NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2015-2016

PH1012 – Physics A

Nov/Dec 2015 Time Allowed: 2½ Hours

SEAT NUMBER: | | | | |

MATRICULATION NUMBER: | | | | | | | | | |

INSTRUCTIONS TO CANDIDATES

1. This question and answer booklet contains **SIX (6)** questions and comprises **NINETEEN (19)** pages.

2. Answer **ALL SIX (6)** 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** (15)	**3** (15)	**4** (15)	**5** (20)	**6** (15)	**Total** (100)
Marks							

Q1 (20 marks) /20

As shown in Figure 1(a), an object of mass $m_1 = 0.160$ kg is released from rest at the top edge (labelled A) of a frictionless hemispherical bowl of radius $R = 0.40$ m with center at O. The object slides down on the inner surface of the bowl and has a velocity of 2.80 m/s at the bottom of the bowl (labelled B). You can treat all objects in the bowl as point masses and assume that the bowl remains stationary all the time.

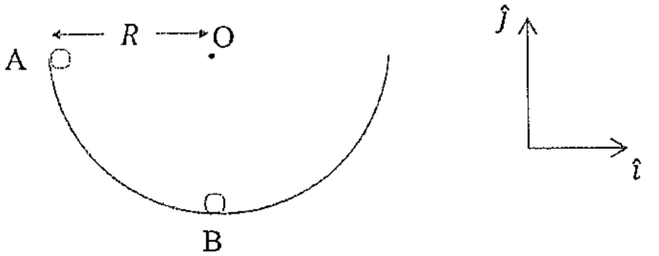
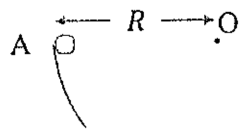


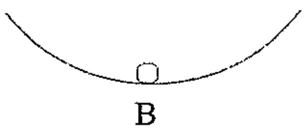
Figure 1(a)

(a) We will study the acceleration, velocity and position of the object in the bowl.

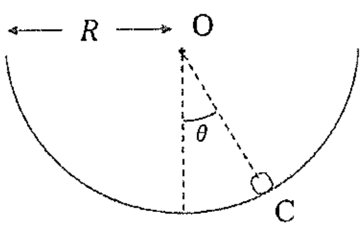
i. Using the diagram below, indicate the direction of acceleration of the object when it is just released from rest at point A with an arrow labelled a_A.



ii. Using the diagram below, indicate the direction of the velocity with one arrow labelled v_B and the direction of acceleration with another arrow labelled a_B when the object is at the bottom of the bowl B.



iii. Using the diagram below, indicate the direction of acceleration of the object at point C where $\theta = 30°$ with an arrow labelled a_C. Write down the position of the object when it is at point C in vector form. Use O as the origin.



ANS: ______________

Note: Question No. 1 continues on Page 3

(b) Calculate the normal force F_N acting on the object at the bottom of the bowl.

ANS: ______________

(c) In another situation, an object of mass $m_2 = 0.040$ kg is originally at rest at the bottom of the same bowl as shown in Figure 1(b). The object with mass m_1 is released from rest at the top edge of the bowl as before. The two masses stick together after collision and slide up the other side of the bowl.

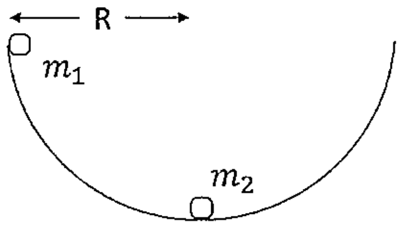


Figure 1(b)

i. Calculate the common velocity of the two objects immediately after collision.

ANS: ______________

Note: Question No. 1 continues on Page 4

ii. Calculate the impulse on mass m_1 due to the collision.

ANS: ________________

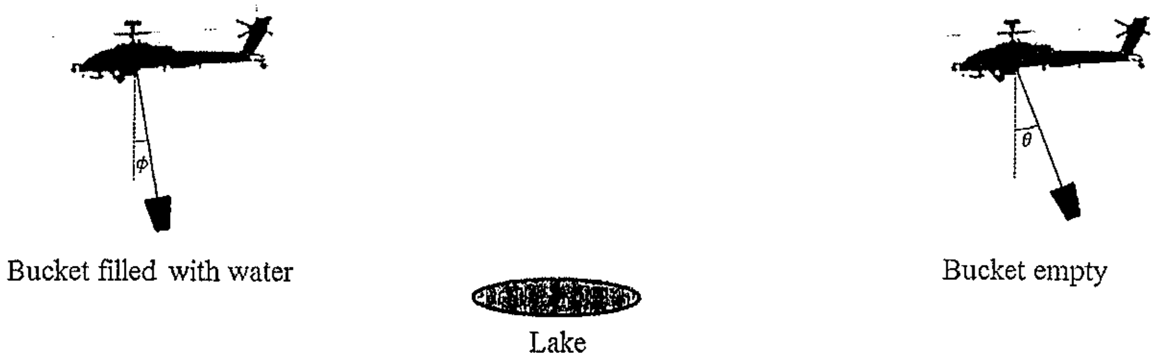
(d) If the collision in 1(c) is elastic, calculate the height h_1 from the bottom of the bowl that mass m_1 will slide up to after the collision.

ANS: ________________

Q2 (15 marks) /15

One form of aerial fire-fighting to put out forest fires involves using a helicopter to fill up a water bucket (also known as "heli-bucket") with water from a lake and then releasing the water from the bucket on the targeted area on fire.

(a) When the helicopter is flying at a constant horizontal velocity on a windless day, the effect of air resistance on the bucket results in a constant horizontal force F on the bucket. The empty bucket has mass m = 210 kg. When the bucket is moving at a <u>constant horizontal velocity</u>, the cords holding the empty bucket makes an angle $\theta = 57.0°$. When the bucket is filled with water flying at the same <u>constant horizontal velocity</u>, the angle $\phi = 2.5°$. See Figure 2(a).



