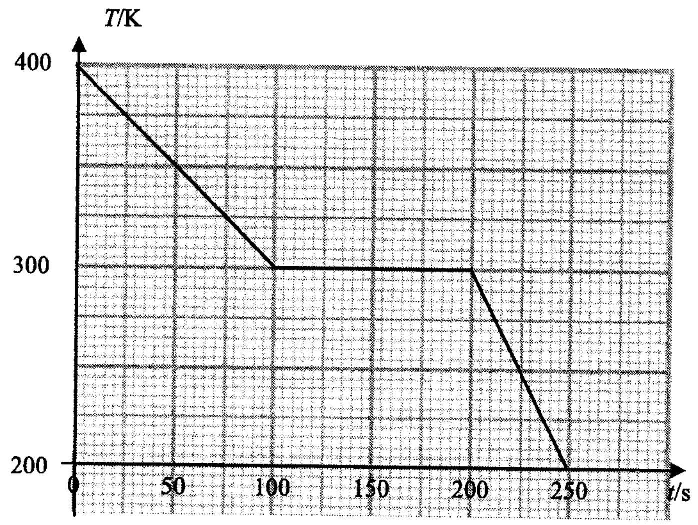
A Gravitational force

B Gravitational potential energy

C Linear speed

D Kinetic energy

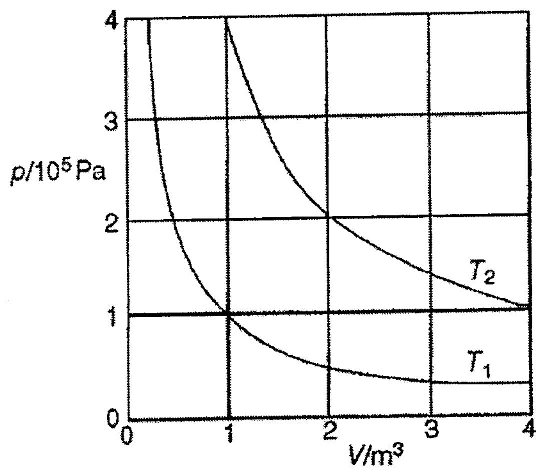
9. The graph shows the variation of temperature T against time t of a certain substance. Originally, it is in a liquid state at $t = 0$ s. Heat is removed from it at a constant rate until it becomes a solid.



Which of the following could be correct?

	specific heat capacity of liquid/J kg^{-1} K^{-1}	specific heat capacity of solid/J kg^{-1} K^{-1}
A	1500	3000
B	1800	900
C	2500	2500
D	4500	3000

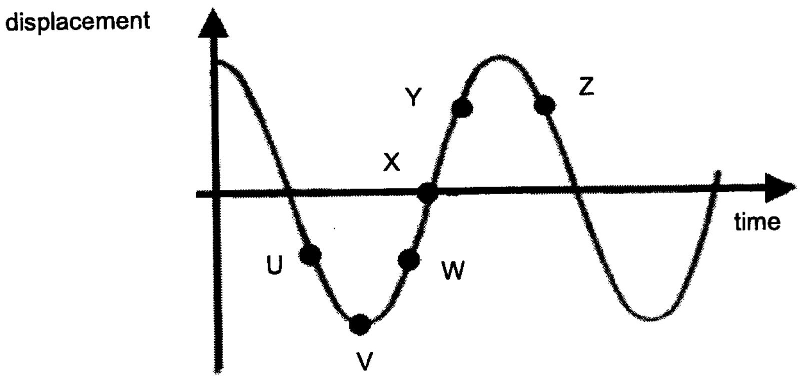
10. The two curves shown below are two different isothermal curves for a fixed mass of an ideal gas.



What is the ratio $\dfrac{\text{r.m.s. speed of the molecules at temperature } T_2}{\text{r.m.s. speed of the molecules at temperature } T_1}$?

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

11. The diagram below shows a displacement-time graph of a body performing simple harmonic motion.



At which points, U, V, W, X, Y or Z, are the body travelling *and* accelerating in the opposite direction?

A U and Y B V and X C U and Z D W and Z

12. A mass of 20 g is oscillating vertically in simple harmonic motion. The displacement of the mass is given by the equation

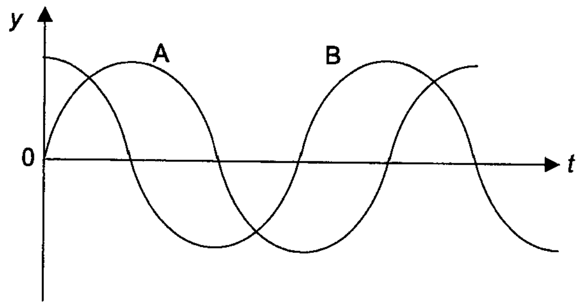
$$x = 6.0 \times 10^{-3} \sin(3\pi t)$$

where x is in metres and t in seconds.

What is the magnitude of the maximum force acting on the mass?

A 0.011 N   B 0.50 N   C 1.8 N   D 11 N

13. Two wave particles A and B are on the same wave. The graph below shows how their displacements *y* vary with time *t*:



What can be said about A and B?

A A leads B by 45°
B A lags B by 45°
C A leads B by 90°
D A lags B by 90°

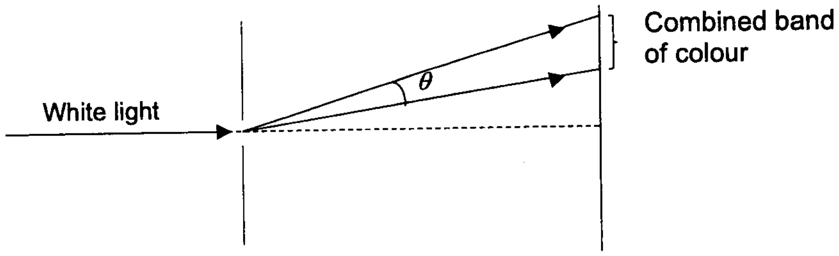
14. A wave has an amplitude of 3.0 cm, wavelength of 15 cm and speed of 4.0 m s^{-1}. What is the maximum speed of a particle on the wave?

A 7.1×10^{-3} m s^{-1} B 3.0×10^{-2} m s^{-1}
C 4.0 m s^{-1} D 5.0 m s^{-1}

15. Images viewed through a single slit may or may not be well resolved. Which of the following will improve the resolving power of the slit?

A Making the slit narrower
B Making the slit wider
C Decreasing the distances between the images and the slit
D Increasing the distances between the images and the slit

16. White light is shone through a diffraction grating that contains 300 lines per mm. It is observed that the second and third order spectra overlap, forming a combined band of colour in the region of overlap on a screen with an angular width θ, as shown:



What is the value of θ?
[Range of visible light wavelengths: 400 nm to 700 nm]

A 3.7° B 11° C 18° D 25°

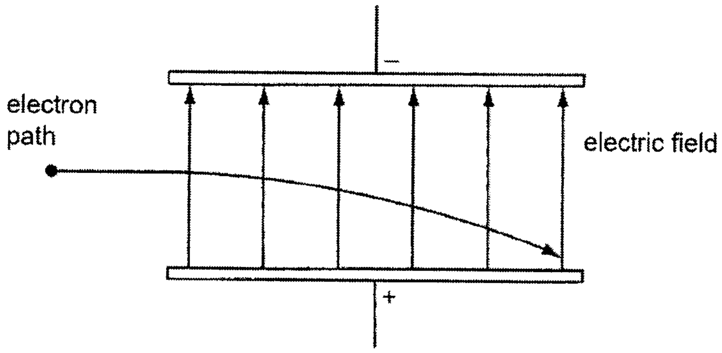
17. A positive charge of 2.6×10^{-8} C is in a uniform electric field of field strength 3.0×10^{5} N C^{-1}.

How much work must be done on the charge in order to slowly move it a distance of 4.0 mm in the opposite direction to the direction of the field?

A -3.1×10^{-2} J B -3.1×10^{-5} J

C 3.1×10^{-5} J D 3.1×10^{-2} J

18. An electron is projected horizontally into the vertical electric field in the space between two horizontal charged plates. The electron follows a curved path as shown.

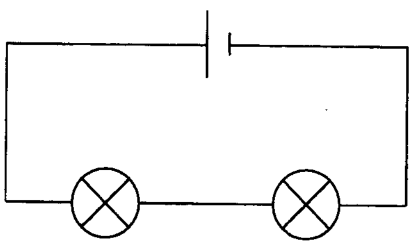


There are changes to the electron's electric potential energy and to its gravitational potential energy.

Which row correctly identifies these changes?

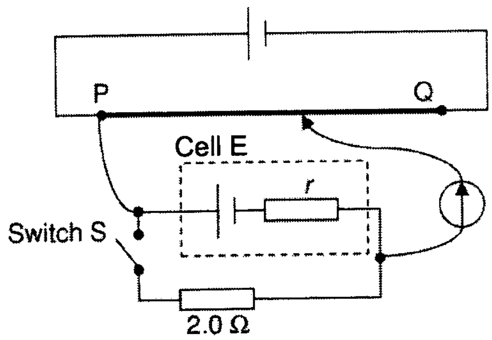
	electric potential energy	gravitational potential energy
A	Decreases	Decreases
B	Decreases	Increases
C	Increases	Decreases
D	Increases	Increases

19. The circuit below contains a cell and 2 identical lamps X and Y. What will happen to the brightness of the 2 lamps if an additional identical lamp is added in parallel to X?



