NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2012-2013

PH1011 – Physics

Nov/Dec 2012 Time Allowed: 2½ Hours

SEAT NUMBER:

MATRICULATION NUMBER:

INSTRUCTIONS TO CANDIDATES

1. This question and answer booklet contains **SEVEN (7)** questions and comprises **TWENTY-THREE (23)** pages.
2. Answer **ALL SEVEN (7)** questions. All workings must be clearly shown.
3. Marks for each question are as indicated.
4. This is a **CLOSED BOOK** examination.
5. All your solutions should be written in this booklet within the space provided after each question.

For examiners:

Questions	**1** (20)	**2** (10)	**3** (20)	**4** (15)	**5** (15)	**6** (10)	**7** (10)	**Total** (100)
Marks								

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Q1 (20 marks)

/20

(a) An iron disk with a circular hole in the center is rotating freely at a constant angular velocity $\omega = 0.6\ \text{rad/s}$ with its axis of rotation vertical and passing through the center of the disk. As shown in Figure 1(a1), a small drop of liquid lead at rest is released from height $h = 0.45\ \text{m}$ at time $t = 0\ \text{s}$ (when the line marked on the disk is just directly below the drop). At time $t = t_1$, the small drop hits the rotating iron disk, solidifies, sticks at the point of contact and moves off with the same angular velocity as the disk. [You can assume that the mass of the liquid lead is negligible. Take acceleration of free fall as $g = 9.81\ \text{m/s}^2$ and ignore the effects of air resistance for this question.]

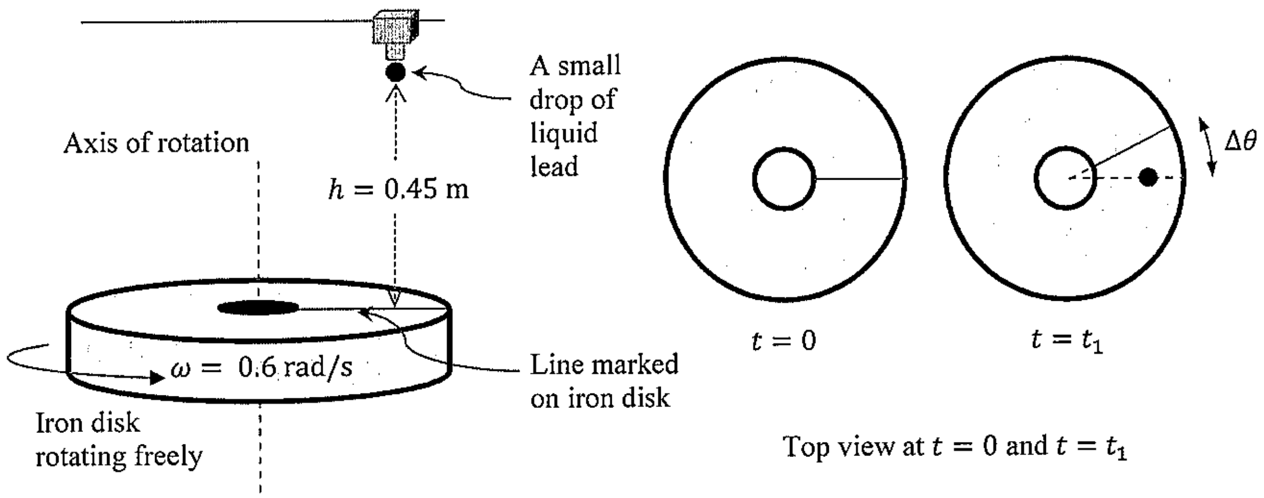


Figure 1(a1)

i. Calculate time t_1.

ANS:________________

Note: Question No. 1 continues on Page 4

ii. The iron disk has rotated through an angle $\Delta\theta$ in time t_1. Calculate $\Delta\theta$.

ANS:__________________

(4 marks)

In a modified set up shown in Figure 1(a2), the device that dispenses liquid lead moves horizontally along the cable such that its radial distance $r(\tau)$ from the axis of rotation at time τ (in s) is given by $r(\tau) = (0.05 + 0.02\tau + 0.03\tau^2)$ m. The horizontal cable intersects with the axis of rotation of the iron disk. The radius of the disk is $R = 0.21\ m$. When $r(\tau) = R$, the dispenser stops and moves back to $r(\tau = 0)$.