<u>Figure 2(a)</u>

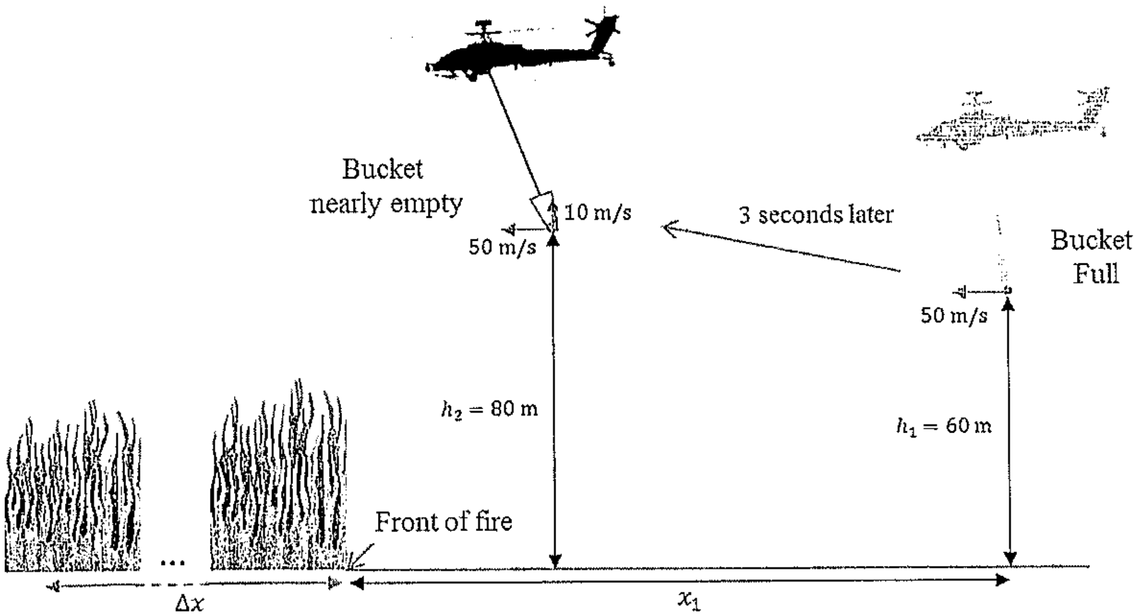
i. Using the diagram below, indicate (with labeled arrows) the three forces acting on the bucket. (Note: You can ignore upthrust or buoyant force.)

ii. By considering the forces acting on the bucket before and after filling with water, calculate the mass M of the bucket filled with water. You can assume that the force F is the same before and after the bucket is filled with water.

ANS: ______________

Note: Question No. 2 continues on Page 6

(b) Now the helicopter is flying horizontally at a constant velocity of 50 m/s towards the forest fire such that the bucket is at height $h_1 = 60$ m (see Figure 2(b)) above the ground. When the bucket first opened, the initial velocity of the water released is 50 m/s in the horizontal direction relative to the ground. It takes 3 s to empty all the water in the bucket. For safety reasons in this case, in the period of 3 s, the helicopter climbed higher such that the bucket is at $h_2 = 80$ m above the ground with an additional velocity of 10 m/s in the vertical direction.



Note: Figure not drawn to scale

Figure 2(b)

Though not too realistic, we will assume that the effects of air resistance on the water released from the bucket can be ignored to keep the analysis simple.

i. Calculate the horizontal distance x_1 where water has to be first released at $h_1 = 60$ m so that it will land at just the front of the fire on the ground.

ANS: ______________

Note: Question No. 2 continues on Page 7

ii. After 3 s at $h_2 = 80$ m, the last bit of water released has an initial velocity of 10 m/s in the vertical direction and 50 m/s in the horizontal direction. Calculate the horizontal distance Δx on the ground that has been sprayed with water.

ANS: ______________

(c) We will next study how the path of the water will be affected by the effects of air resistance. The magnitude of the horizontal resistive force $|F_H|$ acting on the water moving at horizontal velocity v_H can be modelled using the equation $|F_H| = bv_H^2$ where b is a constant. The same applies for the vertical direction, $|F_V| = bv_V^2$.

i. An object is projected in a vacuum with an initial horizontal velocity. As shown in Figure 2(c), the positions of the object at $t = 0$ s, 1 s, 2 s and 3 s are indicated with •. Without doing any detailed calculations, mark on Figure 2(c) with ∘ at $t = 1$ s, 2 s and 3 s to show how the position of the object will change because of air resistance.

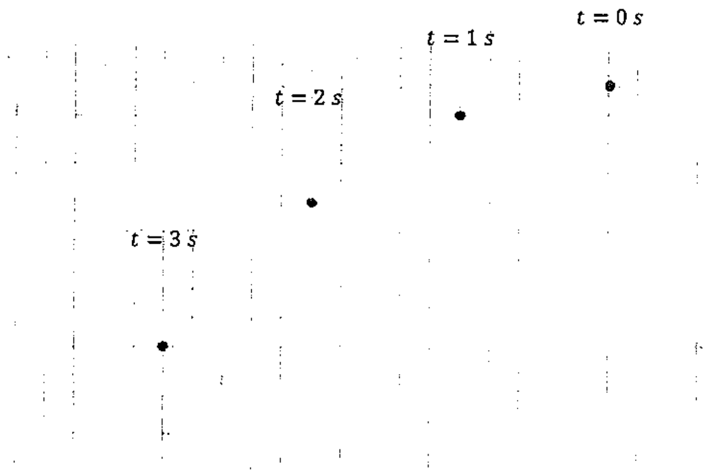


Figure 2(c)

ii. With the above analysis involving air resistance, how should the value of x_1 in part 2(bi) be modified? Please circle your answer below.

Be smaller Same Be larger Cannot be determined

Q3 (15 marks)

/15

(a) As shown in Figure 3(a), a uniform beam of length $L = 0.80$ m and mass $M = 24.0$ kg has one end supported by an inextensible, massless cable and the other end mounted by a small hinge to the wall. The cable is at an angle $\phi = 27°$ from the horizontal and the beam is held at $\theta = 54°$ to the vertical.

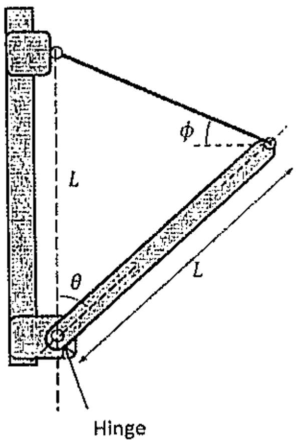
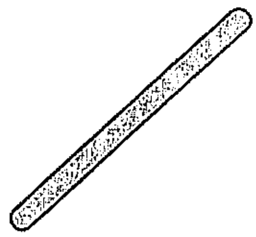


Figure 3(a)

i. Using the diagram below, indicate (with labeled arrows) the forces acting on the beam.



ii. The system is in equilibrium. Calculate the magnitude of the tension acting in the cable and the vertical component of the force at the hinge.

ANS:__________________

Note: Question No. 3 continues on Page 9

As shown in Figure 3(b), the cable breaks and the beam rotates from rest about the hinge. As before, the angle $\theta = 54°$ when the cable breaks. The frictional forces at the hinge can be neglected in your calculations.

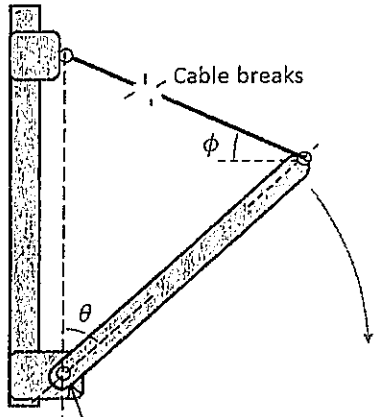


Figure 3(b)

iii. Calculate the angular acceleration α and angular velocity ω of the beam when it is in the horizontal position, i.e. when $\theta = 90°$.

ANS:________________

ANS:________________

Note: Question No. 3 continues on Page 10

5

(b) In a modified set-up as shown in Figure 3(c), the same beam (mass $M = 24.0$ kg and length $L = 0.80$ m) is connected to an inextensible, massless cable which passes over a pulley with mass $M_p = 1.2$ kg and radius $r = 0.20$ m. The other end of the cable is connected to a block of mass $M_B = 5.0$ kg on a frictionless inclined plane with angle $\beta = 40°$. The frictional force at the axle of the pulley is negligible. When the beam is released from rest with $\phi = 27°$ and $\theta = 54°$, the pulley rotates without slipping and the block accelerates up the slope. The cable does not slip on the pulley. The pulley can be treated as a uniform solid disc.