A Both X and Y are less bright.
B X is less bright, Y is brighter.
C X is brighter, Y is less bright.
D Both X and Y are brighter.

20. The diagram below shows a simple potentiometer circuit used to determine the internal resistance r of a cell E. The driver cell has an e.m.f. of 2.0 V with negligible internal resistance and the resistance wire PQ is 1.0 m long. Cell E is connected in parallel with a resistor of 2.0 Ω. When the switch is open, the balance length is 0.70 m and when the switch is closed, the balance length is 0.50 m.



What is the internal resistance r of cell E?

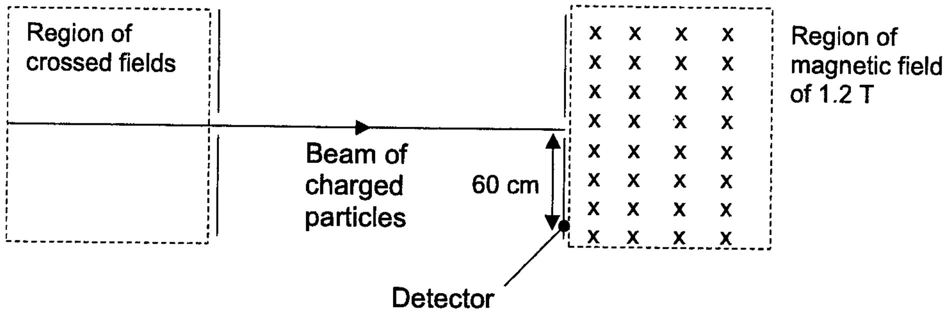
A. 0.15 Ω B. 0.40 Ω C. 0.50 Ω D. 0.80 Ω

21. A compass placed horizontally points north due to the horizontal component of the Earth's magnetic field, which is 3.5×10^{-5} T. A vertical wire is placed 9.0 mm due south of the compass. When a current of 3.0 A flows downwards through the wire, the compass needle deflects.

What is the angle and direction of the deflection?

A 28° east of north
B 28° west of north
C 62° east of north
D 62° west of north

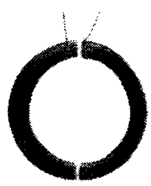
22. A horizontal beam of doubly-charged particles passes through a crossed field, consisting of an electric field of 6.0×10^2 N C^{-1} and a magnetic field of 2.0×10^{-5} T. Particles which emerge from the crossed field undeflected are allowed to pass through a small hole. This beam is then directed at another small hole, beyond which a uniform field of 1.2 T is applied. This field is horizontal, but perpendicular to the original direction of motion of the beam. The beam then impacts a detector placed 60 cm beside the second hole, as shown below:



What is the mass of each particle?

A 3.8×10^{-27} kg B 7.7×10^{-27} kg
C 3.5×10^{-12} kg D 7.0×10^{-12} kg

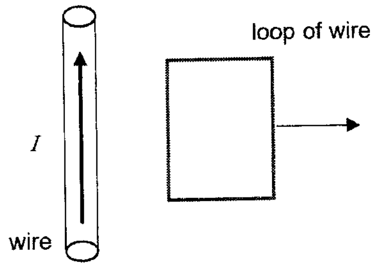
23. A flat circular coil of 120 turns, each of diameter 30 cm, is placed with its axis parallel to a uniform magnetic field. The ends of the coil are not connected to form a closed circuit (as shown below).



The flux density of the magnetic field is changed steadily from 80 mT to 20 mT over a period of 4.0 s. What is the e.m.f. induced in the coil during this time?

A 0 B 1.1 mV C 130 mV D 510 mV

24. A rectangular loop of wire is held close to a long vertical wire carrying a current I. The loop is then pulled to the right as shown.



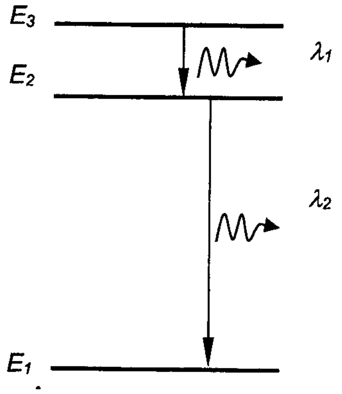
What are the directions of the induced current in the loop and the net magnetic force on the loop as it is being pulled?

	induced current	net magnetic force
A	anticlockwise	to the left
B	clockwise	to the left
C	anticlockwise	to the right
D	clockwise	to the right

25. When a sinusoidal e.m.f of peak value V is connected across a resistor R, a current of peak value I flows through it.
What is the mean power dissipated in the resistor?

A I^2R B $\frac{IV}{\sqrt{2}}$ C $\frac{I^2R}{\sqrt{2}}$ D $\frac{V^2}{2R}$

26. The diagram below shows a simplified representation of the three electron energy levels in an atom.



Cool vapour of this element at low pressure is bombarded with electrons accelerated from rest across a potential difference *V*. Two possible transitions which result in the emission of photons of wavelengths $\lambda_1 = 6.22 \times 10^{-7}$ m and $\lambda_2 = 1.78 \times 10^{-7}$ m are observed.

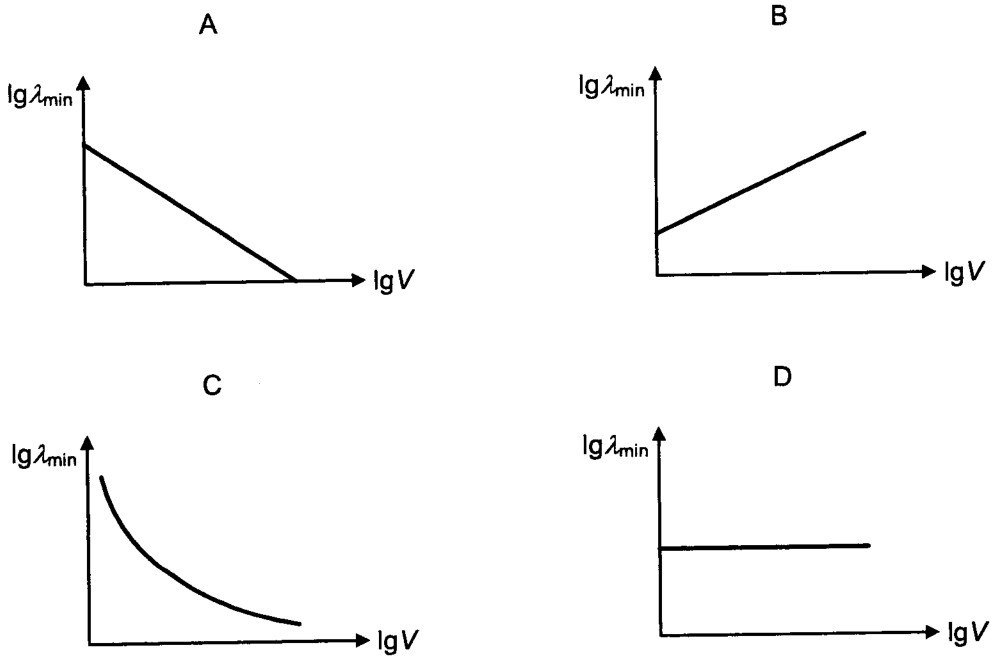
What is the minimum value of *V* for the above transitions to occur?

A 1.56 V B 2.80 V C 7.00 V D 9.00 V

27. The position of a subatomic particle with a momentum of 2×10^{-22} N s is measured to within an uncertainty of $\pm 1 \times 10^{-10}$ m. What is the minimum percentage uncertainty in the kinetic energy of the particle?

A 0.03% B 0.07% C 3% D 7%

28. Electrons accelerated from rest by a potential difference V are directed to hit a metallic target to produce X-rays. It produces continuous as well as characteristic X-rays. If λ_{min} is the shortest possible wavelength of X-ray in the spectrum, which of the following shows the variation with $\lg V$ of $\lg \lambda_{min}$?



29. The nuclear reaction P + Q $\rightarrow$ X + Y proceeds with a release of energy. Which of the following statement must be correct?

A Mass of X and Y is larger than mass of P and Q.
B Momentum of X and Y is larger than momentum of P and Q.
C Total binding energy of X and Y is larger than total binding energy of P and Q.
D Binding energy per nucleon of both X and Y are larger than binding energy per nucleon of P or Q.

30. A radioactive sample of half-life of 10 minutes is placed 40.0 cm away from a radiation detector. The detector gives an average count-rate of 39.0 s^{-1}. In the absence of the radioactive sample, the detector records an average count-rate of 5.0 s^{-1}.

After 20 minutes, the detector, which is still facing the radioactive sample, is moved 20.0 cm nearer the radioactive sample. The sample can be regarded as a point source of radiation.

What is the average count rate on the detector?

