ACTUAL 2005 STPM
PHYSICS EXAMINATION PAPER

PAPER 1

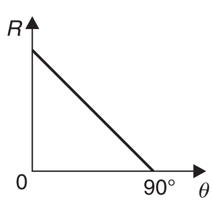
Time: 1h 45 min

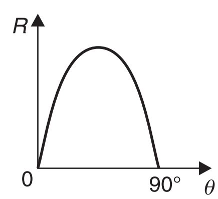
There are fifty questions in this paper.
Answer all questions. Marks will not be deducted for wrong answers.

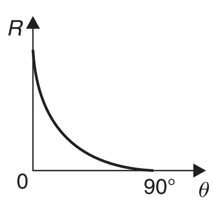
1. The dimension of angular velocity is

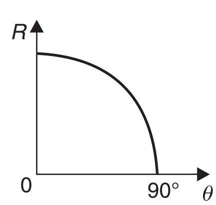
   A T^{-1} **C** LT^{-2}
   B LT^{-1} **D** L^2T^{-1}

2. A ball is thrown upwards several times at the same velocity at different angles of projection. Which of the following graphs shows the variation of the horizontal range R with the angle of projection θ?

   A


   C


   B


   D


3. An athlete leaps over a hurdle of height 1.0 m. The athlete leaps at a distance of 2.0 m before the hurdle and lands 2.0 m after the hurdle. If the angle of the leap is at 45° with the horizontal line, what is the speed at which the athlete leaps?

   A 4.4 m s^{-1} **C** 8.9 m s^{-1}
   B 6.3 m s^{-1} **D** 9.8 m s^{-1}

4. A car of mass m with effective power P climbs a hill of height h at initial velocity u. The car arrives at the peak of the hill at velocity v in time t. Which of the following is true of the motion?
   [Neglect the friction and resistance of motion.]

   A $Pt + \frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mgh$

   B $Pt + \frac{1}{2}mv^2 = \frac{1}{2}mu^2 + mgh$

   C $Pt + mgh = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$

   D $Pt + mgh = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

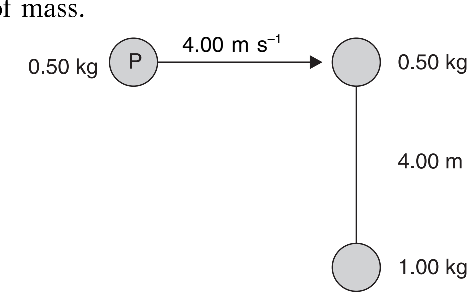
5. Work done for a displacement ds is given by

   A $dW = \vec{F} \cdot d\vec{s}$ **C** $dW = \vec{F} \times d\vec{s}$
   B $dW = \vec{F} \cdot \vec{s}$ **D** $dW = \vec{F} \times \vec{s}$

6. The period of a particle which moves at speed v in a horizontal circle of radius r is

   A $\frac{2\pi}{v}$ **C** $\frac{2\pi r}{v}$
   B $\frac{v}{2\pi}$ **D** $\frac{v}{2\pi r}$

7. The diagram below shows two bodies of masses 0.50 kg and 1.00 kg connected by a light rigid rod of length 4.00 m and placed on a smooth surface. A body P of mass 0.50 kg which moves at velocity 4.00 m s^{-1} collides and sticks to the body of mass 0.50 kg and the system of masses rotates about the centre of mass.



   The angular velocity of the system of masses is

   A 0.25 rad s^{-1} **C** 0.50 rad s^{-1}
   B 0.33 rad s^{-1} **D** 1.00 rad s^{-1}

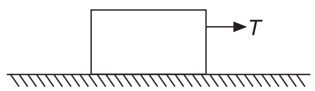
8. A steel ball of mass m and radius r rolls on a surface without slipping. The moment of inertia of the ball about the axis through the centre is $\frac{2}{5}\pi mr^2$. The ratio of the translational

kinetic energy to the rotational kinetic energy is

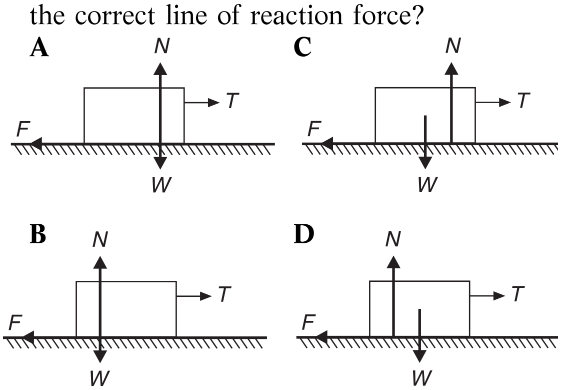
A 2 : 5 **C** 2r : 5
B 5 : 2 **D** 5r : 2

9. If the gravitational field strength at a certain area is uniform, which of the following statements is true?
 A No work is done when a mass is displaced in that area.
 B The gravitational field strength is the same at all points in that area.
 C The gravitational potential is the same at all points in that area.
 D The gradient of the gravitational field strength is of the same magnitude as the gravitational potential.

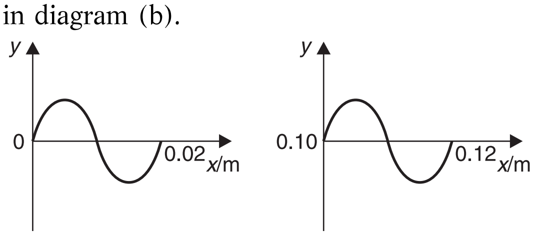
10. The diagram below shows a block of weight W being pulled by force T on a rough horizontal surface.



If the block is not tilted up, with N the normal reaction of the horizontal surface on the block and F the friction between the block and the surface, which of the following diagrams shows the correct line of reaction force?



11. Diagram (a) below shows a graph of displacement y against distance x for a progressive wave at a certain time. At time 0.4 s later, the profile of the wave is shown in diagram (b).

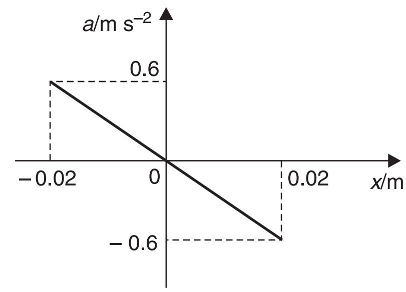


(a) (b)

The frequency of the wave is

A 0.5 Hz **C** 5.0 Hz
B 2.5 Hz **D** 12.5 Hz

12. The graph below shows the variation of acceleration a with displacement x of a particle performing a simple harmonic motion.



The frequency of oscillation of the simple harmonic motion is

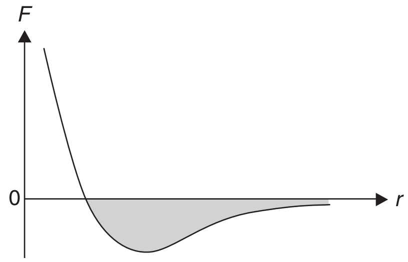
A 0.87 Hz **C** 4.77 Hz
B 1.15 Hz **D** 34.41 Hz

13. A particle performs an oscillation without damping. Which of the following quantities is **not** constant for the oscillation?
 A Force **C** Total energy
 B Amplitude **D** Angular frequency

14. When sound waves propagate in air, two particles which are 0.2 m apart vibrate antiphase. If the speed of sound in air is 320 m s^{-1}, the frequency of the sound waves is
 A 64 Hz **C** 800 Hz
 B 80 Hz **D** 1600 Hz

15. Standing waves on a string can be produced by vibrating one end of a taut string at a certain frequency with the other end fixed. Standing waves can also be produced in a closed pipe by putting a vibrating tuning fork near the open end. Which of the following is true of the standing waves on the string and the standing waves in the pipe?
 A Both standing waves vibrate with the speed of sound in air.
 B The sound of both standing waves cannot be heard because standing waves do not propagate.
 C The standing waves on the string have nodes while the standing waves in pipe do not have nodes.
 D The standing waves on the string are transverse waves while the standing waves in the pipe are longitudinal waves.