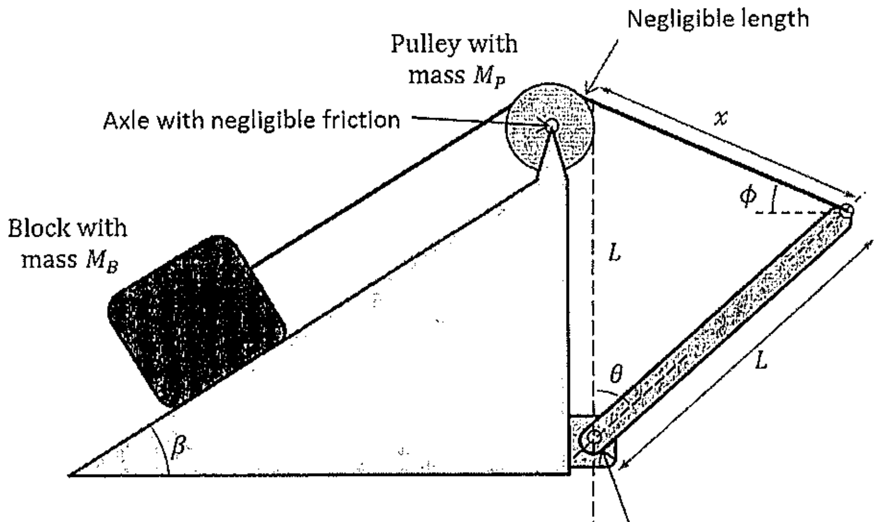


Figure 3(c)

Calculate the angular velocity of the beam when it is horizontal, i.e. $\theta = 90°$. [Hint: One of the approaches involves relating the length x to the angle θ. You can ignore the segment marked "Negligible length" here.]

ANS:________________

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6

6

Q4 (15 marks)

/15

The indicator diagram for an ideal heat engine shown in Figure 4 uses 0.080 moles of diatomic gas as a working substance round a cycle: the process **1** → **2** is adiabatic; **2** → **3** is at constant volume V_{min}; **3** → **4** is adiabatic; and **4** → **1** is at constant volume V_{max}. Here, we know that $P_{max} = 40.0 \times 10^5$ Pa, $P_2 = 18.4 \times 10^5$ Pa, $P_{min} = 1.0 \times 10^5$ Pa, $V_{min} = 2.5 \times 10^{-4}$ m^3, and $V_{max} = 20.0 \times 10^{-4}$ m^3. The molar heat capacity of a diatomic ideal gas at constant volume is $C_V = \frac{5}{2}R$ and at constant pressure is $C_p = \frac{7}{2}R$ where R is the universal gas constant. The ratio $\gamma = \frac{C_p}{C_V} = 7/5$.

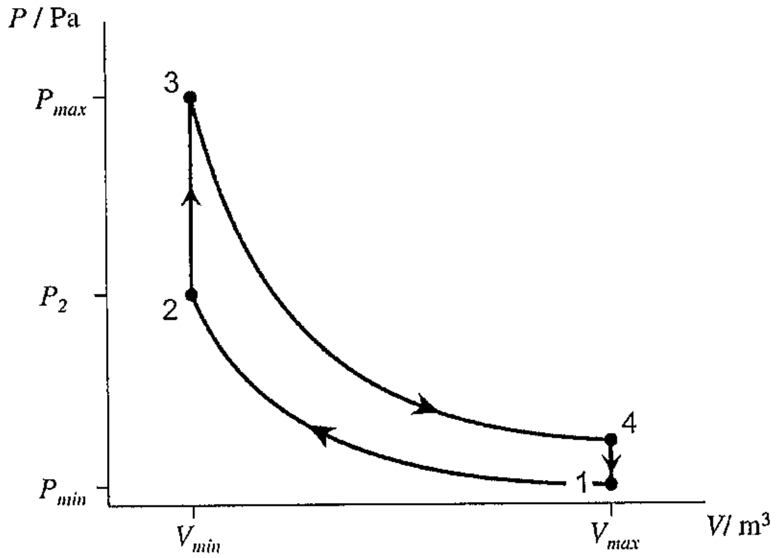

Figure 4

i. Calculate the temperature T_2 at point 2.

ANS: ____________________

ii. The processes for this heat engine include heat entering the system and expansion with no heat loss. Identify these two processes from Figure 4.

Heat entering system: ____→____; Expansion with no heat loss: ____→____

Note: Question No. 4 continues on Page 13

iii. Calculate the net work done for one complete cycle $1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 1$ for the heat engine in Figure 4.

ANS: ____________________

iv. Calculate the heat input for the heat engine in Figure 4.

ANS: ____________________

v. If the temperatures in the engine for the four points 1, 2, 3, 4 are T_1, T_2, T_3 and T_4 respectively, determine the general expression for the efficiency for this engine in terms of these four temperatures.

ANS: ____________________

vi. As mentioned, the engine given in Figure 4 is an ideal design. State one physical difficulty in realizing the processes shown in Figure 4 in real life.

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Q5 (20 marks) /20

(a) Positive charge Q is distributed uniformly throughout the volume of an insulating sphere with radius r_o. The charge per unit volume of the sphere is ρ.

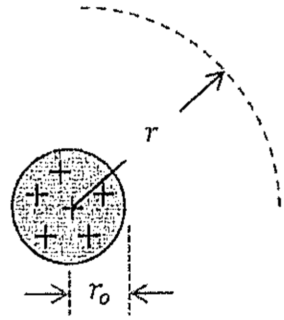
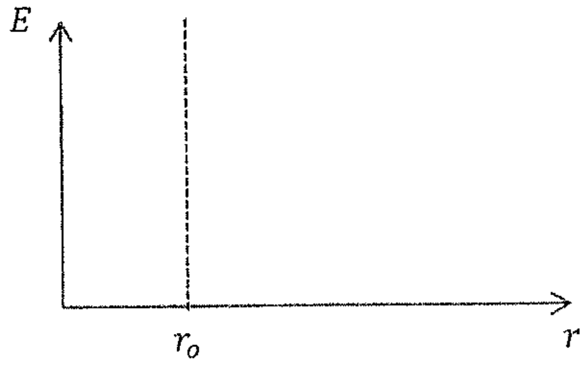


Figure 5(a)

i. Using Gauss's law, determine the electric field E at a distance r (from the center) outside the sphere ($r > r_o$) as shown in Figure 5(a). Express your answer in terms of r_o, ρ, r and any other relevant physical constant(s).

ANS: ________________

ii. Sketch using the axes below to show how the electric field E varies with distance r inside ($r < r_o$) and outside ($r \geq r_o$) the sphere.