A 8.5 s^{-1} B 13.5 s^{-1} C 34.0 s^{-1} D 39.0 s^{-1}

End of paper

VICTORIA JUNIOR COLLEGE
2022 JC2 PRELIMINARY EXAMINATIONS
Higher 2

Name : ______________________ CT group : ______________

PHYSICS **9749 / 02**

Paper 2 Structured Questions

8 – 10 am
2 Hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and CT group at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use a soft pencil for any diagrams or graphs.

Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
sf	
units	
g	
Total (max. 80)	

This question set consists of a total of **16** printed pages.

Data

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permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
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elementary charge,	$e = 1.60 \times 10^{-19}$ C
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the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
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Formulae

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work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\varphi = -\frac{GM}{r}$
temperature	$T/K = T/°C + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \dots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \dots$
electric potential,	$V = Q/4\pi\varepsilon_0 r$
alternating current/voltage,	$x = x_0 \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** questions in the spaces provided

1(a) A massive truck is parked along the roadside on a flat surface. Adam pushes the truck, and it does not move. He justifies this by saying that the two forces that he and the truck exert on each other are equal and opposite, so they cancel out each other. Using Newton's laws of motion, comment on his explanation and explain why the truck does not move. [4]

(b)(i) State the principle of conservation of momentum. [1]

(ii) In Figure 1.1 below, an 80 kg man is on a ladder hanging from a balloon that has a total mass of 320 kg (including the basket passenger). The balloon is initially stationary relative to the ground. The man on the ladder begins to climb at 2.5 m s^{-1} as seen by an observer on the ground.

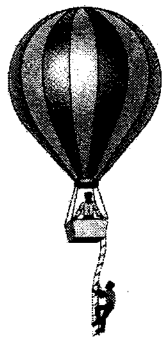


Fig. 1.1

(1) Determine the speed and direction that the balloon moves at. [3]

(2) The man decides to stop climbing. State the speed of the balloon. [1]

2(a) Figure 2.1 shows a light spring of a spring constant k = 160 N m^{-1} rests vertically on the bottom of a large beaker of water. A 5.0 kg block of wood, with a density of 650 kg m^{-3}, is connected to the spring, and the block-spring system is allowed to come to a static equilibrium. The block of wood has two-thirds of its volume partially submerged in the water. Density of water is 1000 kg m^{-3}.

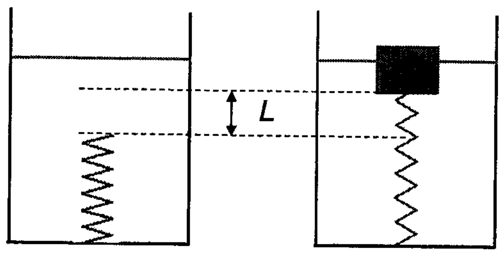


Figure 2.1

(i) Using the figure below, draw and label clearly all the forces exerting on the block of wood. [2]

(ii) Determine L. [3]

(b) A 1200 N uniform boom AC is supported by a cable perpendicular to the boom as shown in Figure 2.2. The cable joins the boom at point B where BC = $\frac{AC}{4}$. The boom is hinged at the bottom, and a 2000 N weight hangs from its top.

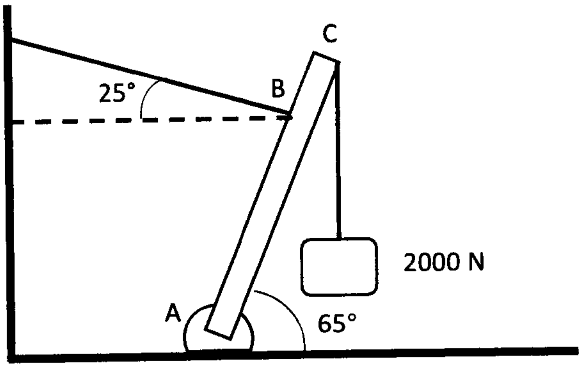


Figure 2.2

(i) Determine the tension in the supporting cable. [3]

(ii) Explain why the force acting on the boom at the hinge is not vertical. [2]

3. 350 g of liquid water at 100 °C is turned into steam at 100 °C at an atmospheric pressure of 1.0×10^5 Pa.
[Density of water = 1000 kg m^{-3};
Mass of one mole of water molecules = 18 g;
Specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}]

(a) Assuming that the steam behaves like an ideal gas, calculate its volume. [3]

(b) Calculate the work done by the steam as it expands against the atmosphere. [3]

(c) Calculate the increase in internal energy of the liquid water as it turns into steam. [3]

(d) State the form of energy that the increase in internal energy takes. [1]

4(a) A small ball rests at point P on a curved track of radius r, as shown in Fig 4.1:

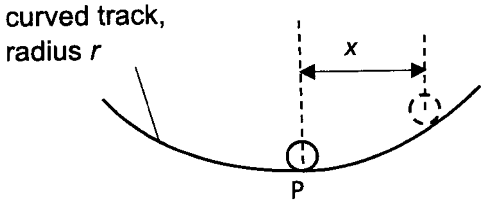


Fig 4.1

The ball is moved a small distance to one side and is then released. The horizontal displacement x of the ball is related to its acceleration a towards P by the expression

$$a = -\frac{gx}{r}$$

where g is the acceleration of free fall.

(i) Explain why the ball will undergo simple harmonic motion. [2]

(ii) The radius r of curvature of the track is 28 cm.
Determine the time interval τ between the ball passing point P and then returning to point P. [3]

(b) The variation with time *t* of the displacement *x* of the ball in **(a)** is shown in Fig 4.2.

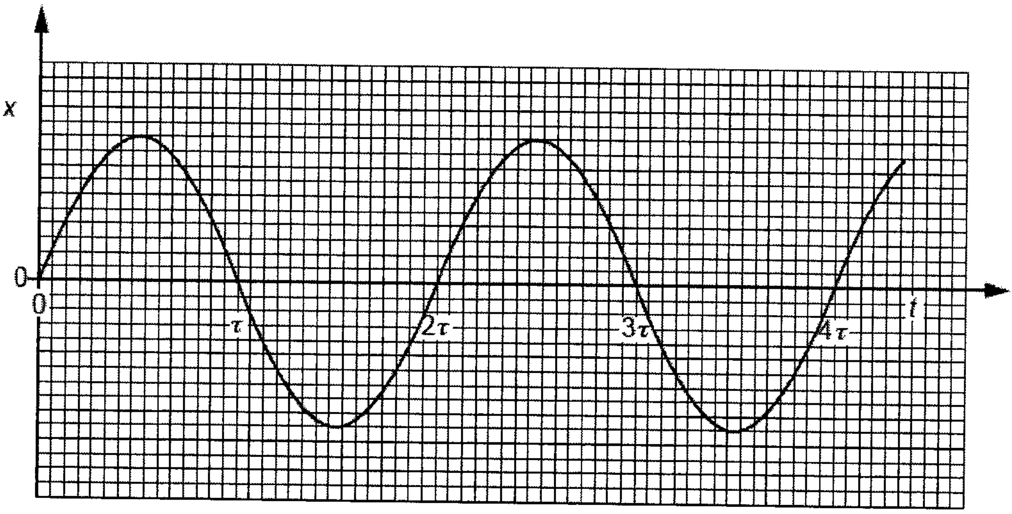


Fig 4.2

Some moisture now forms on the track, causing the ball to come to rest eventually.

On the axes of Fig 4.2, sketch the variation with time *t* of the displacement *x* of the ball for the first two periods after the moisture has formed. Assume the moisture forms at *t* = 0. [2]

5. The pick-up on an electric guitar produces an electrical signal from the vibrations of the guitar strings. The pick-up consists of a small coil of insulated wire wound round a small cylindrical magnet as illustrated in Fig. 5.1.

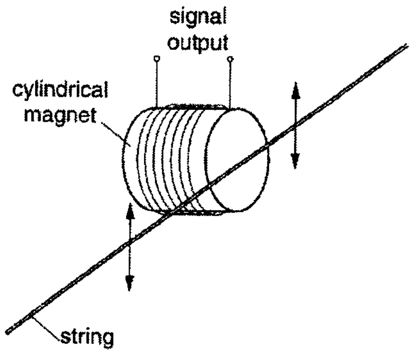


Fig. 5.1

The strings of the electric guitar are made of steel. When a string vibrates, an electrical signal is generated between the terminals of the coil.

(a)(i) State Faraday's law of electromagnetic induction. [1]

(ii) Use Faraday's law to explain why an electric signal is generated between the terminals of the coil. [3]

(iii) Suggest why nylon strings cannot be used for an electric guitar. [1]

(b) Consider a guitar string which is stretched between two fixed clamps 64.0 cm apart. The wire is set vibrating at its fundamental (lowest) frequency and the speed of the waves propagating along the string is 300 m s^{-1}.

Show that the string is vibrating at a frequency of 230 Hz. [2]

(c) Assume that the magnet (seen in Fig. 5.1) produces a uniform magnetic flux density of 4.50 mT over a 2.00 cm segment of the string. (The magnetic field over the rest of the string is negligible.) The section of the string in the magnetic field vibrates with an amplitude of 1.50 cm and in a direction that is perpendicular to the field. This means that, besides the e.m.f. induced in the pick-up coil, there is also an e.m.f. induced between the ends of the string.