16. The diagram below shows the variation of force F with separation r between two atoms.



The shaded area represents
A the energy required to ionise both atoms
B the energy to break the bond between the two atoms
C the kinetic energy of the two atoms at the equilibrium separation
D the energy to change the bond in solid state to the bond in liquid state

17. A wire is stretched without exceeding the proportional limit. The following data is obtained.

Force exerted on the wire	100 N
Cross-sectional area of wire	10^{-6} m^2
Extension of wire	2×10^{-3} m
Original length of wire	2 m

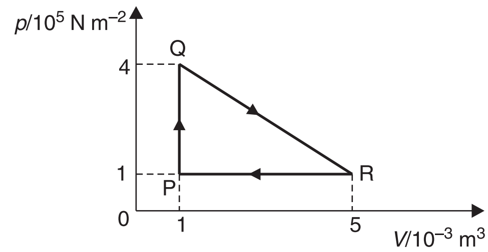
Which of the following statements is **not** true?
A The strain produced is 1×10^{-3}.
B The stress produced is 1×10^{8} N m^{-2}.
C The force constant is 5×10^{4} N m^{-1}.
D The energy stored in the wire is 50 J.

18. Which of the following influence the degree of freedom of a gas molecule?
A The number of atoms per molecule and the temperature of the gas
B The mass of the gas molecule and the temperature of the gas
C The mass of the gas molecule and the pressure of the gas
D The rms speed of the gas molecule and the pressure of the gas

19. The rms speed of the molecules of a certain gas is c. When the volume and pressure of the gas are doubled, the rms speed of the gas molecules is

A $\frac{1}{2}c$ **C** $\sqrt{2}c$
B $\frac{1}{\sqrt{2}}c$ **D** $2c$

20. The graph below shows the variation of pressure p with volume V of an ideal gas undergoing a cyclic process. The points P, Q and R represent three states of the gas.



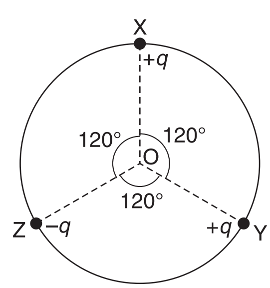
Which states of the gas are the coldest and the hottest?

	Coldest	*Hottest*
A	P	Q
B	P	R
C	Q	R
D	R	Q

21. The specific heat capacity at constant volume of an ideal gas is 2.4×10^{2} J K^{-1} kg^{-1}. The change in the internal energy of 5.0×10^{-3} kg of the gas when the temperature of the gas is increased from 27 °C to 327 °C is
A 32 J **C** 180 J
B 49 J **D** 360 J

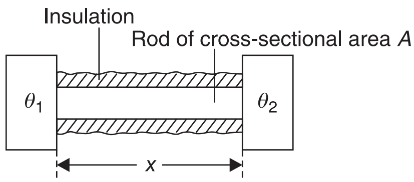
22. The electric field strength at point P at distance 20 cm from a point charge is 0.40 V m^{-1}. The electric potential at point P is
A 0.02 V **C** 0.20 V
B 0.08 V **D** 0.80 V

23. The diagram below shows charges $+q$, $+q$ and $-q$ which are fixed at points X, Y and Z of a circle respectively.



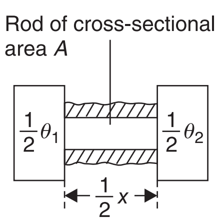
The resultant electric field at centre O of the circle is in the direction of
A OY **C** YO
B OZ **D** ZO

24. The diagram below shows a uniform rod of length x and cross-sectional area A which is perfectly insulated. The two ends of the rod are maintained at temperatures θ_1 and θ_2, where $\theta_1 > \theta_2$.

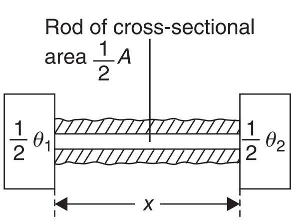


If the same material is used, which of the following set-ups will produce the same rate of flow of heat as the above set-up?

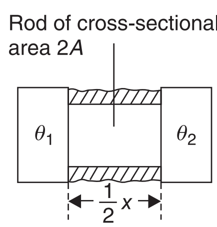
A



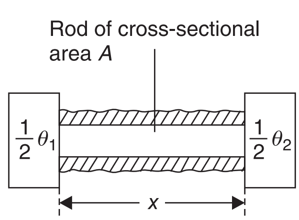
B



C



D



25. A wire of length ℓ and cross-sectional area A has a resistance R. If the resistivity of the material of the wire is ρ, the electrical conductivity σ is

A $\dfrac{\rho AL}{\ell}$

B $\dfrac{\ell}{RA}$

C $\dfrac{R}{\rho\ell}$

D $\dfrac{\rho R}{LA}$

26. Two cylindrical resistors are each made from copper and aluminium. The cross-sectional area and resistivity of aluminium are three times the cross-sectional area and resistivity of copper. If the volume of the two resistors are the same, what is the ratio of the resistance of the aluminium resistor to the resistance of the copper resistor?

A 9 : 1
B 3 : 1
C 1 : 3
D 1 : 9

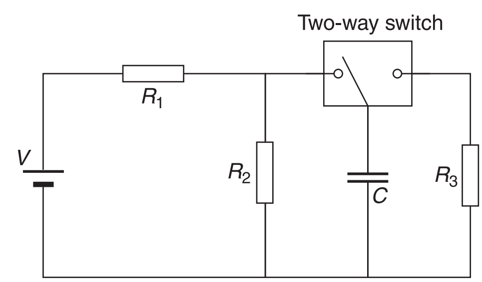
27. A cell of internal resistance 2.0 Ω is connected to a resistor of 8.0 Ω. The percentage of power from the cell which is supplied to the resistor is

A 20%
B 64%
C 80%
D 100%

28. A 5 μF capacitor is charged until the potential difference is 12 V before it is disconnected from the supply. The capacitor is then connected in parallel to an uncharged 10 μF capacitor. The common potential difference of the two capacitors is

A 4.0 V
B 6.0 V
C 9.0 V
D 12.0 V

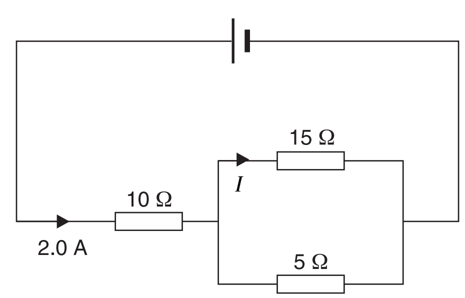
29. In the circuit shown below, capacitor C can be fully charged and then fully discharged by using a two-way switch.



Which of the following influences the time constant of the circuit when capacitor C is discharged?