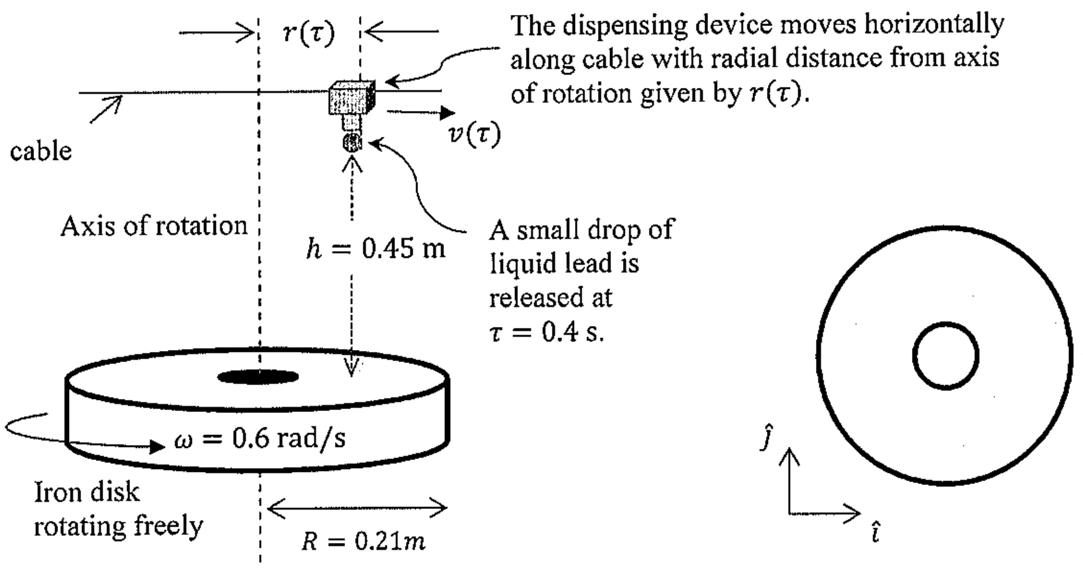


Figure 1(a2)

Note: Question No. 1 continues on Page 5

A drop of liquid lead is released at $\tau = 0.4$ s.

iii. Calculate the distance $r(\tau)$ and velocity $v(\tau)$ of the dispensing device at time $\tau = 0.4$ s.

ANS:____________________

____

iv. Calculate the distance from the center of the disk where the drop of liquid lead lands.

ANS: ____________________

Note: Question No. 1 continues on Page 6

v. Calculate the velocity (expressed in vector form) of the liquid lead just <u>after</u> it sticks to the disk. Explain how your answer will change if the mass of the drop of lead is not negligible but significant compared to the mass of the disk.

ANS: ____________________

Comment: ____

____

vi. Calculate the time τ when the dispenser first stops and moves back to $r(\tau = 0)$,

ANS: ____________________

(12 marks)

Note: Question No. 1 continues on Page 7

(b) Figure 1(b1) shows a block of mass m sliding down a frictionless slope. Figure 1(b2) shows a girl sliding down a curved frictionless water slide. Take the acceleration of free fall as g in both cases.

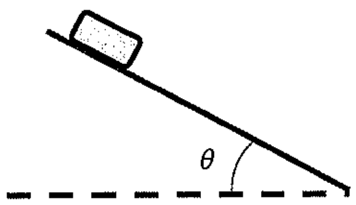


Figure 1(b1)

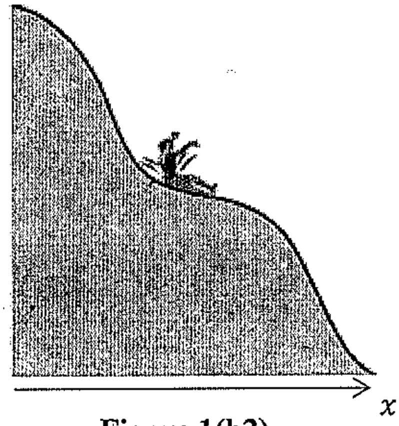
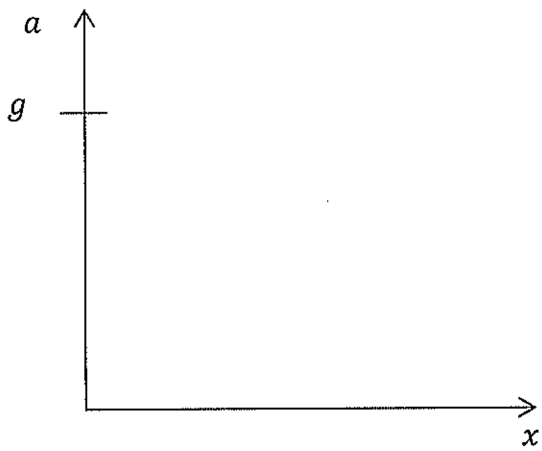