Using your answer from (b), calculate the maximum e.m.f. induced between the ends of the string. (Ignore the e.m.f. induced in the pick-up coil.) [3]

6(a) Isotope X undergoes radioactive decay to form isotope Y. The half-life of isotope X is 2.0×10^5 years. The activity of a pure sample of isotope X extracted from an ore is measured to be 1.1×10^7 Bq.

(i) Explain why the measured activity of the sample X is relatively constant. [2]

(iii) It is discovered that isotope Y undergoes radioactive decay to form isotope Z. The half-life of isotope Y is 1.5 hours.

1. Calculate the decay constant of Y. [1]

2. The number of isotope Y in the sample is found to be constant. Explain how this is possible. [1]

3. Hence, calculate this constant number of nuclei of Y. [2]

b(i) Th-232 decays by alpha-emission with a decay constant of 4.95×10^{-11} yr^{-1}. This is the beginning of a decay chain which eventually ends in Pb-208. A sample of rock is found to contain both Th-232 and Pb-208 such that the ratio of the number of nuclei of Th-232 to Pb-208 is 5:1.

When the rock was formed, there was no Pb-208 present in the sample. Estimate the age of the rock in years. [2]

(ii) State the assumption made in **(b)(i)** regarding the intermediate product nuclei. [1]

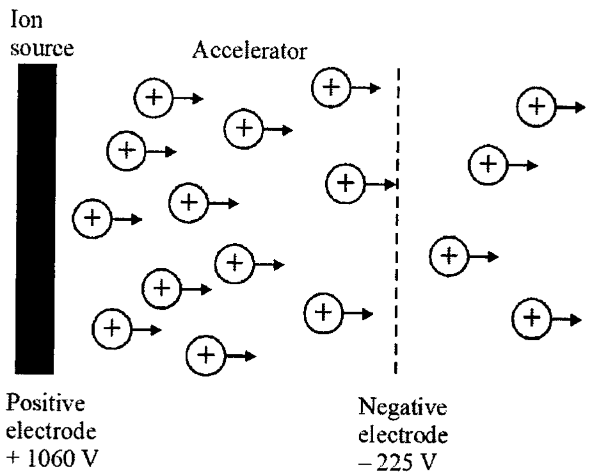
(iii) State with a reason, whether your answer in **(b)(i)** is an overestimate or an underestimate of the age of the rock if the assumption in **(b)(ii)** is not valid. [1]

7. This question examines two ways to propel a spacecraft: using an ion engine and using a solar sail.

Using an ion engine: Deep Space 1

In 1998 NASA launched the probe called Deep Space 1. It was designed to test new technologies for future deep space and interplanetary missions. Once in orbit, this probe was the first to use an ion engine to propel it on its mission.

The diagram below simplifies the main features of the ion engine.



Atoms of xenon were ionised by the loss of a single electron and then accelerated until they were ejected out of the rear of the probe, providing the means of propulsion. The mass of a xenon ion is 2.2×10^{-25} kg. The positive and negative electrodes were operating at +1060 V and −225 V respectively.

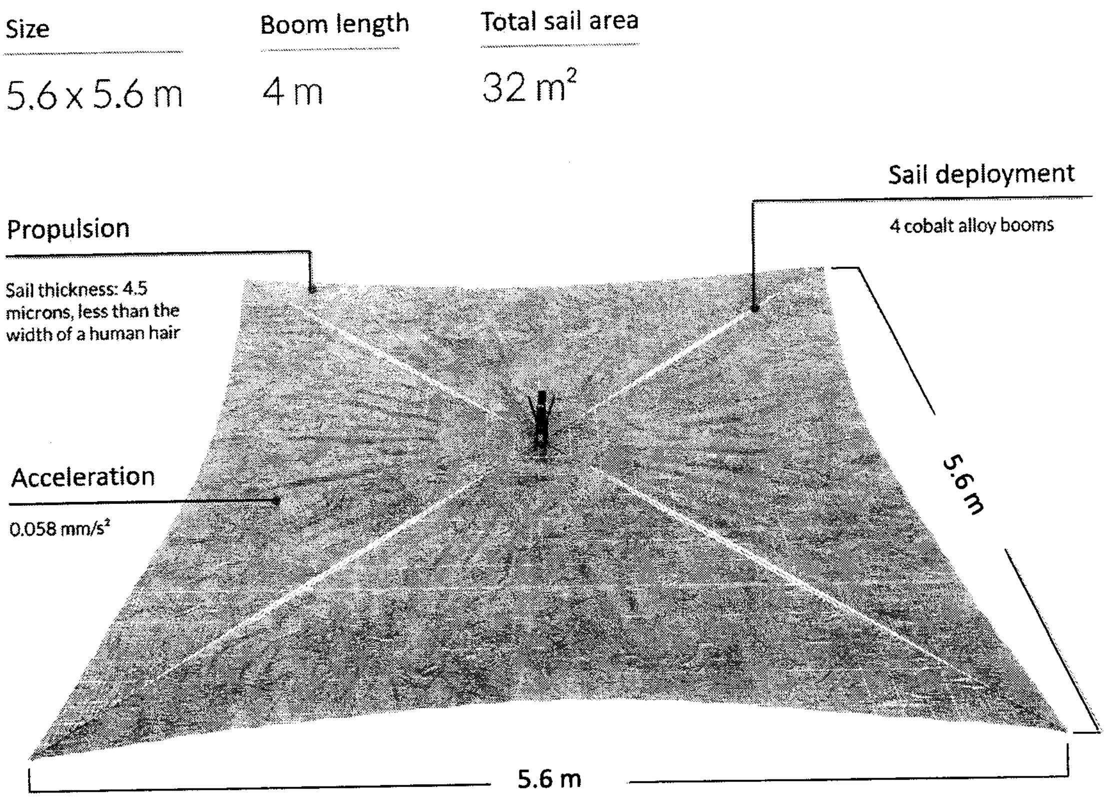
The ion engine used only a very small amount of xenon at a time. It may take 4 days or more just to use up 1 kg of xenon. For its whole mission, Deep Space 1 used about 74 kg of xenon to accelerate to a speed of about 4.3 km s^{-1}. At that time, this was greater than any spacecraft had ever been able to change its speed. The ion engine thrusted for 678 days, far longer than any propulsion system had ever been operated.

Using a solar sail: LightSail 2

LightSail® is a crowdfunded project from The Planetary Society to demonstrate that solar sailing is a viable means of propulsion. The LightSail 2 spacecraft, launched on June 25, 2019, uses sunlight alone to change its orbit, and is currently operating under an extended mission to further advance solar sailing technology.

A solar sail, simply put, is a spacecraft propelled by sunlight. Whereas conventional rockets are propelled by the combustion of rocket fuel, a solar sail is pushed forward by light from the Sun. A solar sail does this by capturing the momentum of photons with sheets of large, reflective material such as Mylar.

The picture below shows the LightSail 2 spacecraft.



The sail is 4.5 μm thick and its total area is 32 m^2. The picture also suggests that the spacecraft experiences an acceleration of 0.058 mm s^{-2}.

LightSail 2 is currently orbiting Earth with an orbital radius of about 7020 km. The solar radiation flux (intensity) at that altitude is about 1400 W m^{-2}. The mass of Earth is 6.0×10^{24} kg.

(a) Show that the speed of a xenon ion after being accelerated is about 4.3×10^4 m s^{-1}. [3]

(b)(i) Show that the maximum mass of xenon ejected by the engine per second is 2.9×10^{-6} kg. [2]

(ii) Calculate the maximum thrust (the force of propulsion) on Deep Space 1. [2]

(c) Assuming that the mass of Deep Space 1 remains constant, estimate its mass. [2]

(d) Simply firing xenon ions into space would leave Deep Space 1 negatively charged. Suggest a reason why this would lead to reduced thrust. [1]

(e) Chemical rockets eject their propellant at about a tenth of the velocity achieved by ion engines but produce much greater thrust by ejecting more than a thousand kilograms per second. Suggest why ion engines may be preferable for missions extending over long distances and periods of time. [2]

(f)(i) Show that the energy E and momentum p of a photon are related by the expression $E = pc$, where c is the speed of light. [2]

(ii) For LightSail 2, show that the total momentum of the photons striking 1 m^2 of sail in one second is 4.7×10^{-6} N s. Assume that the photons strike the sail at right angles. [2]

(iii) Hence, find the force exerted on the whole sail if it is completely reflective. [2]

(iv) Explain how this force in (iii) will change if the whole sail is completely non-reflective so that all of the incident light is absorbed. [2]

(g) Discuss whether the centripetal acceleration of LightSail 2 can be 0.058 mm s^{-2}. [2]

(h) Comparing the solar sail with the ion engine, suggest one advantage and one disadvantage of the solar sail. [2]

End of paper

VICTORIA JUNIOR COLLEGE
2022 JC2 PRELIMINARY EXAMINATIONS
Higher 2

Name : ______________________________ CT group : __________

PHYSICS **9749 / 03**
Paper 3 Longer Structured Questions **0800 – 1000 h**
2 Hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and CT group at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use staples, paper clips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer **one** question only.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
Section B	
7	
8	
Total (max. 80)	

This document consists of **20** printed pages.