A Voltage V
B Resistance R_1
C Resistance R_2
D Resistance R_3

30. An electric circuit is shown below.



If the current flowing through the 10 Ω resistor is 2.0 A, the current I flowing through the 15 Ω resistor is

A 0.50 A
B 0.67 A
C 1.33 A
D 1.50 A

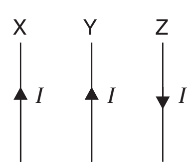
31. The coil of a moving coil galvanometer has N turns and area A. The coil is in a radial field of magnetic flux density B. When current I flows, the coil is deflected through angle θ. The sensitivity $\frac{\theta}{I}$ of the galvanometer is proportional to

A BAN
B BAN^2
C $\frac{1}{BAN}$
D $\frac{1}{BAN^2}$

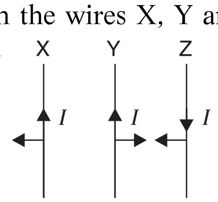
32. Which of the following statements about the motion of a charged particle entering a uniform magnetic field is **not** true?

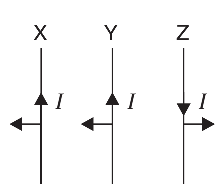
A The path of the particle is parabolic if the direction of motion of the particle is parallel to the direction of the magnetic field.
B The path of the particle is circular if the direction of motion of the particle is perpendicular to the direction of the magnetic field.
C The magnitude of the magnetic force is directly proportional to the charge of the particle.
D The magnitude of the magnetic force is maximum if the direction of motion of the particle is perpendicular to the direction of the magnetic field.

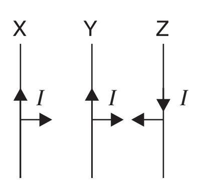
33. The diagram below shows three parallel long wires X, Y and Z each carrying current I of the same magnitude in the directions shown.

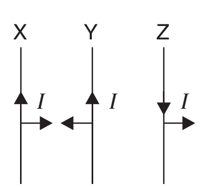


If the distances between X and Y and between Y and Z are the same, which of the following diagrams shows the directions of forces acting on the wires X, Y and Z?

A


B


C


D


34. When the load of an electric motor is decreased, the speed of rotation of the motor increases while the current that flows through it decreases. Which of following statements explains the decrease in the current?

A The resistance of the coil of the motor increases.
B The power dissipated in the coil of the motor increases.
C The back emf induced in the coil of the motor increases.
D It is more difficult for the current to flow into the coil of the motor.

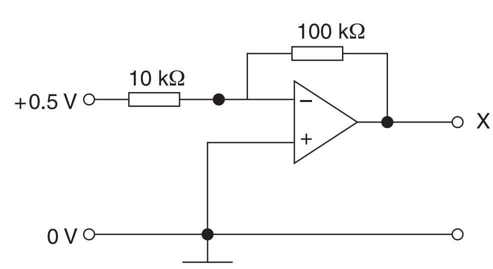
35. When a resistor is connected directly to a sinusoidal voltage supply of 240 V rms, the current has a peak value of 10 A. What are the resistance of the resistor and the power dissipated?

	Resistance	*Power dissipated*
A	24 Ω	1700 W
B	24 Ω	2400 W
C	34 Ω	1700 W
D	34 Ω	2400 W

36. A steady current I produces power P in a resistor. When an alternating current flows through the resistor, the power produced is $\frac{1}{4}P$. What is the peak value of the alternating current?

A $\frac{1}{4}I$
B $\frac{1}{\sqrt{2}}I$
C $\sqrt{2}\,I$
D $2I$

37. The diagram below shows an operational amplifier which is connected to a voltage supply of +15 V and –15 V.



If the input voltage is + 0.5 V, what is the potential at point X?

A –15 V
B –5 V
C +5 V
D +15 V

38. Which of the following statements is **not** true of an electromagnetic wave?
 A It can be polarised.
 B It is a transverse wave.
 C It consists of vibrations in magnetic and electric fields.
 D The expression for its speed is $\sqrt{\mu_0\varepsilon_0}$.

39. A monochromatic light propagates in vacuum and enters a glass medium. Which of the following is true of the light in the glass?

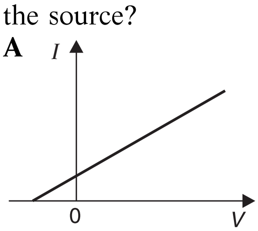
	Speed	*Wavelength*	*Frequency*
A	Increases	Increases	Increases
B	Decreases	Decreases	Decreases
C	Decreases	Increases	No change
D	Decreases	Decreases	No change

40. A convex lens of focal length 6 cm is in contact with a concave lens of focal length 12 cm. The focal length of the combined lens is
 A –6 cm **C** 12 cm
 B 4 cm **D** 18 cm

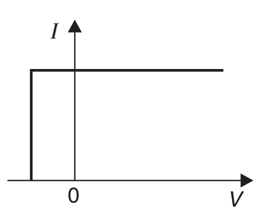
41. A plane-polarised light is passed through a polariser. The polarisation axis is adjusted until the intensity of light produced is at its maximum value I_{max}. Through what angle should the polariser be further rotated so that the intensity of light becomes 25% of I_{max}?
 A 30.0° **C** 60.0°
 B 41.4° **D** 75.5°

42. Light with constant intensity is incident onto a photo cell which is connected to a direct current voltage source. Which of the following graphs shows the variation of the current I through the photo cell with the voltage V of the source?

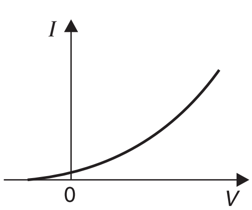
A



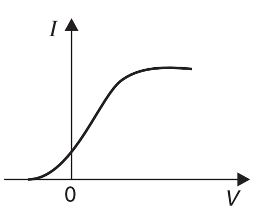
C



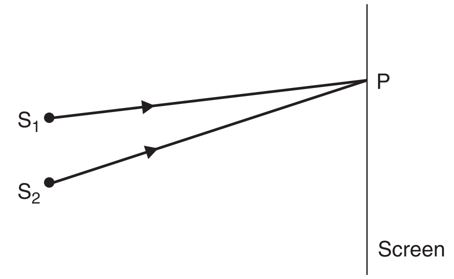
B



D



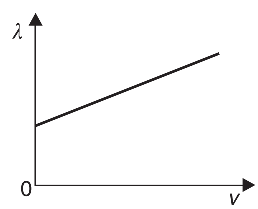
43. The diagram below shows two coherent light sources S_1 and S_2 of wavelength λ which produce an interference pattern on the screen.



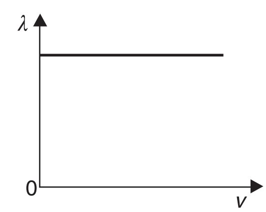
If the mth dark fringe is formed at P, what is the path difference $(S_2P - S_1P)$?
 A λ **C** $m\lambda$
 B $\left(m - \frac{1}{2}\right)\lambda$ **D** $(m + 1)\lambda$

44. According to de Broglie, an electron of velocity v may behave like a wave of wavelength λ. Which of the following graphs shows the variation of λ with v?

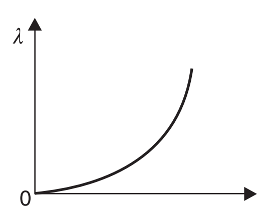
A



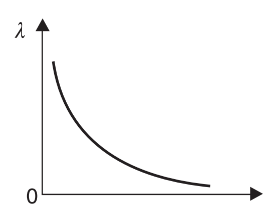
C



B

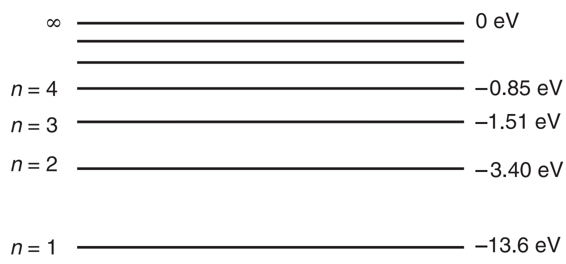


D



45. In 1913, Niels Bohr suggested several postulates to explain the origin of the spectrum of the hydrogen atom. Which of the following is **not** true of the suggestion?
 A The energy of an atom is discrete.
 B The angular momentum of an orbiting electron is quantised.
 C The linear momentum of an orbiting electron may have any value.
 D The radiation energy emitted corresponds to the difference between two energy levels.