Figure 1(b2)

i. Write down acceleration a of the block in terms of g and the angle θ.

ANS: ____________________

ii. Sketch, using the axis provided below, to show how the acceleration a experienced by the girl along the water slide varies with the x coordinate.



(4 marks)

Q2 (10 marks)

/10

A "ballistic spring system" is set up to measure the speeds of bullets. A bullet of mass m is fired horizontally into a stationary block of mass M. The block, with the embedded bullet, then slides horizontally across a frictionless table and collides with a horizontal spring of negligible mass with spring constant k. The opposite end of the spring is mounted to the wall. The spring's maximum compression d is measured.

i. Determine the expression for the bullet's speed v_B in terms of the variables m, M, k and d.

ANS:________________________

Note: Question No. 2 continues on Page 9

ii. Calculate the speed of the bullet if $m = 7.0$ g, $M = 2.0$ kg, $k = 50$ N/m and $d = 10.0$ cm.

ANS: ____________________

iii. If the bullet penetrated 3.5 cm horizontally into the block after collision, use the values in part (ii) to calculate the average force acting on the bullet as it penetrated the block.

ANS: ____________________

(10 marks)

Q3 (20 marks) /20

(a) A 2.8 kg block, on a rough 30° inclined plane, is attached to a string of negligible mass to a solid cylindrical drum with mass 0.90 kg and radius 5.0 cm as shown in Figure 3(a). The frictional force at the axle of the drum is negligible. When released, the drum rotates without slipping and the block accelerates down the slope at $1.6\ \mathrm{m/s^2}$.

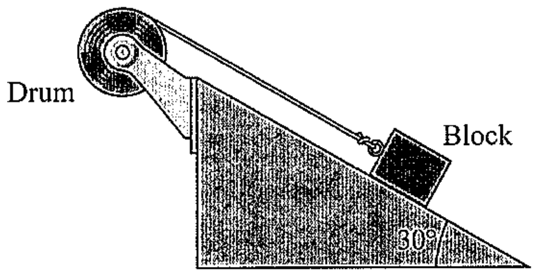
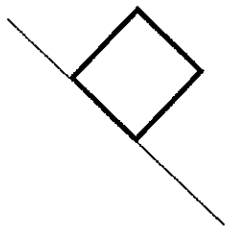


Figure 3(a)

i. Using the sketch provided below, draw and label arrows to indicate the forces acting on the block.



ii. Applying Newton's second law (for translational and rotational motion), set up the equations of motion for the drum and the block.

Note: Question No. 3 continues on Page 11

iii. Find the coefficient of kinetic friction between the block and the slope.

ANS: ____________________

(12 marks)

Note: Question No. 3 continues on Page 12

(b) Shown in Figure 3(b) is a rod of mass M and length l with non-uniform linear density λ that varies with x according to the relation

$$\lambda(x) = \lambda_o\left(1 + \frac{x}{l}\right)$$

where λ_o is a constant. You are given that the total mass of the rod as

$$M = \int_{x=0}^{l} \lambda(x)dx = \frac{3}{2}\lambda_o l.$$

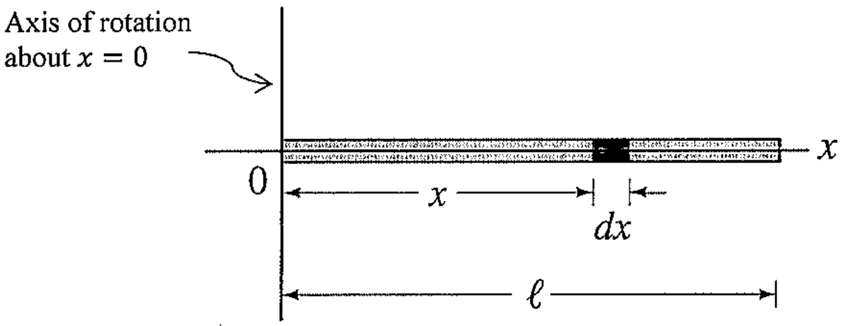


Figure 3(b)

i. Determine the moment of inertia of the rod $I_{x=0}$ about the axis passing through the origin $x = 0$ in terms of M and l.