Note: Question No. 5 continues on Page 15

(b) As shown in Figure 5(b), two point charges $q_1 = +2.0$ μC and $q_2 = -5.0$ μC are separated by 6.0 cm. A point P, 8.0 cm from q_2, forms a right-angle triangle with the two charges.

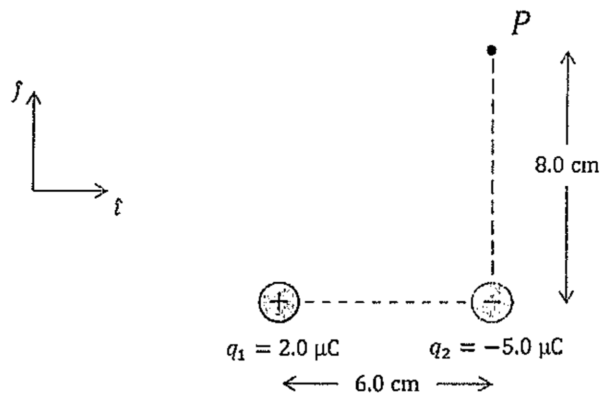


Figure 5(b)

i. Calculate the electric field at point P. Leave your answer in vector form.

ANS: ________________

ii. An electron is released from rest at point P. Calculate the speed of the electron when it passes a point where the electric potential is -3.6×10^5 V.

ANS: ________________

Note: Question No. 5 continues on Page 16

(c) A Helmholtz coil is a device for producing a region of nearly uniform magnetic field. A Helmholtz pair consists of two identical circular coils that are placed symmetrically along a common axis, one on each side of the experimental area, and separated by a distance equal to the radius R of the coil as shown in Figure 5(c). Each coil carries an equal electric current in the same direction. The directions of electric current I in the coil and the corresponding magnetic field B are shown in Figure 5(d).

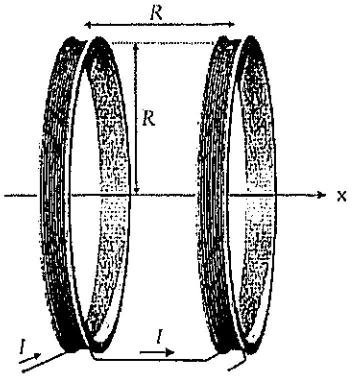


Figure 5(c)

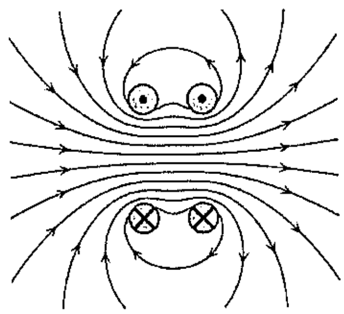


Figure 5(d)

The magnetic field B at the mid-point between the two coils is given by

$$B = \left(\frac{4}{5}\right)^{\frac{3}{2}} \frac{\mu_o n I}{R}$$

where n is the number of turns in each coil and μ_o is the permeability of free space. In a given set-up, $n = 250$ and $R = 0.20$ m. The current I in the coils varies with time as shown in Figure 5(e).

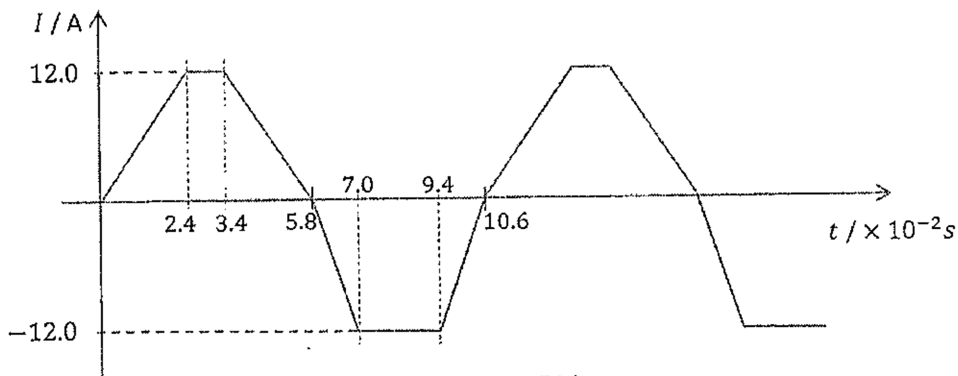


Figure 5(e)

i. Calculate the magnitude of maximum magnetic field at the mid-point of the two coils.

ANS: ________________

Note: Question No. 5 continues on Page 17

A search coil is placed in the mid-point between the two coils as shown in Figure 5(f). The axis of the search coil and two coils are aligned. The search coil has 12 turns and cross sectional area of $0.020\ m^2$.

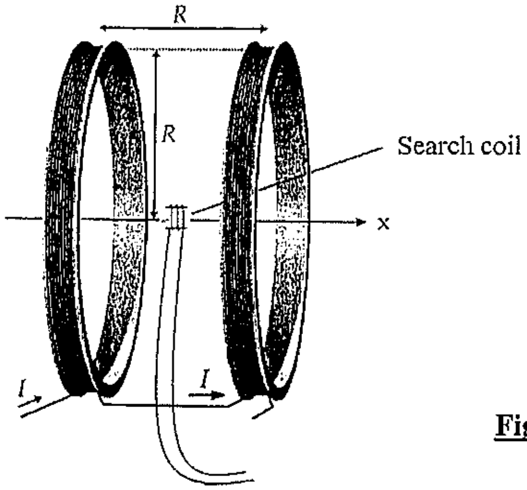
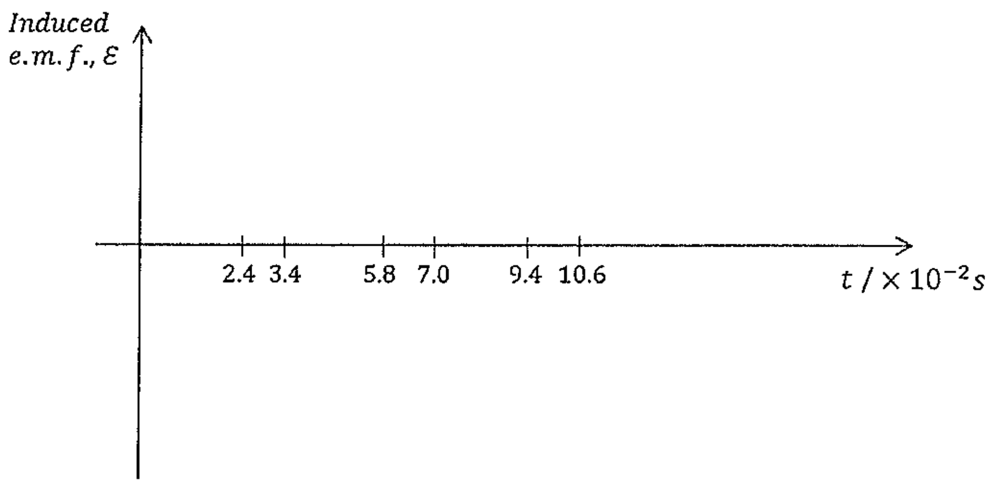


Figure 5(f)

ii. Sketch using the axes below, the corresponding time variation of the induced e.m.f., $\mathcal{E}$ in the search coil from $t = 0$ s to $t = 10.6 \times 10^{-2}$s.



iii. Calculate the magnitude of the maximum induced e.m.f. in the search coil.