46. The diagram below shows several energy levels of the hydrogen atom.



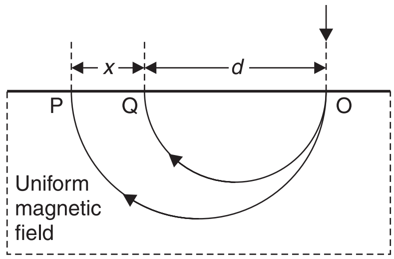
A radiation of wavelength 486 nm from a hydrogen discharge lamp is detected. Which of the following transitions emits this radiation?

A $n = 3 \rightarrow n = 1$
B $n = 3 \rightarrow n = 2$
C $n = 4 \rightarrow n = 1$
D $n = 4 \rightarrow n = 2$

47. The penetration power of X-rays which is produced from an X-ray tube can be upgraded by

A increasing the current which flows through the cathode
B increasing the potential difference between the anode and the cathode
C focusing the electron beam by using a collimator
D using an anode from an element of large atomic number

48. The diagram below shows two paths of positive ions in a mass spectrometer. Point P is the effect of a positive ion of mass m_1 and point Q is the effect of a positive ion of mass m_2.



If the two positive ions carry the same charge, m_2 is equal to

A $\frac{x}{d}m_1$
B $\left(\frac{d}{d + 2x}\right)m_1$
C $\left(\frac{d}{d + x}\right)m_1$
D $\left(d + \frac{x}{2}\right)m_1$

49. Which of the following statements is **not** true of radioactive decay?

A Radioactive decay is a random process.
B Radioactive decay emits an α-particle, a β-particle or γ-rays.
C A radioactive nucleus decays immediately to a stable nucleus.
D A radioactive nucleus decays and changes the numbers of neutrons and protons.

50. The following equation represents the bombardment of a stationary nucleus of ${}^{13}_{6}C$ with a proton of energy 2 MeV.

$${}^{1}_{1}P + {}^{13}_{6}C \rightarrow {}^{13}_{7}N + {}^{1}_{0}n$$

What is the energy released and can the reaction occur?

[Mass ${}^{13}_{6}C$ = 13.003355 u, ${}^{1}_{1}H$ = 1.007825 u, ${}^{13}_{7}N$ = 13.005739 u, ${}^{1}_{0}n$ = 1.008665 u.]

A –1 MeV and the reaction can occur
B –1 MeV and the reaction cannot occur
C +5 MeV and the reaction can occur
D +5 MeV and the reaction cannot occur

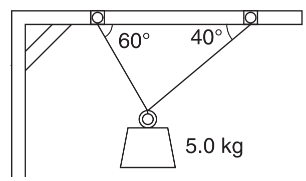
PAPER 2

Time: 2h 30 min

Section A [40 marks]

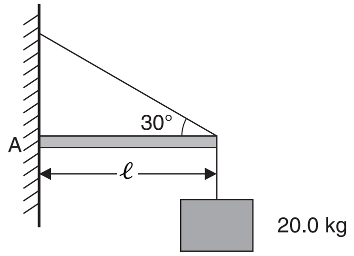
*Answer **all** the questions in this section.*

1. (a) Define a *vector quantity*. [1 *mark*]
   (b) The diagram below shows a 5.0 kg street light suspended by two cables.



   Calculate the tension in each of the cables. [5 *marks*]

2. (a) State the conditions for equilibrium of a rigid body. [2 *marks*]
   (b) The diagram below shows a 20.0 kg mass hanging at the end of a horizontal beam. The beam of length ℓ and negligible mass is hinged on the wall at point A. A cable at an angle of 30° to the horizontal line is used to support the load.



   (i) Calculate the tension in the cable. [2 *marks*]
   (ii) Determine the reaction on the beam by the wall. [2 *marks*]

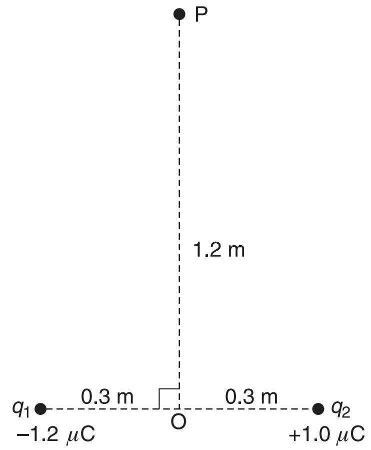
3. A lens of refractive index 1.52 is coated with a layer of transparent material of refractive index 1.38. The thickness of the coating material is such that the reflection of light at wavelength 400 nm can be eliminated.
   (a) Determine the condition for interference to occur. [3 *marks*]
   (b) Calculate the minimum thickness of the coating material. [2 *marks*]

4. (a) State the differences between gaseous, liquid and solid phases in terms of their atomic arrangements and movements. [2 *marks*]
   (b) The variation of repulsive force F_{rep} with distance r between two atoms can be represented by the equation

$$F_{rep} = \frac{a}{r^n},$$

   where a and n are positive constants.
   (i) Sketch a graph of F_{rep} against r. [1 *mark*]
   (ii) Based on the graph in (b)(i), explain why a gas can be compressed but it is almost impossible for a solid. [2 *marks*]

5. The diagram below shows two point charges –1.2 μC and +1.0 μC separated at a distance of 0.6 m. Point O is the midpoint of the two charges. Calculate the electric potential at point P which is 1.2 m vertically above O. [5 *marks*]



6. (a) What is meant by *eddy current*? [2 *marks*]
   (b) How is power loss in a transformer measured? [1 *mark*]
   (c) How is power loss due to eddy current reduced? [2 *marks*]

7. The work function for Cesium is 2.14 eV. Calculate the maximum kinetic energy of photoelectrons emitted from Cesium surface when illuminated by light of wavelength 565 nm. [4 *marks*]

8. A radioisotope tracer was injected into a human body. After 24 hours, the activity of the radioisotope has reduced to 6% of its initial activity. Calculate the half-life of the radioisotope. [4 *marks*]

Section B [60 marks]

Answer any **four** *questions in this section.*

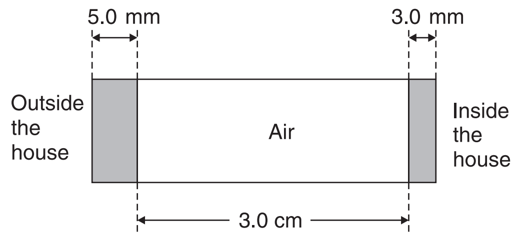
9. (a) Describe briefly a projectile motion. [2 *marks*]
   (b) A marble of mass 30 g rolls off the edge of a table at height 2.0 m and strikes the floor at a horizontal distance of 2.8 m from the edge of the table.
      (i) Calculate the time taken by the marble to reach the floor. [2 *marks*]
      (ii) Determine the speed of the marble just before it falls. [2 *marks*]
      (iii) Calculate the magnitude and direction of the velocity of the marble just before it reaches the floor. [5 *marks*]
      (iv) Determine the average power of the marble. [4 *marks*]