ANS: ____________________

Note: Question No. 3 continues on Page 13

ii. Given that the center of mass of the rod is located at $x = \frac{5}{9}l$, use the parallel axis theorem to determine the moment of inertia of the rod $I_{x=l}$ about the axis passing through $x = l$ in terms of M and l.

ANS: ____________________

(8 marks)

Q4 (15 marks)

/15

A heat engine using n moles of monoatomic ideal gas goes through the following closed cycle **ABCA** as shown in Figure 4:

(1) isochoric heating until pressure is doubled from P to $2P$;
(2) isothermal expansion at temperature $2T$ until pressure is restored to its initial value; and
(3) isobaric compression until the volume is restored to its initial value V.

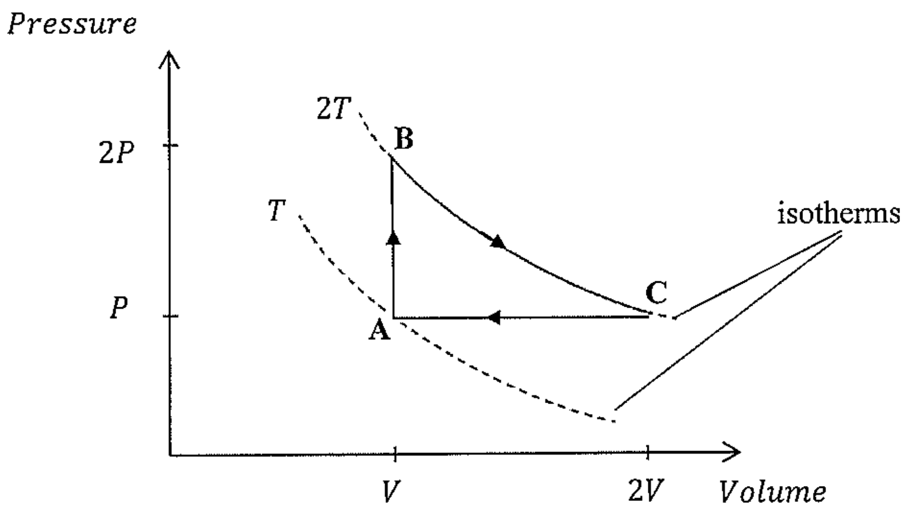


Figure 4

The constant volume molar heat capacity of a monoatomic ideal gas is $C_V = \frac{3}{2}R$ where R is the universal gas constant.

i. The work done in the cycle **ABCA** can be expressed as αnRT where α is a number. Determine α.

ANS: ________________

Note: Question No. 4 continues on Page 15

ii. The heat supplied or lost in each of the process **AB**, **BC** and **CA** can be expressed as $\beta_{AB}nRT, \beta_{BC}nRT$ and $\beta_{CA}nRT$ respectively where β_{AB}, β_{BC} and β_{CA} are numbers. Determine β_{AB}, β_{BC} and β_{CA}. [Indicate clearly if heat is supplied or lost].

ANS: ____________________

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iii. Calculate the thermal efficiency η of this engine, i.e. the ratio of the total work done to the total heat supplied for each cycle **ABCA**.

ANS: ____________________

(15 marks)

Q5 (15 marks)

/15

(a) As shown in Figure 5(a), we have a very long thin straight conductor with uniform charge per unit length λ.

i. Using Gauss's law, derive the expression for the magnitude of the electric field $|\vec{E}|$ at a distance R (near but outside) from the center of the wire.