Data

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

Formulae

uniformly accelerated motion,	$s = ut + (½) at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{GM}{r}$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_o \cos\omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
electric current	$I = Anvq$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = Q/4\pi\varepsilon_0 r$
alternating current/voltage,	$x = x_0 \sin \omega t$
Magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
Magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
Magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided.

1. Figure 1.1 below shows a ball of mass 150 g, attached to an elastic cord, being thrown vertically upwards, with a velocity 5.7 m s^{-1}, from the ground. The cord has a spring constant of 45 N m^{-1}. Initially the cord is unstretched but after a while it becomes stretched. The cord obeys Hooke's law and air resistance is ignored.

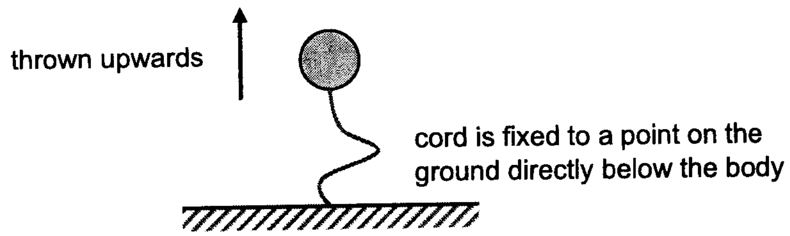


Figure 1.1

(a) Given that the maximum height reached by the ball is 1.12 m, calculate the extension of the elastic cord. Explain your working. [3]

(b) Hence, determine the length of the unstretched cord. [1]

(c) Sketch, on Figure 1.2, the variation with displacement of the kinetic energy *K*, gravitational potential energy *G* and the elastic potential energy *E* when the mass moves from the ground to maximum height. Label your graphs clearly and indicate on the scale with values from parts (a) and (b). [4]

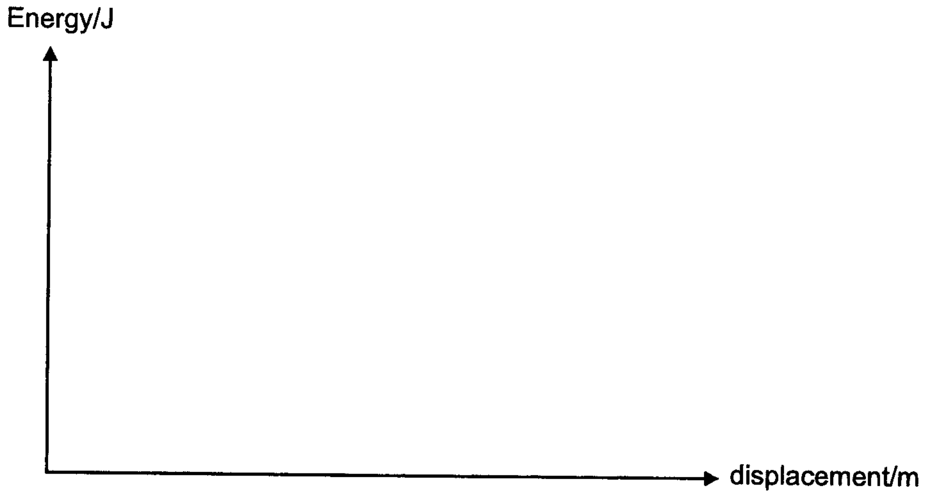


Figure 1.2

(d) The ball, still attached with the elastic cord, is now being swirled into a vertical circle shown in Figure 1.3.

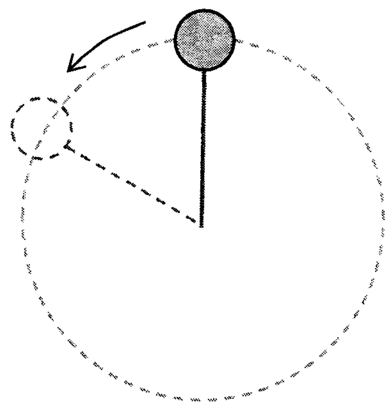


Figure 1.3

Discuss whether any work is done by the tension, in the cord, acting on the ball. [2]

2. A parallel sound beam is emitted from a source perpendicularly towards a wall 15 cm away.

(a) Explain why a stationary wave will be formed between the source and the wall. [2]

(b) The source can be considered to be a node. There are only two more nodes between the source and the wall.

Draw in the space below a diagram representing the stationary wave. Include the source and the wall in your diagram. [1]

(c) The speed of sound is 360 m s^{-1}. Calculate the frequency of the sound. [2]

(d) The location of the node nearest (but not at) the source is marked as 'X'. The source is then replaced with a point source that emits sound uniformly in all directions.

(i) When the sound wave travels directly from the point source to location X, it has an amplitude of 3.0×10^{-5} m. Calculate the amplitude of the wave after it has been reflected by the wall and travels back to location X. Assume that no energy is lost when the wave is reflected by the wall. [3]

(ii) Calculate the amplitude of the resultant sound wave at location X due to the interference of the wave that comes directly from the point source, and the wave that is reflected by the wall. Explain your reasoning. [2]

3(a) State what is meant by electric field strength. [2]

(b) Two point charges A and B are situated a distance 15 cm apart in a vacuum, as illustrated in Fig. 3.1.

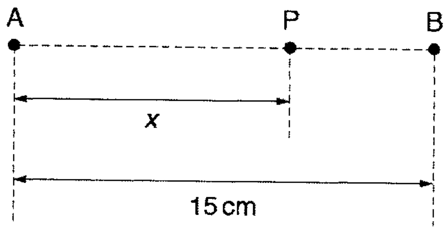


Fig. 3.1

Point P lies on the line joining the charges and is a distance x from charge A.
The variation with distance x of the electric field strength E at point P is shown in Fig. 3.2.

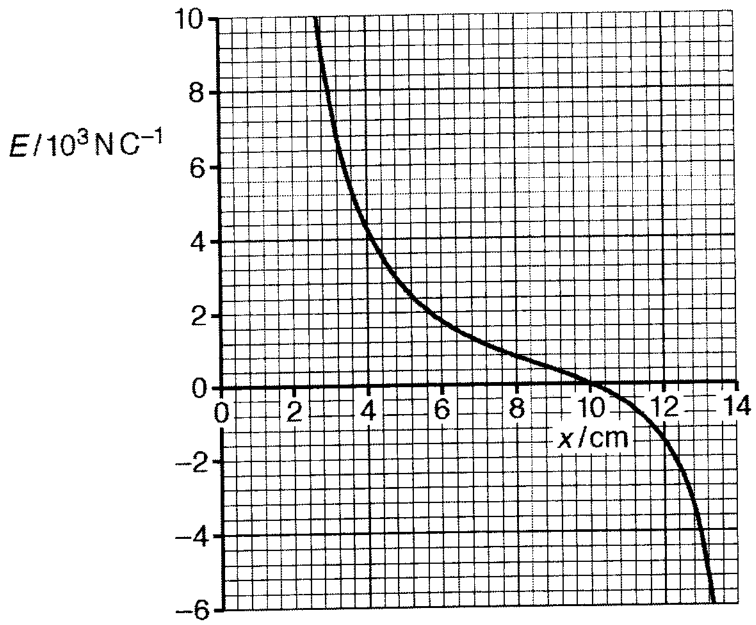


Fig. 3.2

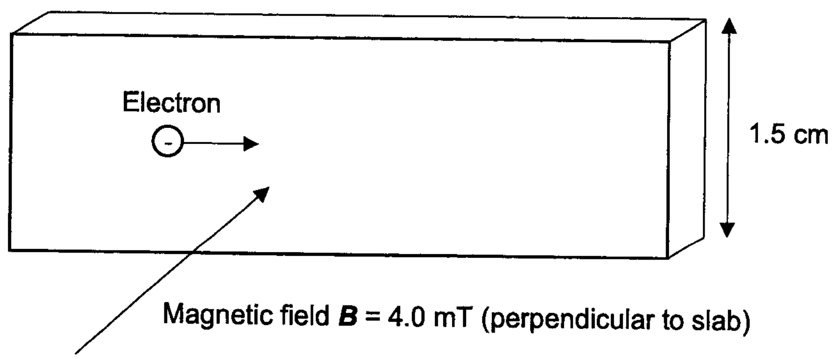
(i) By reference to the direction of the electric field, state and explain whether the charges A and B have the same, or opposite, signs. [2]

(ii) State why, although charge A is a point charge, the electric field strength between x = 3.0 cm and x = 7.0 cm does not obey an inverse-square law. [1]

(iii) A proton is at point P where x = 6.0 cm. Use data from Fig. 3.2 to determine the magnitude of the acceleration of the proton. [3]

(iv) Use Fig. 3.2 to determine the ratio of the magnitude of charge A to the magnitude of charge B. [3]

4. An electric current consisting of electrons flowing horizontally from left to right through a thin slab of conductor of width 1.5 cm. The slab of conductor is immersed in a uniform magnetic field ***B*** of 4.0 mT, which is applied perpendicularly to the slab of conductor, as shown in the diagram below:



(a) The speed of the electrons is 0.60 mm s^{-1}. Calculate the magnetic force acting on each electron. [2]

(b) Because of the magnetic force, the electrons accumulate on one side of the conductor. Indicate on the diagram above, where the electrons will accumulate. [1]

(c) A vertical electric field is created across the slab as a result of the accumulation of electrons.