10. (a) State the characteristics of electromagnetic waves. [2 *marks*]
    (b) The displacement y at distance x and time t of a sound wave propagating in air can be represented by

$$y = 7.5 \times 10^{-4} \sin (315t - 1.05x),$$

    where x and y are in metres and t is in seconds.
      (i) Sketch, on the same axes, a graph of y against x at times $t = 0$ and $t = \frac{T}{4}$, where T is the period of the wave. [2 *marks*]
      (ii) Determine the velocity and the frequency of the wave. [4 *marks*]
      (iii) Calculate the phase difference of a point 2.0 m from the origin. [3 *marks*]
    (c) Describe the principle of Doppler radar used by the police to determine the speed of an automobile. [4 *marks*]

11. (a) (i) What is meant by *work done in an isolated gas system*? [1 *mark*]
(ii) Differentiate between internal energy and thermal energy of a gas system. [2 *marks*]
(iii) State the first law of thermodynamics and the meaning of each symbol used. [2 *marks*]
(b) An isolated system of 3.0 moles of an ideal gas is initially at pressure p_1 and volume V_1. It is then allowed to expand at constant temperature T = 350 K to new pressure p_2 and new volume V_2 which is twice the initial volume V_1.
(i) Sketch the *p*-*V* diagram to show the expansion process and shade the region representing the work done during the process. [2 *marks*]
(ii) Calculate the work done during the process. [3 *marks*]
(c) The diagram below shows an insulated window glass of a house which consists of two glass panels separated by a layer of air.



The area of the window is 2.0 m × 1.5 m. The thicknesses of the outer glass, inner glass and air layer are 5.0 mm, 3.0 mm and 3.0 cm respectively. If the temperature outside the house is 45 °C and the temperature inside the house is kept at 20 °C, calculate the energy per hour that is prevented from entering the window. [5 *marks*]
[Thermal conductivity of glass = 0.84 W $m^{-1}K^{-1}$,
thermal conductivity of air = 0.023 W $m^{-1}K^{-1}$.]

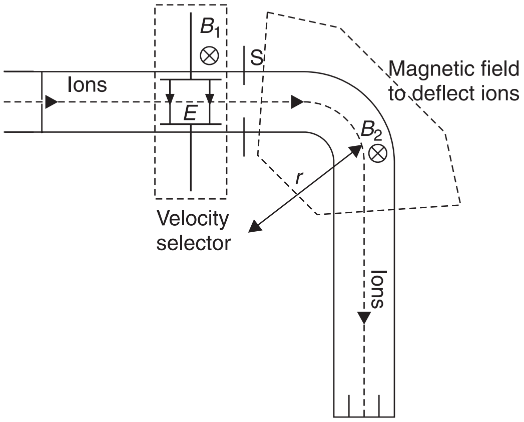
12. (a) State **two** functions of the dielectric in a capacitor. [2 *marks*]
(b) Two pure capacitors of capacitance C_1 = 5.0 μF and C_2 = 10.0 μF are connected in series to a 10.0 V battery.
(i) Derive an expression for the effective capacitance C_T of the circuit and calculate the value of C_T. [4 *marks*]
(ii) Calculate the total energy stored in the circuit. [2 *marks*]
(c) The battery in (b) is replaced by an alternating current supply of maximum voltage 10 V and frequency 120 Hz.
(i) Calculate the reactance of the combined capacitor. [2 *marks*]
(ii) Calculate the maximum current in the circuit. Comment on the phase of the current with reference to the voltage supplied. [3 *marks*]
(iii) Describe briefly the behaviour of the energy stored in the combined capacitor during a cycle of the alternating current supply. [2 *marks*]

13. (a) State de Broglie's hypothesis and give the relationship between momentum p and wavelength λ of a particle. [2 *marks*]
(b) In an electron diffraction experiment, an electron beam which is accelerated on a potential difference is incident normally on a very thin gold film. Several circular diffraction rings are seen on a photographic film.
(i) If the voltage at the anode is increased, what happens to the circular rings? [1 *mark*]
(ii) If a particular ring of radius R is chosen and different values of accelerating voltage V are recorded, sketch a graph of R against $\frac{1}{\sqrt{V}}$. Deduce that the experiment is in agreement with de Broglie's hypothesis. [6 *marks*]

(c) (i) A 60 kg marathon runner runs at a speed of 5.1 m s^{-1}. Calculate the de Broglie wavelength of the marathon runner. [2 *marks*]
(ii) Explain briefly the production of continuous and characteristic X-rays. [4 *marks*]

14. (a) (i) Define *nucleon number* and *proton number*. [1 *mark*]
(ii) What are isotopes? [1 *mark*]

(b) The diagram below shows a schematic model of a mass spectrometer. An ion enters the velocity selector with electric field E and magnetic field B_1. The velocity of the ion of charge q at slit S is v. The ion then enters the region of magnetic field B_2 where it is deflected in a circular path of radius r.



(i) Express v in terms of E and B_1. [1 *mark*]
(ii) Derive an expression for the mass m of an ion in terms of E, B_1, B_2, r and q. [2 *marks*]
(iii) If $B_1 = B_2 = 0.01$ T and $r = 20.0$ cm, calculate two different electric fields to enable the mass spectrometer to differentiate singly charged copper isotopes $^{63}_{29}$Cu and $^{65}_{29}$Cu. [3 *marks*]

[Atomic mass of isotope $^{63}_{29}$Cu = 62.929601 u,

atomic mass of isotope $^{65}_{29}$Cu = 64.927794 u.]

(c) (i) Why does a fusion reaction take place at high temperatures? [1 *mark*]
(ii) Calculate the energy released in the following fusion reaction.

$$^{13}_{6}\text{Cu} + {}^{1}_{1}\text{H} \longrightarrow {}^{14}_{7}\text{N}$$

[3 *marks*]

[Atomic mass of isotope $^{13}_{6}$Cu = 13.003355 u,

atomic mass of isotope $^{1}_{1}$H = 1.007825 u,

atomic mass of isotope $^{14}_{7}$N = 14.003074 u,

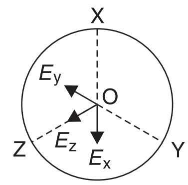
1u ≡ 931 MeV.]

(d) Explain briefly the controlled fission reaction in a nuclear reactor. [3 *marks*]