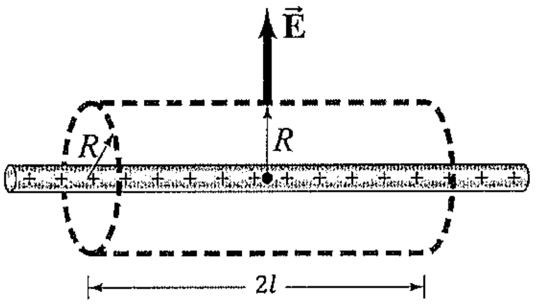

Figure 5(a)

ANS:____________________

ii. A small object with mass m and a small charge $+q$ is released from rest at a radial distance $2R$ from the long wire. Write down the expression for its initial acceleration a.

ANS:____________________

(6 marks)

Note: Question No. 5 continues on Page 17

(b) As shown in Figure 5(b), the L-shaped conductor moves at a constant speed 15 m/s at 45° across a stationary L-shaped conductor. The two conductors are in a uniform 0.12 T magnetic field directed out of the page. At time $t = 0$ s, the two vertices overlap so that the enclosed area is zero. At time $t > 0$ s, the area enclosed is always in the shape of a square. The conductors have a resistance of 0.01 ohms per meter and the resistances at the contact points are negligible.

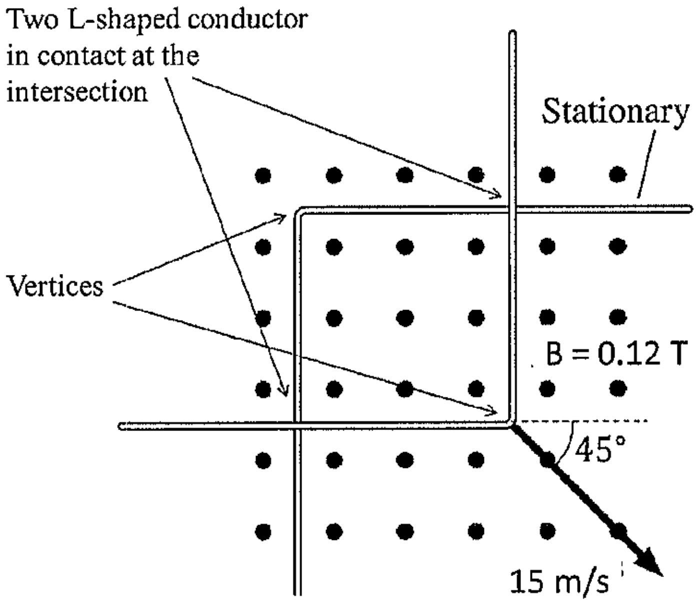

Figure 5(b)

i. At the instant shown in Figure 5(b), what is the direction of the induced current? Clockwise or anti-clockwise?

ANS: ___________________

ii. At $t = 0.10$ s, what is the total magnetic flux enclosed by the two L-shaped conductor?

ANS: ___________________

Note: Question No. 5 continues on Page 18

iii. By considering the total magnetic flux enclosed at any time t, determine the induced e.m.f. and induced current at $t = 0.10$ s.

ANS: ____________________

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(9 marks)

Q6 (10 marks)

/10

(a) Figure 6(a) shows a long straight wire carrying current I.

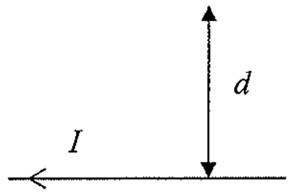

Figure 6(a)

Using Ampere's Law, show that the expression for the magnitude of the magnetic field $\boldsymbol{B}$ at a distance d from the long straight wire is

$$B = \frac{\mu_o I}{2\pi d}$$

(3 marks)

Note: Question No. 6 continues on Page 20

(b) A long wire carrying current $I = 150$ A lies in the plane of a rigid rectangular loop carrying current $I_1 = 140$ A, parallel to its longer sides as shown in the sketch [not drawn to scale] in Figure 6(b1). The rectangular loop has sides $a = 1.00$ m, $b = 15.0$ m and the distance d between the long wire and nearer side of the loop is 0.004 m.

i. Find the magnitude and direction (indicate in Figure 6(b1) below) of the resultant force acting on the loop.