(i) Draw on the diagram above an arrow to represent the electric field. Label it as ***E***. [1]

(ii) As more and more electrons accumulate, the electric field gets stronger and stronger. The rate of electron accumulation decreases. Eventually, further electrons do not accumulate anymore, but continue to travel horizontally.

1. Explain why the rate of accumulation of electrons decreases, and why eventually further electrons do not accumulate anymore. [3]

2. Calculate the potential difference across the horizontall sides of the slab of conductor when the accumulation of electrons stops. [3]

5. When light illuminates a clean surface of potassium, electrons can be emitted. This is the photoelectric effect. Fig 5.1 shows a section of the surface at a microscopic scale.

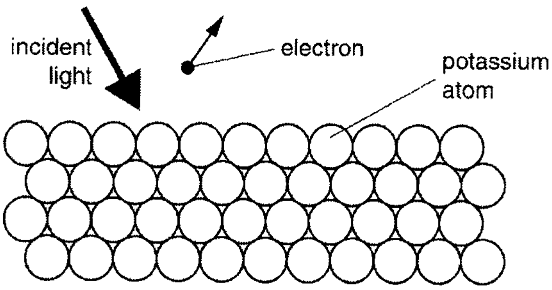


Fig 5.1

(a) Electrons are emitted when the incident light is violet, but not when the incident light is red. Increasing the intensity of violet light causes more electrons to be emitted. Increasing the intensity of red light has no effect.

Use the quantum theory of light to explain these observations. [4]

(b) Einstein explained the photoelectric effect by suggesting that there is a minimum energy ϕ, the work function, which must be supplied to remove an electron from the surface of a metal.

The work function for potassium is 4.5×10^{-19} J.

Show that photons of frequency less than 6.8×10^{14} Hz cannot remove electrons from a potassium surface. [2]

(c) The variation with frequency f of the maximum kinetic energy E_k of the emitted electrons is shown in Fig. 5.2

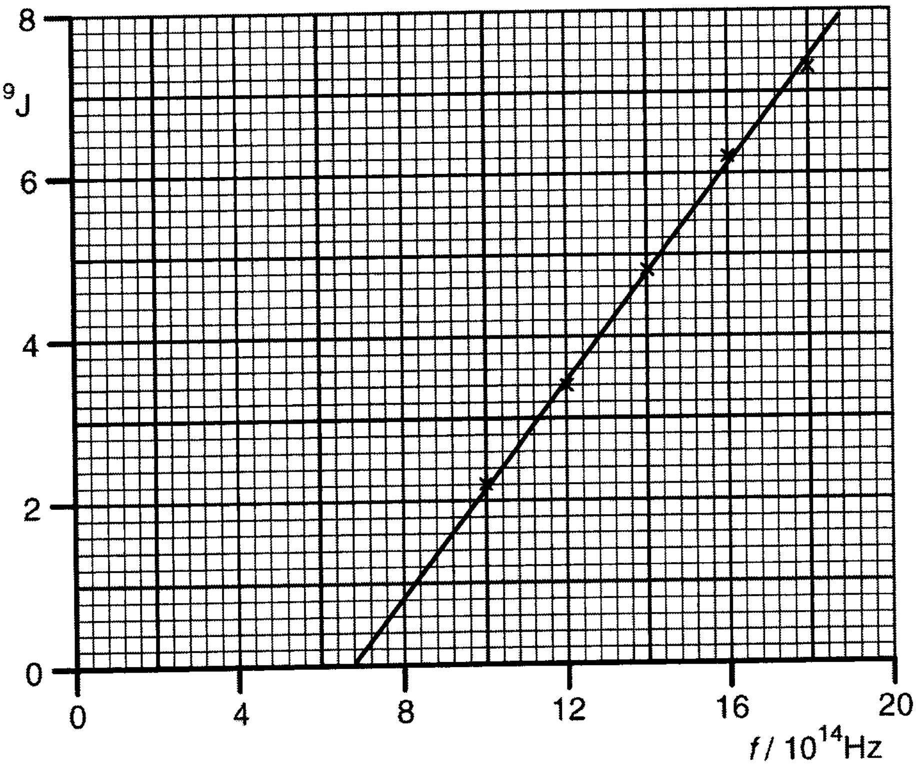


Fig. 5.2

(i) Explain the shape of the graph in Fig.5.2. [2]

(ii) Use Fig. 5.2 to determine a value for the Planck constant. [2]

6(a) Define binding energy. [1]

(b) A minimum energy Q is required to remove a neutron from a helium-4 nuclide to form a helium-3 nuclide. The following data is given:

Binding energy per nucleon of helium-4 nuclide = 6.8465 MeV
Binding energy per nucleon of helium-3 nuclide = 2.2666 MeV
Mass of neutron = 1.0097 u
1u = 931.494 MeV

(i) Write the nuclear equation for this reaction. [1]

(ii) Calculate Q. [3]

(iii) Hence, calculate the difference in mass between the helium-3 and helium-4 nuclides. [3]

(iv) With reference to the above process, explain why the mass difference is less than the mass of a neutron. [1]

Section B

Answer **one** question from this section in the spaces provided.

7(a) State *Newton's law of gravitation.* [2]

(b) A satellite of mass m is to be placed into orbit round the Earth at a vertical distance of 350 km above the Earth's surface.
(mass of Earth = 6.0×10^{24} kg, radius of Earth = 6.4×10^{6} m)

(i) Calculate the magnitude of the gravitational field strength at a point P, 350 km above the Earth's surface and state its direction. [3]

(ii) Calculate, using the answer in (b)(i), the time taken for the satellite to complete one orbit round the Earth. [2]

(c)(i) Define gravitational potential at a point in a gravitational field. [1]

(ii) Explain why gravitational potential is always negative. [2]

(iii) Fig. 7 below shows the variation of potential between the surface of the Moon and the surface of Earth along the line joining their centres.

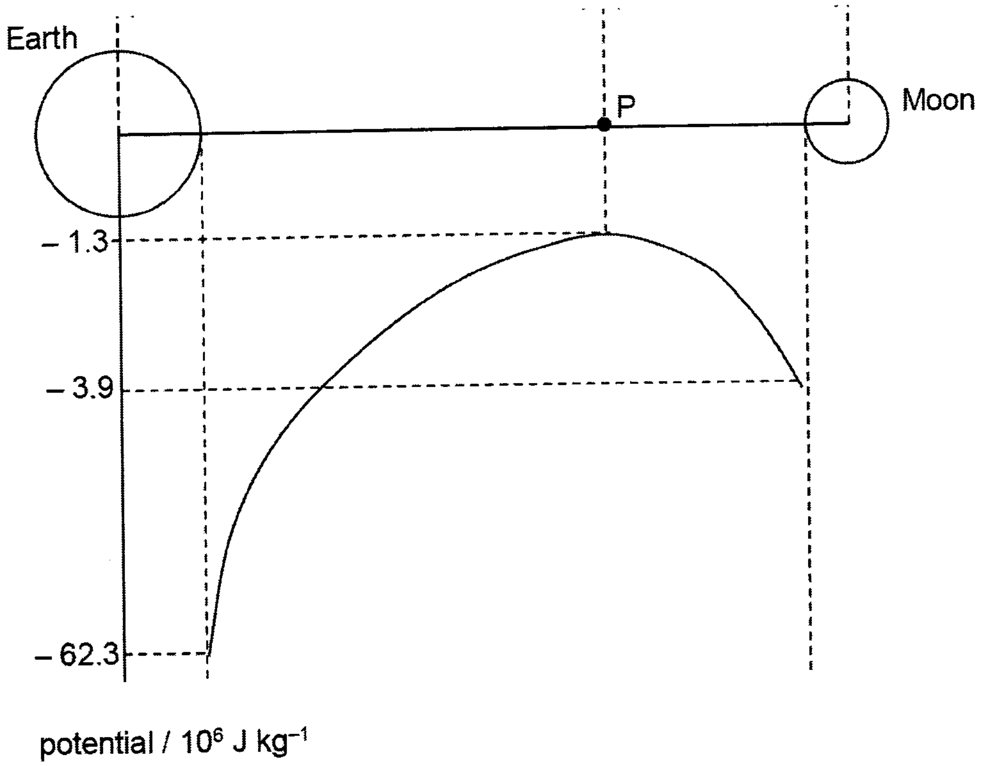


Fig. 7

Explain why the gradient of the potential graph near the surface of the Earth and that near the surface of the Moon have *opposite* signs. [3]

(iv) Using the values in Fig. 7, determine the *minimum* speed that a spacecraft of mass *m* needs to be propelled from the surface of the Moon if it is to reach the surface of the Earth. [3]

(d)(i) Data for a certain planet are given below:
Mass of planet = 1.20×10^{24} kg
Diameter of planet = 7.50×10^{6} m

Calculate the escape velocity of a mass on this planet. Explain your working. [3]

(ii) An atmosphere is formed when gases such as nitrogen is allowed to orbit around the planet. Given that the average speed of a molecule of nitrogen at the surface of the planet is 3.9×10^{4} m s^{-1}, explain whether this planet has an atmosphere. [1]

8(a) The filament of a 230 V light bulb is 0.72 m long and has a radius of 6.0×10^{-2} mm. The resistivity of the filament metal is $1.2 \times 10^{-5}\,\Omega$ m.