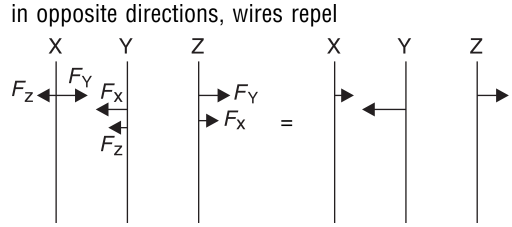
Suggested Answers

PAPER 1

1. A Unit is rad s^{-1}
2. C R is maximum when $\theta = 45°$
3. B Vertical motion: $v = u \sin 45°$, $v = 0$, $a = -g$, $s = 1.0$ m. Use $v^2 = u^2 + 2as$
4. A Work done = $Pt = \left(\frac{1}{2}mv^2 - \frac{1}{2}mu^2\right) + mgh$
5. A Work done is the dot (•) product of force and displacement
6. C Period = $\frac{\text{distance travelled in a complete circle}}{\text{speed}}$
7. C After collision, distance of centre of mass from 1.0 kg mass
$\bar{x} = \frac{(0.5 + 0.5)(4.00) + (1.00)(0)}{(0.5 + 0.5) + 1.00} = 2.00$ m
Angular momentum is conserved,
$[(0.5+0.5)(2.00)^2 + (1.00)(2.00)^2]\omega = (0.5)(4.00)(2.00)$
$\omega = 0.50$ rad s^{-1}
8. B $\frac{\frac{1}{2}mv^2}{\frac{1}{2}I\omega^2} = \frac{m(r\omega)^2}{\left(\frac{2}{5}mr^2\right)\omega^2} = \frac{5}{2}$
[Note: The moment of inertia of the ball about the axis through the centre is $\frac{2}{5}mr^2$.]
9. B E = constant for the whole region
10. C W must act through the centre of gravity (C.G.).
Taking moments about C.G.,
clockwise moments of T and F = anticlockwise moment of N.
In D, there is **no** anticlockwise moment about the C.G.
11. D Distance travelled by the wave in 0.40 s
= (0.10 – 0) = 0.10 m
Speed $v = \frac{0.10}{0.40} = 0.25$ m s^{-1}, $\lambda = 0.02$ m
$f = \frac{v}{\lambda} = \frac{0.25}{0.02} = 12.5$ Hz
12. A $a_{max} = \omega^2 x_0 = (2\pi f)^2(0.02) = 0.6$
$f = 0.87$ Hz
13. A $F = m(-\omega^2 x)$, varies with displacement x
14. C $\lambda = 2(0.2)$ m, $f = \frac{v}{\lambda} = \frac{320}{0.40} = 800$ Hz
15. D
16. B Area under F-r curve = work done (or energy required)
17. D Energy stored = $\frac{1}{2}Fe = \frac{1}{2}(100)(2 \times 10^{-3}) = 0.10$ J
18. A f depends on whether the molecule is monatomic, diatomic or polyatomic, and f is greater at high temperatures
19. D $pV = nRT$, $c \propto \sqrt{T}$. $(2p)(2V) = nRT_1$
$T_1 = 4T$, $c_1 \propto \sqrt{4T}$, $c_1 = 2c$
20. B $pV = nRT$, $T \propto pV$. At P, $pV = 100$ J.
At Q,
$pV = 400$ J. At R, $pV = 500$ J
21. D $\Delta U = mc(\Delta T) = (5.0 \times 10^{-3})(2.4 \times 10^2)(327 - 27)$
= 360 J
22. B $E = \frac{Q}{4\pi\varepsilon_0 r^2}$, $V = \frac{Q}{4\pi\varepsilon_0 r} = rE = (0.20)(0.40) = 0.08$ V
23. B



24. A $\frac{dQ}{dt} = kA\frac{(\theta_1 - \theta_2)}{x} = kA\frac{\left(\frac{1}{2}\theta_1 - \frac{1}{2}\theta_2\right)}{0.5\,x}$
25. B $\rho = \frac{RA}{\ell}$, $\sigma = \frac{1}{\rho} = \frac{\ell}{RA}$
26. C Volume = $\ell_C A = \ell_A(3A)$, $\frac{\ell_A}{\ell_c} = \frac{1}{3}$ and $R = \frac{\rho\ell}{A}$
$\frac{R_A}{R_C} = \frac{\ell_A}{\ell_C} = \frac{1}{3}$
27. C $\frac{\text{Power in resistor}}{\text{Power from cell}} = \frac{IV}{IE} = \frac{R}{R + r} = \frac{8.0}{8.0 + 2.0} = 0.80$
28. A Charge conserved, $Q = (5 + 10)V_1 = (5)(12)$
$V_1 = 4.0$ V
29. D Time constant of discharge circuit = CR_3
30. A $I = \left(\frac{5}{5 + 15}\right)(2.0) = 0.50$ A
31. A $BINA = k\theta$, $\frac{\theta}{I} = \frac{BNA}{k} \propto BAN$
32. A When v is parallel to B, force on the charge, $F = 0$. Path is a straight line
33. D Currents in the same direction, wires attract; currents in opposite directions, wires repel



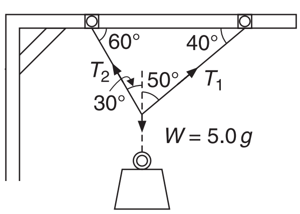
34. C Back emf ∝ speed of rotation
35. C $R = \frac{V_0}{I_0} = \frac{240\sqrt{2}}{10} = 34\ \Omega$
$P = \frac{1}{2}I_0^2 R = \frac{1}{2}(10)^2(34) = 1700$ W
36. B $P = I^2R$, $\frac{1}{4}P = \frac{1}{2}I_0^2 R$. Hence $I_0 = \frac{1}{\sqrt{2}}I$
37. B $V_0 = -\frac{R_f}{R_i}V_i = -\left(\frac{100}{10}\right)(0.5) = -5$V
38. D Speed, $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$
39. D $v = f\lambda$, f unchanged
40. C $\frac{1}{F} = \frac{1}{6} + \frac{1}{-12}$, $F = 12$ cm

41. C $I = (0.25)I_{max} = I_{max}\cos^2\theta$. Therefore $\theta = 60.0°$
42. D Characteristic curve of a photocell
43. B For dark fringe: Path difference = $\frac{1}{2}\lambda, \frac{3}{2}\lambda, \ldots$
44. D $\lambda = \frac{h}{mv}$
45. C Linear momentum is quantised
46. D $E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{(486 \times 10^{-9})(1.60 \times 10^{-19})} = 2.55$ eV
$= E_4 - E_2$
47. B Penetration power increases when λ decreases.
$\lambda = \frac{hc}{eV}$
48. C $F = qvB = \frac{mv^2}{r}$, $m = \frac{qBr}{v} \propto r$. $m_2 = \left(\frac{d}{d + x}\right)m_1$
49. C Product of decay need not be stable
50. B Energy released, E
= [(1.007825+13.003355)(934 MeV) + 2 MeV]
– (13.005739+1.008665)(934 MeV) = –1 MeV
Reaction cannot occur because total energy before < total energy after

PAPER 2 Section A

1. (a) A vector quantity is a physical quantity which has magnitude and direction

(b)



Resolving forces horizontally,

$T_1 \sin 50° = T_2 \sin 30°$, $T_2 = \frac{\sin 50°}{\sin 30°}T_1$

Resolving forces vertically,

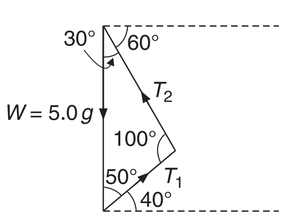
$T_1 \cos 50° + T_2 \cos 30° = 5.0g$

$T_1 \cos 50° + \left(\frac{\sin 50°}{\sin 30°}T_1\right)\cos 30° = 5.0g$

$T_1 = \frac{5.0 \times 9.81}{\cos 50° + (\sin 50° \cos 30°/ \sin 30°)} = 25$ N

$T_2 = \frac{\sin 50°}{\sin 30°}T_1 = 38$ N

Alternative solution [Note: Shorter answer]
Since the forces W, T_1 and T_2 are in equilibrium, they can be represented by the triangle of forces. Using the sine rule,



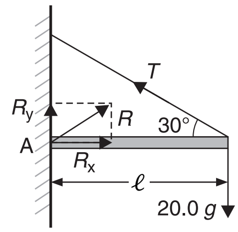
$\frac{T_1}{\sin 30°} = \frac{T_2}{\sin 50°} = \frac{W}{\sin 100°}$

$T_1 = \frac{(5.0 \times 9.81)(\sin 30°)}{\sin 100°} = 24.9$ N

$T_2 = \frac{(5.0 \times 9.81)(\sin 50°)}{\sin 100°} = 38$ N

2. (a) Conditions of equilibrium of a rigid body:
– Resultant force = 0
– Resultant torque about any point = 0

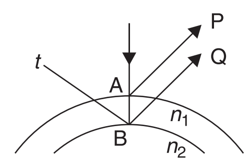
(b) (i)



Let T = tension in the cable and taking moments about A,
$T(\ell \sin 30°) = (20.0 \times 9.81)\ell$, $T = 392$ N

(ii) Let R = reaction at A, and R_x and R_y the horizontal and vertical components of R.
Equating horizontal forces,
$R_x = T\cos 30° = 392 \cos 30° = 339$ N
Equating vertical forces,
$R_y + T\sin 30° = (20.0 \times 9.81)$
$R_y = (20.0 \times 9.81) - (392 \sin 30°) = 0$
Hence reaction at A, $R = R_x = 339$ N perpendicular to the wall

3. (a)



Condition for (destructive) interference:

Path difference between AP and BQ = $\left(m - \frac{1}{2}\right)\lambda$

$2n_1 t = \left(m - \frac{1}{2}\right)\lambda$ for $m = 1, 2, 3, \ldots$

$2(1.38)t = \left(m - \frac{1}{2}\right)(400 \text{ nm})$

[t = thickness of coating material]

(b) Thickness t is minimum when $m = 1$.