ANS: ________________

Q6 (15 marks)

/15

Figure 6(a) shows a circuit where $V_1, V_2, V_3, V_4, V_5, V_6 = 1\text{ V}, 2\text{ V}, 3\text{ V}, 4\text{ V}, 5\text{ V}, 6\text{ V}$ respectively and $R_1, R_2, R_3, R_4, R_5, R_6 = 1\,\Omega, 2\,\Omega, 3\,\Omega, 4\,\Omega, 5\,\Omega, 6\,\Omega$ respectively. Calculate the current passing through R_2.

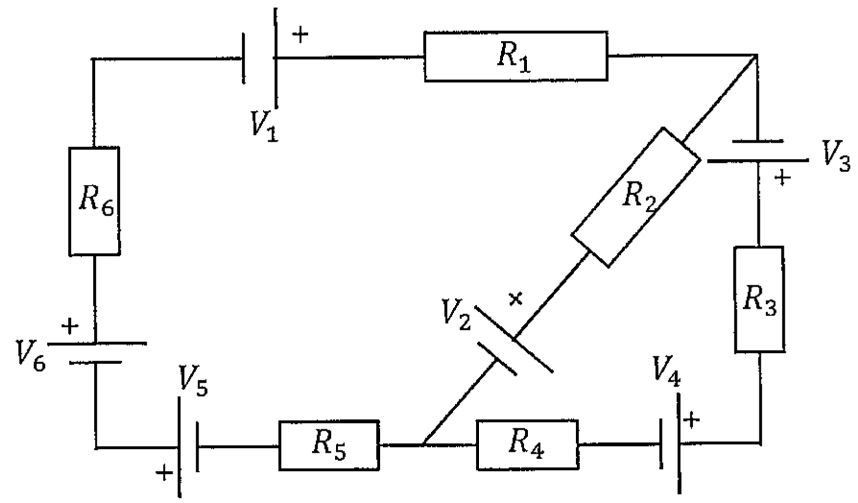


Figure 6(a)

ANS: ____________________

Note: Question No. 6 continues on Page 19

(b) Consider a RC circuit with $V = 15.0$ V, $R_1 = 200\ \Omega$ and $R_2 = 100\ \Omega$. The capacitors are $C_1 = 1.0\ \mu$F, $C_2 = 2.0\ \mu$F and $C_3 = 3.0\ \mu$F.

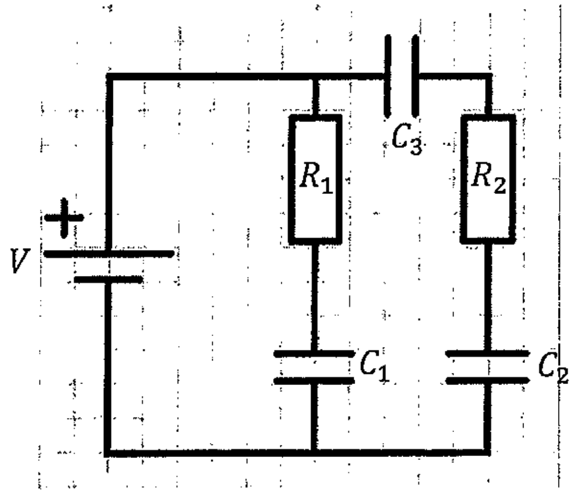


Figure 6(b)

i. All the capacitors are initially uncharged. At $t = 0$, the battery is connected and charging starts. Calculate the current through R_2 immediately when charging starts.

ANS: __________________

ii. After a long time, the 3 capacitors are fully charged. Calculate the energy stored in C_1.

ANS: __________________

- End of Paper -

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Subject Code : PH 1012	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics A	
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Q1.

a. i. $m = 0.16\,kg$ $g = 9.8\,m/s^2$ $R = 0.4\,m$ $V_{bottom} = 2.8\,m/s$

$\downarrow a_A$ $a_{A\,radial} = \frac{v^2}{r} = \frac{0}{r} = 0$

$\downarrow mg$ $a_{A_F} = \frac{F}{m} = \frac{mg}{m} = g$

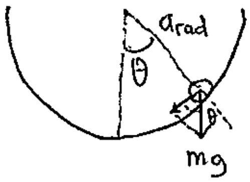
$\Big\}\ a = \sqrt{g^2 + 0} = g$ (gravitation) ($9.8\,m/s^2$)

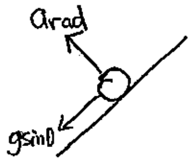
ii.

$a_{mg} = 0$

$a_{radial} = \frac{v_b^2}{r} = \frac{(2.8)^2}{0.4} = \underline{19.6\,m/s^2}$

iii.





$a_\perp = \frac{F}{m} = \frac{mg\sin\theta}{m} = g\sin\theta$

$a_{rad} = \frac{v_c^2}{r}$

We can find V_c using:

$E_{k1} + E_{p1} = E_{k2} + E_{p2}$

$\frac{1}{2}mv_b^2 + 0 = \frac{1}{2}mv_c^2 + mg(R - R\cos\theta)$

$v_b^2 = v_c^2 + 2gR(1-\cos\theta)$

$v_c^2 = v_b^2 - 2gR(1-\cos\theta)$ ← subtitute

$a_{rad} = \frac{1}{r}\left(v_b^2 - 2gR(1-\cos\theta)\right)$

$a_{rad} = \frac{1}{0.4}\left(2.8^2 - 2\cdot 9.8\cdot 0.4(1-\cos 30)\right)$

$a_{rad} = 17$

$a^2 = a_{rad}^2 + a_\perp^2$

$= 17^2 + (9.8\cdot\sin 30°)^2$

$a = \underline{17.7\,m/s^2}$

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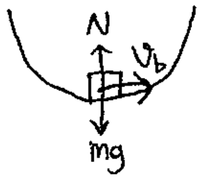
b.



$\Sigma F_s = m\frac{v^2}{r}$

$N - mg = m\frac{v^2}{r}$

$N = m\{g + \frac{v^2}{r}\}$

$N = 0.16(9.8 + \frac{(2.8)^2}{0.4}) = \underline{4.704\ N}$

c. $m_2 = 0.04\ kg$

i. $\overset{\rightarrow v_b}{O}_{m_1}$ $\quad O_{m_2}$ (stick together)

momentum conserved: $m_1 v_b = (m_1 + m_2) V'$

$V' = \frac{m_1}{m_1 + m_2} v_b = \frac{0.16}{0.16 + 0.04} \cdot 2.8 = \underline{2.24\ m/s}$

ii. Impuls $I = \Delta p$

$= m_1 \Delta V_1$

$= m_1(v' - v_b)$

$= 0.16(2.24 - 2.8)$

$I = -0.0896\ kg\ m/s$

d. if elastic

$m_1 v_b = m_1 v_1 + m_2 v_2 \quad \ldots (1)$

$e = 1 = -\frac{V_1 - V_2}{V_b - 0}$

$-V_b = V_1 - V_2$

$v_2 = v_1 + v_b \ldots (2)$

$m_1 v_b = m_1 v_1 + m_2(v_1 + v_b)$

$(m_1 - m_2) v_b = (m_1 + m_2) v_1$

$v_1 = \frac{m_1 - m_2}{m_1 + m_2} v_b$

$v_1 = \frac{0.16 - 0.04}{0.16 + 0.04} \cdot 2.8$

$\leftarrow v_1 = \underline{1.68}\ m/s$

Energy conserved:

$E_1 = \frac{1}{2} m_1 v_1^2 = \frac{1}{2} \cdot 0.16(1.68)^2$

$E_1 = 0.226\ J = mgh_1$

$h_1 = \frac{E_1}{mg} = \frac{0.226}{0.16 \cdot 9.8} = \underline{0.144\ m}$

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Subject Name : Physics A	
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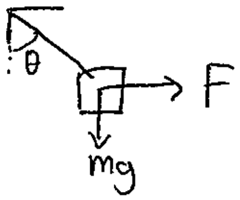
Q2.

a. i.



$m_0 = 210\,kg$ (empty)

$\theta_0 = 57^\circ \qquad \phi = 2.5^\circ$

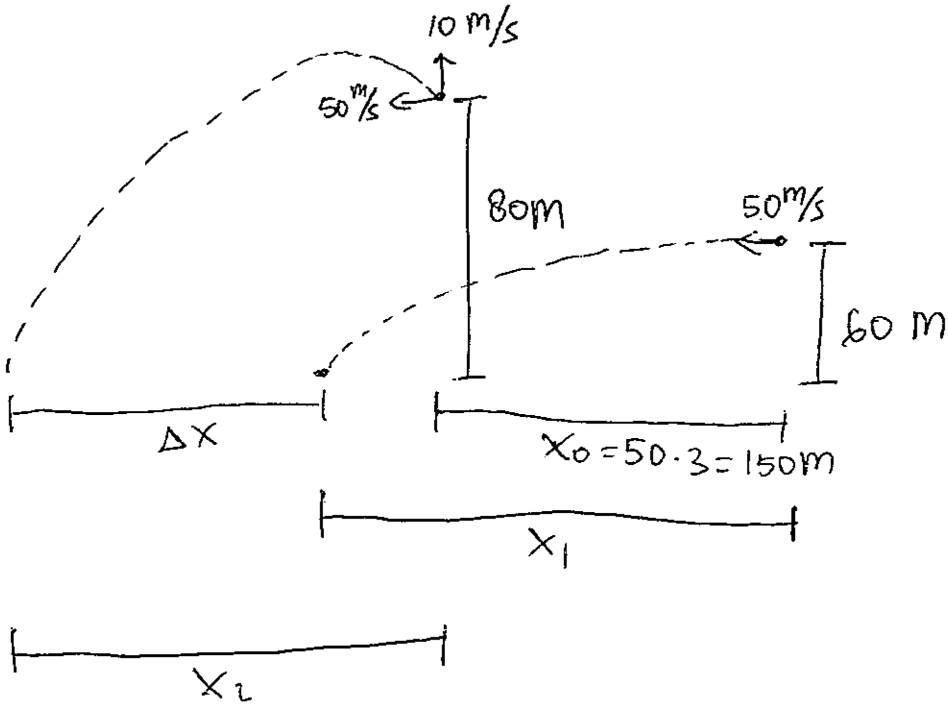
ii. $\tan\theta = \frac{F}{mg} \rightarrow F = mg\tan\theta \qquad \tan\phi = \frac{F}{Mg} \rightarrow F = Mg\tan\phi$

$$F = F$$

$$Mg\tan\phi = mg\tan\theta$$

$$M = m\frac{\tan\theta}{\tan\phi} = 210\cdot\frac{\tan 57}{\tan 2.5} \Rightarrow M = \underline{7406.43\,kg}$$

b.



$$\Delta x = x_2 - \{x_1 - x_0\}$$

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b.i. x axis: $x_1 = v t$

$x_1 = v \sqrt{\frac{2h}{g}}$

$x_1 = 50 \cdot \sqrt{\frac{2 \cdot 60}{9.8}} = 175$

y axis: $h = 0 + \frac{1}{2} g t^2$

$t = \sqrt{\frac{2h}{g}}$

$h' = h_0 + v_{0y} t - \frac{1}{2} g t^2$

$0 = 80 + 10t - 5t^2$

$5t^2 - 10t - 80 = 0$

$t^2 - 2t - 16 = 0$

$t = \frac{2 \pm \sqrt{4 - 4 \cdot (-16)}}{2}$

$= \frac{2 \pm \sqrt{4 + 64}}{2}$

$t = 5.123 s$

$x_2 = 50 \cdot t_2$

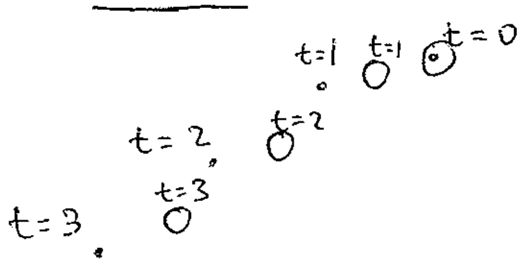
$x_2 = 50 \cdot 5.123$

$x_2 = 256.15 \, m$

ii. $\Delta x = 256.15 - (175 - 150)$

$\Delta x = 231.15 \, m$

c.i.



ii. Be smaller

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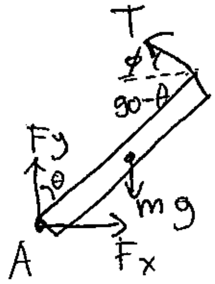
Q3.

a. i.



$L = 0.8\,m$
$M = 24\,kg$
$\phi = 27°$
$\theta = 54°$

ii. $\Sigma F_x = 0$

$F_x = T\cos\phi \ldots (1)$

$\Sigma F_y = 0$

$F_y + T\sin\phi = mg \ldots (2)$

$$\Sigma \tau_A = 0$$

$$T\sin(90-\theta+\phi)\cdot \cancel{L} = mg\sin\theta \cdot \frac{1}{2}\cancel{L}$$

$$T\sin(90-(\theta-\phi)) = mg\sin\theta\cdot\frac{1}{2}$$

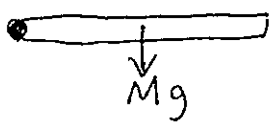
$$T\cos(\theta-\phi) = mg\sin\theta\cdot\frac{1}{2} \ldots (3)$$

$$T = \frac{mg\sin\theta}{2\cos(\theta-\phi)} = \frac{24\cdot 9.8\cdot\sin 54}{2\cos(54-27)}$$

$$T = \underline{106.78\,N}$$

$$(2)\ldots F_y = mg - T\sin\phi$$
$$= 24\cdot 9.8 - 106.78\sin 27$$
$$F_y = \underline{186.723\,N}$$

iii.