(i) Calculate the resistance of the filament of the light bulb. [2]

(ii) Calculate the power supplied by the 230 V supply. [2]

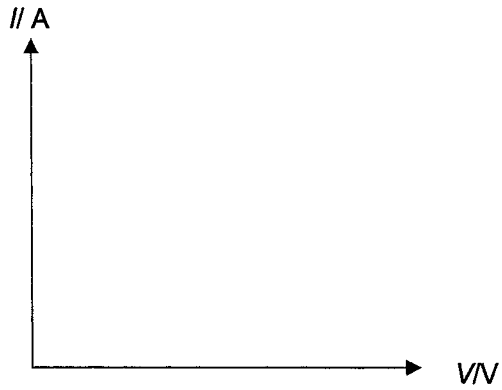
(iii) The filament of the bulb becomes thinner over time. Suggest why this happens. [1]

(iv) Explain the effect the thinning of the filament wire will have on:

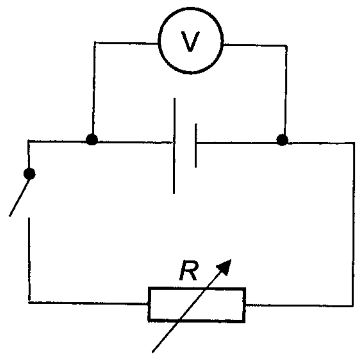
1. the resistance of the filament, [2]

2. its power output. [1]

(v) On the same graph, sketch the current-voltage characteristics for a filament lamp and an ohmic device. [2]



(b) The following circuit is set up, with an ideal voltmeter connected across the terminals of a dry-cell battery. The battery is connected to a variable resistor *R*.



(i) Initially the switch is open and the voltmeter reads 2.10 V.

1. Determine the e.m.f. of the battery. [1]

2. State the energy supplied by the battery for every coulomb of charge delivered by the battery. [1]

3. With the switch open, explain whether any energy is being generated in the battery if the voltmeter is ideal. [2]

(ii) The variable resistance *R* is set to 10 Ω. When the switch is closed, the voltmeter reading drops to 2.00 V. Deduce a value for the internal resistance of the battery. [3]

(iii) The efficiency of the dry-cell battery is defined as the ratio of energy dissipated in variable resistor *R* over the energy dissipated in the complete circuit. Explain how the efficiency of cell will change when *R* increases. [3]

End of paper

2022 VJC Prelim H2 P1 Suggested solution

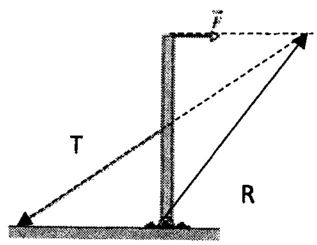
Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans	Qn	Ans
1	D	6	D	11	A	16	A	21	C	26	D
2	B	7	B	12	A	17	C	22	A	27	D
3	B	8	B	13	D	18	A	23	C	28	A
4	A	9	B	14	D	19	B	24	B	29	C
5	C	10	B	15	B	20	D	25	D	30	D

1. **Ans: D**

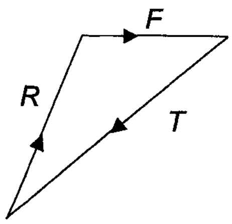
Base units of self-inductance $= \frac{V}{As^{-1}} = \left(\frac{W}{A}\right)\frac{1}{As^{-1}} = \left(\frac{kgm^2s^{-2}}{As}\right)\frac{1}{As^{-1}} = kgm^2s^{-2}A^{-2}$

2. **Ans: B**

For the rod to be in equilibrium, the 3 forces acting on the rod should extrapolate and intercept at a common point.



The 3 forces should form a vector triangle with the forces pointing in a single direction.



3. **Ans: B**

Total momentum = $2Mv - Mv = Mv$

Option A is a correct statement (so don't choose it). The spheres cannot come to rest at the same time as that will give a total momentum of 0 and not *Mv*.

Option C is a correct statement. For total momentum to be conserved, the change in momentum of A and B must be equal and opposite.

Option D is a correct statement. Newton's 3rd law.

4. **Ans: A**

Work done by F on object = area under the graph = $K + L + M$
Work done against frictional force = $L + M$ (friction is constant, = 5 N)

Net work done by F = work done by F – work done against frictional force
= $K + L + M - (L + M)$
= K
= gain in kinetic energy of the object

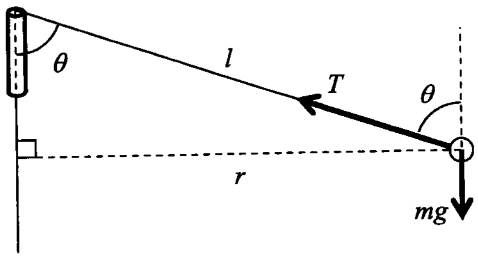
5. **Ans: C**

Output power, $P_o = 0.25P_i = (0.25)(10) = 2.5$ W

$$P_o = \frac{E}{t}$$

$$t = \frac{E}{P_o} = \frac{mgh}{P_o} = \frac{(20)(0.50)}{2.5} = 4.0 \text{ s}$$

6. **Ans: D**



For circular motion,
Horizontally, $T\sin\theta = mr\omega^2$ where T = tension in string
θ = angle between string and vertical.
m = mass of bob
r = radius of circular motion.

$$\Rightarrow T\sin\theta = m(l\sin\theta)(2\pi f)^2$$

$$l = \frac{T}{4\pi^2 m f^2}$$

$$l \propto \frac{1}{f^2}$$

Note: T is constant as it is equal to the weight of the brass weights.

7. Ans: B

Magnitude of gravitational acceleration = potential gradient

At the height of 370 km, $g = \frac{[-617.0-(-649.6)]\times 10^3}{[380-360]\times 10^3} = 1.63\,\text{m s}^{-1}$

8. Ans: B

At a *higher* orbit, r is *increased,*

Gravitational force *decreases* $F_G = \frac{GMm}{r^2}$

Gravitational potential energy *increases* $U = -\frac{GMm}{r}$

Linear speed *decreases* $\frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{GM}{r}}$

Kinetic energy *decreases* $\frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow \frac{1}{2}mv^2 = \frac{GMm}{2r}$

9. Ans: B

Heat was removed from it at a constant rate when it was totally liquid, and when totally solid.

$$mc_{liquid}\left(\frac{\Delta T}{t}\right)_{liquid} = mc_{solid}\left(\frac{\Delta T}{t}\right)_{solid}$$

$$c_{liquid}\left(\frac{400-300}{100}\right)_{liquid} = c_{solid}\left(\frac{300-200}{50}\right)_{solid}$$

$$c_{liquid} = 2c_{solid}$$

10. Ans: B

$$C_{rms} = \sqrt{\frac{3RT}{M}} \propto \sqrt{T} \propto \sqrt{PV} \text{ since } PV = nRT$$

$$\frac{C_{rms2}}{C_{rms1}} = \sqrt{\frac{P_2V_2}{P_1V_1}} = \sqrt{\frac{2(2)}{1(1)}} = 2$$

11. Ans: A

At U, velocity is negative (negative gradient of x-t graph), acceleration is positive (since displacement is negative).
At Y, velocity is positive, acceleration is negative.

12. **Ans: A**

Max force = m a_{max} = m $\omega^2 x_0$
= 20 x 10^{-3} $(3\pi)^2$ (6 x 10^{-3}) = 0.011 N

13. **Ans: D**

The peak of B occurs at t = 0, while the peak of A occurs one quarter of a cycle later. So A lags B by 90°.

14. **Ans: D**

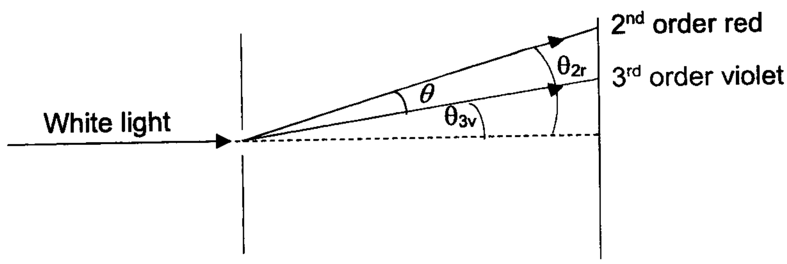
$v_{max} = \omega x_0$
$= 2\pi f x_0$
$= 2\pi \frac{v}{\lambda} x_0$
$= 2\pi \times \frac{4.0}{0.15} \times 0.030$
$= 5.0 \text{ m s}^{-1}$

15. **Ans: B**

High resolving power means objects close together will still be well resolved. To improve the resolving power, the Raleigh's criterion angle θ should be made smaller.