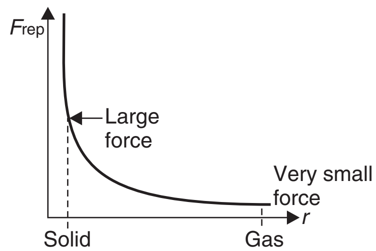
Minimum thickness = $\frac{\left(1 - \frac{1}{2}\right)(400\text{nm})}{2(1.38)}$
= 72.5 nm

4. (a)

	Gaseous	Liquid	Solid
Atomic arrangement	No arrangement at all, constantly changing	Constantly random non-uniform pattern over short range	Regularly repeated pattern over long range

Movement	Free random motion with high speeds	Random motion	Atoms vibrate about mean positions

(b) (i)



(ii) For a gas, r is very large ($r \to \infty$). From the graph, the repulsive force is very small.
Hence a gas can be compressed.
For a solid, r is small. From the graph, the repulsive force is very large.
Hence it is very difficult to compress a solid

5. Distances of the point P from the two charges are the same. $r = \sqrt{(0.3)^2 + (1.2)^2} = 1.24$ m

Electric potential at P, $V = \dfrac{q_1}{4\pi\varepsilon_0 r} + \dfrac{q_2}{4\pi\varepsilon_0 r}$

$= \dfrac{(-1.2 + 1.0) \times 10^{-6}}{4\pi(8.85 \times 10^{-12})(1.24)} = -1.45 \times 10^3$ V

6. (a) Eddy current is the current induced in a conductor placed in a changing magnetic field. Direction of the eddy current opposes the change in the magnetic flux.

(b) Power loss = power input – power output
$= I_p V_p - I_s V_s$
I_p = current in the primary coil
V_p = input voltage
I_s = current in the secondary coil
V_s = output voltage

(c) Power loss is reduced by
– reducing the eddy current. Use laminated core to increase the resistance of the core.
– reducing the resistance of the primary and secondary coils

7. Maximum kinetic energy, E_{max}

$= \dfrac{hc}{\lambda} - W = \dfrac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{(565 \times 10^{-9})(1.60 \times 10^{-19})} - 2.14$ eV
$= 6.02 \times 10^{-2}$ eV

8. If A_0 = initial activity, after t = 24 hours,
activity $A = 6\%A_0 = 0.06A_0$

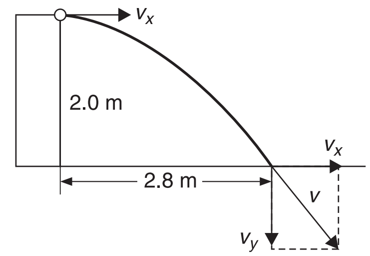
Using $A = \dfrac{A_0}{2^x}$, $2^x = \dfrac{A_0}{0.06A_0} = 16.67$

$x = \dfrac{t}{T_{\frac{1}{2}}} = \dfrac{\log 16.67}{\log 2} = 4.06$, $T_{\frac{1}{2}} = \dfrac{24}{4.06} = 5.91$ hours

Section B

9. (a) Horizontal: Motion under constant speed.
Vertical: Motion under uniform acceleration ($a = g$, acceleration of free-fall).
Path of projectile is a parabola

(b) (i)



Considering vertical motion,
initial velocity = 0, $a = g$, $s = 2.0$ m

Using $s = ut + \frac{1}{2}at^2$, $2.0 = 0 + \frac{1}{2}(9.81)t^2$

$t = \sqrt{\dfrac{2(2.0)}{9.81}} = 0.639$ s

(ii) Considering horizontal motion,

$2.8 \text{ m} = v_x(t)$, $v_x = \dfrac{2.8}{0.639} = 4.38$ m s^{-1}

(iii) After a time t = 0.639 s, vertical component of velocity,
$v_y = 0 + (9.81)(0.639) = 6.27$ m s^{-1}
$v_x = 4.38$ m s^{-1}
$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(4.38)^2 + (6.27)^2} = 7.65$ m s^{-1}

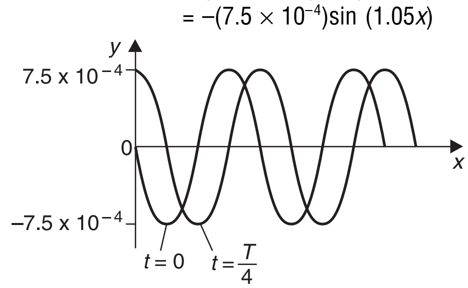
at an angle $\tan^{-1}\left(\dfrac{v_y}{v_x}\right) = \tan^{-1}\left(\dfrac{6.27}{4.38}\right)$
= 55.1° below the horizontal

(iv) Average power of the marble,

$P = \dfrac{mv^2}{2t} = \dfrac{(30 \times 10^{-3})(7.65)^2}{2(0.639)}$
= 1.373 W

10. (a) Characteristics of electromagnetic waves (*state any two*):
– All em waves travel with the same speed of 3.0×10^8 in vacuum.
– Are transverse waves or can be plane-polarised.
– Require no medium for propagation or can travel in vacuum

(b) (i) $y = (7.5 \times 10^{-4})\sin(315t - 1.05x)$
When $t = 0$, $y = (7.5 \times 10^{-4})\sin(-1.05x)$
$= -(7.5 \times 10^{-4})\sin(1.05x)$



(ii) $y = (7.5 \times 10^{-4})\sin(315t - 1.05x)$

Comparing with $y = a \sin\left(2\pi ft - \frac{2\pi}{\lambda}x\right)$

$2\pi f = 315$

Frequency, $f = 50.1$ Hz. Also, $\frac{2\pi}{\lambda} = 1.05$

$\lambda = 5.98$ m

Velocity, $v = f\lambda = (50.1)(5.98) = 300 \text{ m s}^{-1}$

(iii) $\lambda = 5.98$ m $\propto$ phase difference 2π rad.

For a distance of 2.0 m, phase difference

$= \frac{2.0}{5.89}(2\pi)$

$= 2.10$ rad

(c) If f = frequency of radar, frequency received by a car travelling with a speed u towards the source is $f_1 = \left(\frac{c+u}{c}\right)f$

Frequency reflected by car (which acts as the source) is

$f_2 = \left(\frac{c}{c-u}\right)f_1 = \left(\frac{c}{c-u}\right)\left(\frac{c+u}{c}\right)f = \left(\frac{c+u}{c-u}\right)f$

Superposition of the reflected waves of frequency f_2 and emitted frequency f produces beats of frequency

$= f_2 - f = \left(\frac{c+u}{c-u}\right)f - f = \left(\frac{2u}{c-u}\right)f$

The greater the speed u of the car, the higher is the beat frequency

11. (a) (i) In an isolated gas system, work is done by the gas to increase the separation between the gas molecules when the gas expands

(ii) Internal energy is the total kinetic and potential energy of the gas molecules.