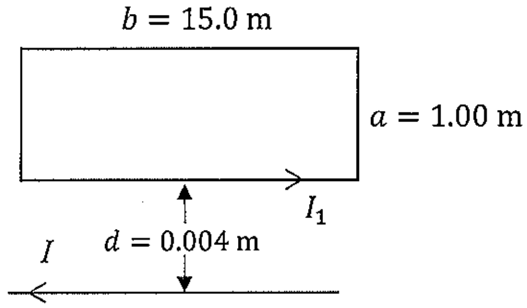

Figure 6(b1)

ANS: ____________________

Note: Question No. 6 continues on Page 21

ii. The arrangement shown in part (i) is used in the design of magnetically levitated trains with many vertical loops (of rectangular coil) fixed on each train carriage directly above a cable on the track bed (see schematic sketch in Figure 6(b2)). The coils and the carriage have the same length b. The carriage has mass per unit length $m = 800\ \text{kg m}^{-1}$.

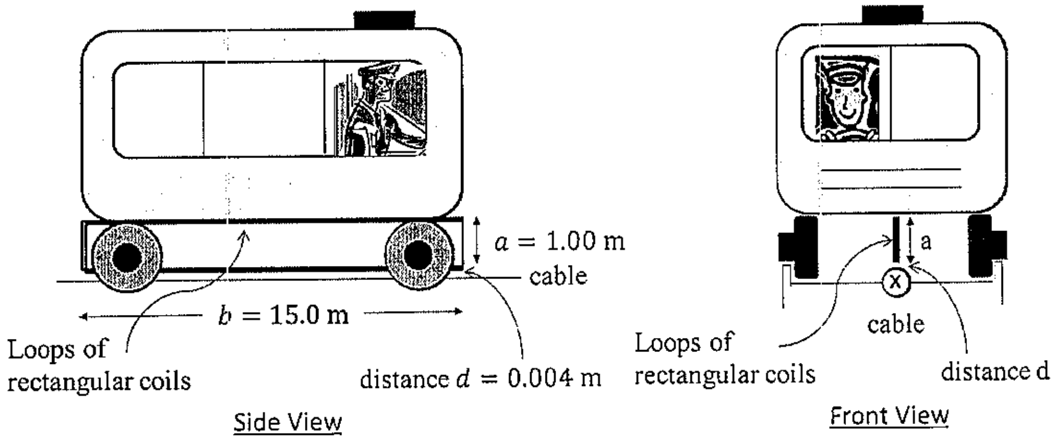

Figure 6(b2)

If the dimensions of the loops of rectangular coil and magnitudes of the currents are the same as in part 6b(i), how many loops of rectangular coil is needed to support the weight of the carriage?

ANS: ____________________

(7 marks)

Q7 (10 marks)

/10

(a) During a Physics demonstration, a fully charged 80 μF capacitor is discharged through a 60 Ω resistor. Calculate the time it takes for the capacitor to lose 70% of its charge.

ANS: ____________________

(3 marks)

(b) In the circuit shown in Figure 7, $E = 15$ V, $R_1 = 12\ \Omega$, $R_2 = 4\ \Omega$ and $R_3 = 10\ \Omega$. The capacitor has capacitance $C = 3$ μF.

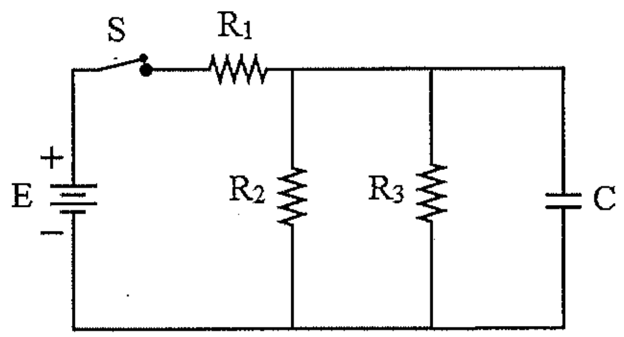

Figure 7

i. Determine the potential difference ΔV_C, across the capacitor after switch S has been closed for a long time.

ANS: ____________________

Note: Question No. 7 continues on Page 23

ii. Determine the energy stored in the capacitor when switch S has been closed for a long time.

ANS: ____________________

iii. After the capacitor is fully charged, switch S is opened. What is the energy is dissipated through R_3 when switch S is opened?

ANS: ____________________

(7 marks)

- End of Paper -

PH1011 PHYSICS

Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.