Since $\sin\theta = \frac{\lambda}{a}$, θ can be reduced by making a, the slit width, bigger.

16. **Ans: A**



For each order, red (longest wavelength) will diffract more than violet (shortest wavelength).

2nd and 3rd orders overlap means the 2nd order red diffracts more than 3rd order violet

Slit separation d = $\frac{1\times10^{-3}}{300}$ = 3.333 x 10^{-6} m

Using $\sin\theta = \frac{n\lambda}{d}$,

For red: $\sin\theta_{2r} = \frac{2\times700\times10^{-9}}{3.333\times10^{-6}}$

$\theta_{2r} = 24.8^o$

For violet: $\sin\theta_{3v} = \frac{3\times400\times10^{-9}}{3.333\times10^{-6}}$

$\theta_{3v} = 21.1^o$

$\therefore \theta = \theta_{2r} - \theta_{3v}$

$= 24.8 - 21.1$
$= 3.7^o$

17. Ans: C

The electric force on the positive charge is pointing in the direction of the E-field. So the external force exerted to move the charge is pointing in the opposite direction to the E-field.

Work done by external force, $W = F s \cos\theta = qEs \cos 0^\circ$
$= (2.6 \times 10^{-8})(3.0 \times 10^{5})(4.0 \times 10^{-3})$
$= +3.1 \times 10^{-5}$ J

18. Ans: A

When the electron moves downward, its gravitational PE decreases. (The Earth's gravitational field is pointing vertically downward.)

The electron has negative charge, so it will accelerate towards the positive plate due to the downward electric force on it. Its gain in KE comes mostly from its loss of electric PE. So its electric PE decreases.

(H2 students can also reason this way: when a negative charge moves from a region of lower electric potential to another region of higher electric potential, its electric PE decreases.)

19. Ans B

With another identical lamp added parallel to X, the effective resistance across X is halved of its initial value. Total resistance in the circuit drops. By potential divider principle, potential difference across X is smaller and across Y is larger. Brightness of the lamp depends on the power ($P=V^2/R$) delivered to lamp, hence X is less bright and Y is brighter.

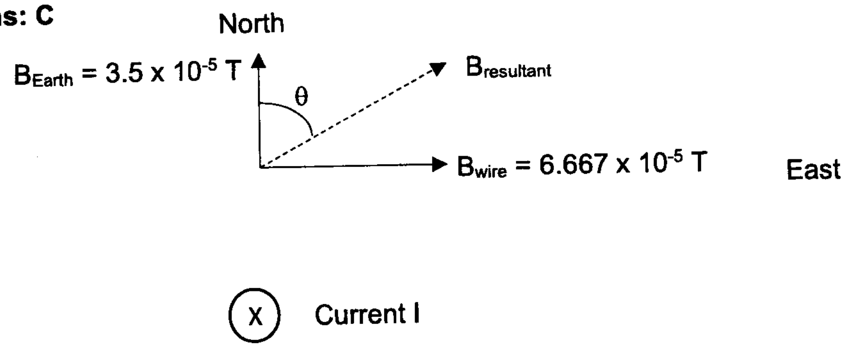
20. **Ans D**

When switch is open,
V_{PQ} = (0.70/1.0) x 2.0 V = 1.4 V
□ E = 1. 4 V

When switch is closed,
V_{PQ} = (0.50/1.0) x 2.0 V = 1.0 V

By potential divider principle,
p.d. across 2.0 Ω□, $V_{2.0□}$ = (2.0/(2.0+r)) x 1. 4 V
1.0 = (2.0/(2.0+r)) x 1. 4
□ r = 0.80 Ω

21. **Ans: C**



By right hand grip rule, magnetic field produced by wire at compass, B_{wire}, points to east.

$$B_{wire} = \frac{\mu_0 I}{2\pi r}$$
$$= \frac{4\pi \times 10^{-7} \times 3.0}{2\pi \times 9 \times 10^{-3}}$$
$$= 6.667 \times 10^{-5}\ T$$

$$\tan\theta = \frac{B_{wire}}{B_{Earth}}$$

$$\theta = \tan^{-1}\frac{6.667}{3.5}$$
$$= 62^{\circ}$$

22. **Ans: A**

Going through crossed fields undeviated: $F_E = F_B$

$$qE = B_1qv$$

$$\text{Speed of particle, } v = \frac{E}{B_1}$$

Going through 2nd field, undergo circular motion of diameter 60 cm:

$$\frac{mv^2}{r} = B_2qv$$

$$m = \frac{B_2qr}{v}$$

$$= \frac{B_1B_2qr}{E}$$

$$= \frac{2.0\times10^{-5}\times1.2\times2\times1.60\times10^{-19}\times0.30}{6.0\times10^2}$$

$$= 3.8 \times 10^{-27} \text{ kg}$$

23. **Ans: C**

Magnitude of emf induced = rate of change of magnetic flux linkage

$$|E| = \frac{\Delta\Phi}{\Delta t}$$

$$= \frac{NA\Delta B}{\Delta t}$$

$$= \frac{N\pi\left(\frac{d}{2}\right)^2\Delta B}{\Delta t}$$

$$= \frac{(120)\pi\left(\frac{0.30}{2}\right)^2(0.080-0.020)}{4.0}$$

$$= 0.127 \text{ V}$$

$$\approx 130 \text{ mV}$$

(Even when the ends of the coil are not connected to form a closed circuit, there is still an emf induced in it due to the decreasing magnetic flux linkage.)

24. **Ans: B**

Using the right-hand grip rule, the current in the vertical wire produces a magnetic field which is directed into the plane of the paper at the location of the loop. Hence, this produces a magnetic flux linkage Φ with the loop. As the loop moves to the right, Φ decreases. By Faraday's law, an emf is induced in the loop and an induced current flows in the loop because it is a closed circuit. By Lenz's law, the current flows in such a direction so as to oppose the decrease in Φ. Using the right-hand grip rule, the current flows clockwise around the loop, so as to produce a magnetic field which is directed into the plane of the paper (within the loop).

Also, by Lenz's law, the induced current will produce a magnetic force which opposes the motion of the loop. So the net magnetic force on the loop will be to the left.

25. **Ans: D**

Mean power $P_{ave} = ½ P_{max}$

$$= \frac{1}{2}\frac{V^2}{R}$$

26. **Ans: D**

$$E_2 - E_1 = \frac{hc}{\lambda_2} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{1.78\times10^{-7}}$$
$$= 1.12\times10^{-18}\text{ J}$$
$$E_3 - E_2 = \frac{hc}{\lambda_1} = \frac{6.63\times10^{-34}\times3.00\times10^{8}}{6.22\times10^{-7}}$$
$$= 0.32\times10^{-18}\text{ J}$$

Hence $E_3 - E_1 = (1.12+0.32)\times10^{-18}$
$$= 1.44\times10^{-18}\text{ J}$$
$$= 9.00\text{ eV}$$

Hence the minimum p.d to excite electrons must be 9.00 V.

27. **Ans: D**

Heisenberg's uncertainty principle, $\Delta p\Delta x \geq h$

Minimum uncertainty in the momentum, $\Delta p = m\Delta v = \dfrac{h}{\Delta x}$

Minimum uncertainty in the speed, $\Delta v = \dfrac{h}{m\Delta x}$

k.e. = ½ mv^2

Minimum $\dfrac{\Delta\text{k.e.}}{\text{k.e.}}$ = 2 x minimum $\dfrac{\Delta v}{v}$

$$= \frac{2h}{mv\Delta x}$$

$$= \frac{2h}{p\Delta x}$$

$$= \frac{2 \times 6.63 \times 10^{-34}}{2 \times 10^{-22} \times 1 \times 10^{-10}}$$

= 0.07 or 7%

28. Ans: A

$$\lambda_{min} = \frac{hc}{eV}$$

$$\Rightarrow \lg \lambda_{min} = \lg\left(\frac{hc}{e}\right) - \lg V$$

Hence plotting $\lg\lambda_{min}$ vs $\lg V$ would be a straight line graph with negative gradient.

29. Ans C

With a release of energy, products X and Y are more stable than reactants P and Q. Hence total binding energy for X and Y is larger.

30. Ans: D

Initial **actual** count rate C_o = 39.0 – 5.0 = 34.0 s^{-1}

After 20 mins = 2 half-lives, the count rate becomes 34.0 x $(1/2)^2$ = 8.5 s^{-1}

Since radioactive decay is random and the sample is a point source, then the count rate will be inversely proportional to the square of the distance from source to detector, ie.

$$C \propto \frac{1}{r^2}$$

$$\frac{C'}{C} = \frac{\frac{1}{20^2}}{\frac{1}{40^2}} = 4$$

That means the count rate at 20 cm from the source would measure 4 times the count rate at 40 cm from source. Thus the count rate at the 20 cm position would read 8.5 x 4 = 34.0 s^{-1}

The **measured** count rate at the 20 cm position would be 34.0 + 5.0 = 39.0 s^{-1}