$$I_{rod} = \frac{1}{3}mL^2$$

$$\Sigma\tau = I\alpha$$

$$\cancel{M}g\frac{1}{2}L = \frac{1}{3}\cancel{M}L^2\alpha$$

$$\alpha = \frac{3}{2}\frac{g}{L} = \frac{3}{2}\cdot\frac{9.8}{0.8} = \underline{18.375}\ \text{rad}/s^2$$

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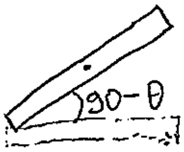


$\Delta H = \frac{1}{2} L \sin(90-\theta) = \frac{1}{2} L \cos\theta$

Energy Conserved

$mg\Delta H = \frac{1}{2} I \omega^2$

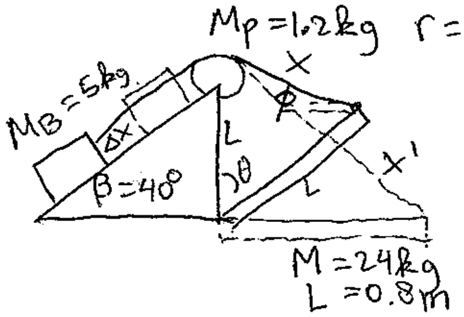
$mg\Delta H = \frac{1}{2} \cdot \frac{1}{3} mL^2 \cdot \omega^2$

$g \frac{1}{2} L \cos\theta = \frac{1}{6} \cdot L^2 \omega^2$

$\omega^2 = \frac{3g}{L} \cos\theta$

$\omega = \sqrt{\frac{3 \cdot 9.8}{0.8} \cos 54} = 4.65 \text{ rad/s}$

b.

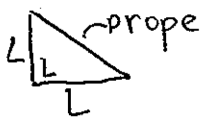


(Initial)

$\phi = 27°$

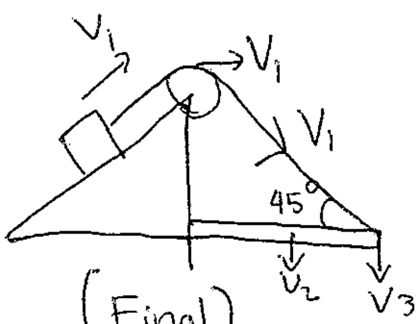
$\theta = 54°$

Initial:  $x_0 = 2L\sin\frac{\theta}{2}$

Final:  $x' = L\sqrt{2}$

$\Delta x = x' - x_0$

$\Delta x = L\sqrt{2} - 2L\sin\frac{\theta}{2}$



(Final)

- v_1 & v_3 relation:

  $v_3 \cos 45° = v_1$

- v_2 & v_3 relation:

  $\omega = \omega$

  $\frac{v_2}{\frac{1}{2}L} = \frac{v_3}{L} \Rightarrow v_2 = 2v_3$

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Hence, v_1 & v_2 relation:

$$\frac{1}{2} v_2 \cos 45^\circ = v_1$$

$$I_{pulley} = \frac{1}{2} M_p r^2$$

$$\omega_p = \frac{v_1}{r}$$

$$I_{beam} = \frac{1}{3} M L^2$$

rod

$$\Delta H_2 = \frac{1}{2} L \cos\theta$$

Object

$$\Delta H_1 = \Delta x \sin 40^\circ$$

$$M g \Delta H_2 = M_B g \Delta H_1 + \frac{1}{2} M_B v_1^2 + \frac{1}{2} I_{pulley} \omega_p^2 + \frac{1}{2} I_{beam} \omega_b^2$$

$$M g \frac{1}{2} L \cos\theta = M_B g \Delta x \sin 40 + \frac{1}{2} M_B v_1^2 + \frac{1}{2} \cdot \frac{1}{2} M_p r^2 \cdot \frac{v_1^2}{r^2} + \frac{1}{2} \cdot \frac{1}{3} M \cdot L^2 \left(\frac{v_2}{\frac{1}{2}L}\right)^2$$

$$\frac{1}{2} M g L \cos\theta = M_B \cdot g \Delta x \sin 40 + \frac{1}{2} M_B v_1^2 + \frac{1}{4} M_p v_1^2 + \frac{1}{6} \cdot 4 M v_2^2$$

$$\frac{1}{2} M g L \cos\theta = M_B g \Delta x \sin 40 + \frac{1}{2} M_B v_1^2 + \frac{1}{4} M_p v_1^2 + \frac{2}{3} M v_2^2$$

$$\frac{1}{2} M g L \cos\theta = M_B g \Delta x \sin 40 + \frac{1}{2} M_B v_1^2 + \frac{1}{4} M_p v_1^2 + \frac{2}{3} M \left(2 v_1 / \cos 45\right)^2$$

$$\frac{1}{2} \cdot 24 \cdot 10 \cdot 0.8 \cdot \cos 54 = 5 \cdot 10 \cdot 0.8 (\sqrt{2} - 2\sin 27) \sin 40 + \frac{1}{2} \cdot 5 \cdot v_1^2 + \frac{1}{4} \cdot 1.2 \cdot v_1^2 + \frac{2}{3} \cdot 24 \cdot \left(2 v_1 / \tfrac{1}{2}\sqrt{2}\right)^2$$

$$56.4 = 13 + \frac{5}{2} v_1^2 + v_1^2 \cdot 0.3 + 16 \left(\frac{4}{\sqrt{2}} v_1\right)^2$$

$$56.4 = 13 + (2.5 + 0.3 + 128) v_1^2$$

$$v_1 = 0.576 \text{ m/s}$$

$$\omega_{beam} = \frac{v_2}{\frac{1}{2}L} = \frac{2 v_1}{\frac{1}{2} L \cos 45} = \frac{2 \cdot 0.576}{\frac{1}{2} \cdot 0.8 \cdot \cos 45} = \underline{4 \text{ rad/s}}$$

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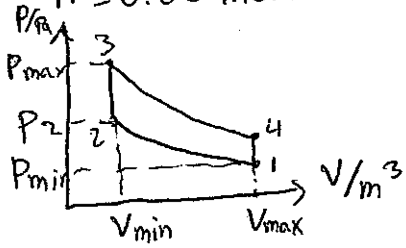
Q4. $n = 0.08$ moles



i. $P_2 \cdot V_{min} = nRT_2$

$$T_2 = \frac{P_2 \cdot V_{min}}{nR} = 691.6K$$

ii. Heat entering system:

$$T_1 = \frac{P_{min} \cdot V_{max}}{n \cdot R} = 300.7K$$

$T_2 = 691.6K$

$$T_3 = \frac{P_{max} \cdot V_{min}}{n \cdot R} = 1503.5K$$

iii. We know $3 \to 4$ is adiabatic, hence

$PV = nRT$ $\qquad PV^{\gamma} = \text{constant}$

$V = \frac{nRT}{P}$ ...(1) $\qquad P_3V_3^{\gamma} = P_4V_4^{\gamma}$ ...(2)

we know $4 \to 1$, volume is constant

$$\frac{V}{nR} = \frac{T}{P} = \text{constant}$$

$$\frac{T_1}{P_1} = \frac{T_4}{P_4} = \frac{300.7}{10^5}$$

$P_4 = 332.56T_4$ ...(3)

$$P_{max} \cdot V_{min}^{\gamma} = \frac{(nRT_4)^{\gamma}}{P_4^{\gamma-1}}$$

$$P_{max} \cdot V_{min}^{\gamma} = \frac{(nR)^{\gamma} \cancel{T_4^{\gamma}}}{(332.56)^{\gamma-1} \cdot \cancel{(T_4)^{\gamma}} T_4^{-1}}$$