Thermal energy is the energy transferred between the gas and the surrounding due to a temperature difference

(iii) First law of thermodynamics

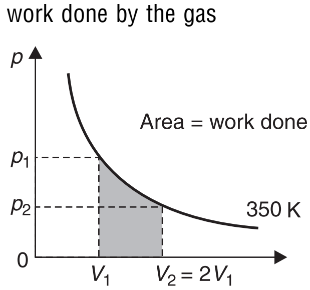
$Q = \Delta U + W$

Q : heat supplied to the gas

ΔU : increase in internal energy of the gas

W : work done by the gas

(b) (i)



(ii) Work done $= nRT \ln\left(\frac{V_2}{V_1}\right)$

$= (3.0)(8.31)(350)$

$\ln\left(\frac{2V_1}{V_1}\right) = 6.05 \times 10^3$ J

(c) If the window consists of only the outer glass panel, rate of heat flow,

$\frac{dQ}{dt} = kA\frac{d\theta}{dx} = (0.84)(2.0 \times 1.5)\left(\frac{45-20}{5.0 \times 10^{-3}}\right)$

$= 1.26 \times 10^4$ W

For the insulated window,

rate of heat flow, $\frac{dQ}{dt} = \frac{\text{temperature difference}}{\text{total thermal resistance}}$

$= \frac{(45-20)(2.0 \times 1.5)}{\frac{(0.005 + 0.003)}{(0.84)} + \frac{0.030}{0.023}} = 57.1$ W

Energy prevented from entering the room in 1 hour

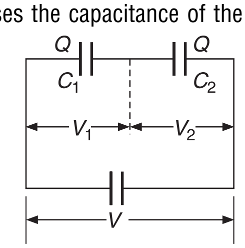
$= (1.26 \times 10^4 - 57.1)(3600) = 4.52 \times 10^7$ J

12. (a) Functions of dielectric:

– It acts as insulator, so that charge does not flow across the capacitor.

– It increases the capacitance of the capacitor

(b) (i)



Charge on both capacitors = Q [the same]

$V_1 = \frac{Q}{C_1}, \quad V_2 = \frac{Q}{C_2}$

$V = V_1 + V_2 = \frac{Q}{C_1} + \frac{Q}{C_2}$

$\frac{V}{Q} = \frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{5.0} + \frac{1}{10.0}$

$C_T = 3.33\ \mu$F

(ii) Energy stored $= \frac{1}{2}C_T V^2$

$= \frac{1}{2}(3.33 \times 10^{-6})(10.0)^2 = 1.67 \times 10^{-4}$ J

(c) (i) Reactance, $X_c = \frac{1}{2\pi fC}$

$= \frac{1}{2\pi(120)(3.33 \times 10^{-6})} = 398\ \Omega$

(ii) Maximum current, $I_{max} = \frac{V_{max}}{X_c} = \frac{10}{398}$

$= 2.51 \times 10^{-2}$ A

The current leads the voltage by $\frac{\pi}{2}$ radians

(iii) From $t = 0$ to $t = \frac{T}{4}\left(\text{first } \frac{1}{4}\text{-cycle}\right)$, energy flows into the capacitor.

From $t = \frac{T}{4}$ to $t = \frac{T}{2}\left(\text{second } \frac{1}{4}\text{-cycle}\right)$, energy flows from the capacitor back to the battery. The process is then repeated during the third $\frac{1}{4}$-cycle and final $\frac{1}{4}$-cycle

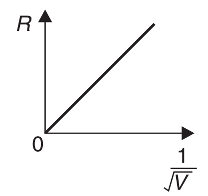
13. (a) de Broglie's hypothesis: A particle moving with a velocity v behaves as a wave of wavelength λ.

de Broglie's wavelength, $\lambda = \frac{h}{p}$

[h = Planck's constant]

(b) (i) When the voltage increases, λ decreases and the radii of the circular rings decreases

(ii)



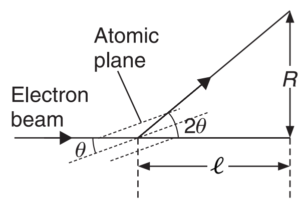
Velocity v of electron after being accelerated through a voltage V is given by

$\frac{1}{2}mv^2 = eV$, $v = \sqrt{\frac{2eV}{m}}$

[m = electron mass]

de Broglie's wavelength, $\lambda = \frac{h}{mv}$

$= \frac{h}{m\sqrt{\frac{2eV}{m}}} = \frac{h}{\sqrt{2meV}}$



Using Bragg's equation, $2d \sin \theta = n\lambda$, when θ is small, $\sin \theta = \theta$ rad.

$2d\theta = n\lambda$, $d(2\theta) = n\lambda$

Since θ is small, 2θ rad $= \tan 2\theta = \frac{R}{\ell}$

Hence, from $d(2\theta) = n\lambda$ and $\lambda = \frac{h}{\sqrt{2meV}}$,

$d\frac{R}{\ell} = n\frac{h}{\sqrt{2meV}}$, $R = \frac{nh\ell}{d\sqrt{2meV}} \propto \frac{1}{\sqrt{V}}$

The experimental result is in agreement with de Broglie's hypothesis

(c) (i) de Broglie's wavelength, $\lambda = \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}}{(60)(5.1)}$

$= 2.2 \times 10^{-36}$ m

(ii) Continuous X-ray spectrum is produced when fast electrons are decelerated during collisions with a heavy metal.

Because the fraction of the kinetic energy of the electron which is converted into a photon of X-ray is random in nature, X-rays of various wavelengths are produced.

These X-rays form the continuous spectrum.

A photon of the characteristic X-rays is produced when

– a fast electron from the cathode ejects an electron from the inner shell of the target atom.

– when an electron from a higher shell drops to the lower shell to fill the vacancy. The difference in the energy, $(E_2 - E_1)$ of this electron is emitted as a photon of characteristic X-ray

14. (a) (i) Nucleon number: Number of nucleons (or protons and neutrons) in the nucleus.

Proton number: Number of protons in the nucleus

(ii) Isotopes have the same proton number but different nucleon number

(b) (i) $v = \frac{E}{B_1}$

(ii) In the magnetic field B_2,

$qvB_2 = \frac{mv^2}{r}$

$m = \frac{qrB_2}{v} = \frac{qrB_1B_2}{E}$

(iii) From $m = \frac{qrB_1B_2}{E}$, $E = \frac{qrB_1B_2}{m}$

For $^{63}_{29}$Cu, $E = \frac{(1.60 \times 10^{-19})(0.200)(0.01)(0.01)}{(62.929601)(1.66 \times 10^{-27})}$

$= 30.6$ V m^{-1}

For $^{65}_{29}$Cu, $E = \frac{(1.60 \times 10^{-19})(0.200)(0.01)(0.01)}{(64.927794)(1.66 \times 10^{-27})}$

$= 29.7$ V m^{-1}

(c) (i) Hydrogen nuclei require a large amount of energy to overcome the repulsive force between each other.

Kinetic energy of the hydrogen nuclei is raised by increasing its temperature to a very high value

(ii) Mass difference, Δm

$= (13.003355 + 1.007825)$u $- 14.003074$ u

$= 8.106 \times 10^{-3}$ u

Energy released [1 u ≡ 934 MeV]

$= (8.106 \times 10^{-3})(931$ MeV$) = 7.55$ MeV

(d) Water is used as a moderator to slow down the neutrons.

Contol rods of cadmium are used to absorb two out of the three secondary neutrons so that the fission reaction occurs at a constant rate