$36.24 = 0.0554T_4$

$T_4 = 654.45K$

total work = $Q_{in} - Q_{out}$

$Q_{in} = \Delta Q_{23} = 1330.00$

$Q_{out} = \Delta Q_{41} = 588.22$

$W = 761.78$

iv. $Q_{in} = \Delta Q_{23} = 1350$

v. $\text{Efficiency} = \dfrac{Q_{in} - Q_{out}}{Q_{in}} = \dfrac{(T_3 - T_2) - (T_1 - T_4)}{T_3 - T_2}$

$= \dfrac{T_3 - T_2 + T_4 - T_1}{T_3 - T_2}$

vi. Adiabatic process is very hard to be carried since we need to maintain that there isn't any heat transfer with environment.

Q5. Charge Q, distributed uniform to sphere $(r = r_0)$
charge / unit volume $= \rho$

i. 

Using Gauss' Law:

$\oint E\,dA = \dfrac{Q_{enc}}{\varepsilon_0}$

$E \cdot 4\pi r^2 = \dfrac{Q}{\varepsilon_0}$

$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ with $Q = \rho \cdot \frac{4}{3}\pi r_0^3$

hence $E = \dfrac{\rho \cdot r_0^3}{3\varepsilon_0 r^2}\hat{r}$

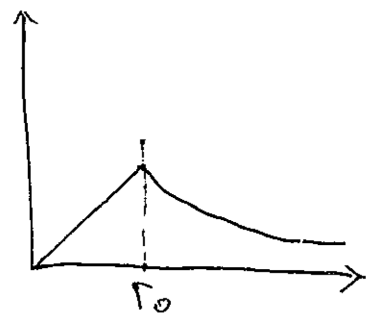
ii. 

Gauss' Law:

$\oint E \cdot dA = \dfrac{Q_{enc}}{\varepsilon_0}$

$E \cdot 4\pi r^2 = \frac{4}{3}\pi r^3 \rho / \varepsilon_0$

$E = \dfrac{\rho r}{3\varepsilon_0}\hat{r}$

so 

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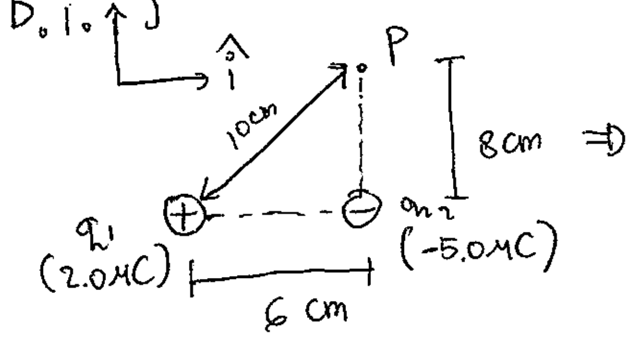
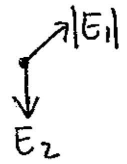
b. i.



If we look at point P



So $E_i = |E_1| \cos\theta$

$E_j = |E_1| \sin\theta - |E_2|$

$|E_1| = \frac{q_1}{4\pi\varepsilon_0 (10\cdot 10^{-2})^2} = 1.80\cdot 10^6\ N/C$

$|E_2| = \frac{|q_2|}{4\pi\varepsilon_0 (8.0\cdot 10^{-2})^2} = 7.02\cdot 10^6\ N/C$

So, $E = 1.08\cdot 10^6\ \hat{i} + (-5.58\cdot 10^6)\hat{j}$

ii. first, we need to calculate potential at P

$V_0 = V_1 + V_2$

$V_1 = \frac{q_1}{4\pi\varepsilon_0 r_1} = \frac{2\cdot 10^{-6}}{4\pi\varepsilon_0 \cdot 10\cdot 10^{-2}} = 1.8\cdot 10^5$

$V_2 = \frac{q_2}{4\pi\varepsilon_0 r_2} = \frac{-5\cdot 10^{-6}}{4\pi\varepsilon_0 \cdot 8\cdot 10^{-2}} = -5.62\cdot 10^5$

So $V_0 = V_1 + V_2 = -3.82\cdot 10^5$ Volt

Energy conserved:

$e\cdot V_0 = \frac{1}{2} m_e \cdot v_e^2 + e\cdot V_t$

$V_t = -3.6\cdot 10^5\ V$ and $e = -1.6\cdot 10^{-19}\ C$

Hence

$6.112\cdot 10^{-14} = \frac{m_e}{2} v_e^2 + 5.76\cdot 10^{-14}$

$3.52\cdot 10^{-15} = 4.555\cdot 10^{-31}\ v_e^2$

$v_e = 8.79\cdot 10^7\ m/s$

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C. i. $B = \left(\frac{4}{5}\right)^{3/2} \cdot \frac{\mu_0 n I}{R}$ $n = 250$, $R = 0.2$

$$B_{max} = \left(\frac{4}{5}\right)^{3/2} \frac{4\pi \cdot 10^{-7} \cdot 250}{0.2} \cdot I_{max} \rightarrow I_{max} = 12\,A$$

$$= \left(\frac{4}{5}\right)^{3/2} \frac{4\pi \cdot 10^{-7} \cdot 250 \cdot 12}{0.2}$$

$$B_{max} = \underline{0.0135 \text{ Tesla}}$$

ii. $\varepsilon = -N\frac{d\phi}{dt}$ $N = 12$, $A = 0.02$ $\phi = BA$

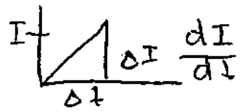
$$\varepsilon = -NA\frac{dB}{dt}$$

$$= -12 \cdot 0.02 \cdot \frac{dB}{dt}$$

$$\varepsilon = -0.24 \cdot \frac{dB}{dt}$$

$$= 0.24 \cdot \left(\frac{4}{5}\right)^{3/2} \cdot \frac{4\pi \cdot 10^{-7} \cdot 250}{0.2} \cdot \frac{dI}{dt}$$

$$\varepsilon = \frac{6}{25} \cdot \frac{dI}{dt}$$



Δt	dI/dt	ε
0 → 2.4	$\frac{dI}{dt} = \frac{12}{2.4} = 5$	$\frac{6}{25} \cdot 5 = 1.2$
2.4 → 3.4	$\frac{dI}{dt} = 0$	0
3.4 → 5.8	$\frac{dI}{dt} = \frac{-12}{2.4} = -5$	−1.2
5.8 → 7.0	$\frac{dI}{dt} = \frac{-12}{1.2} = -10$	$-\frac{6}{25} \cdot 10 = -2.4$
7.0 → 9.4	$\frac{dI}{dt} = 0$	0
9.4 → 10.6	$\frac{dI}{dt} = \frac{12}{1.2} = 10$	2.4

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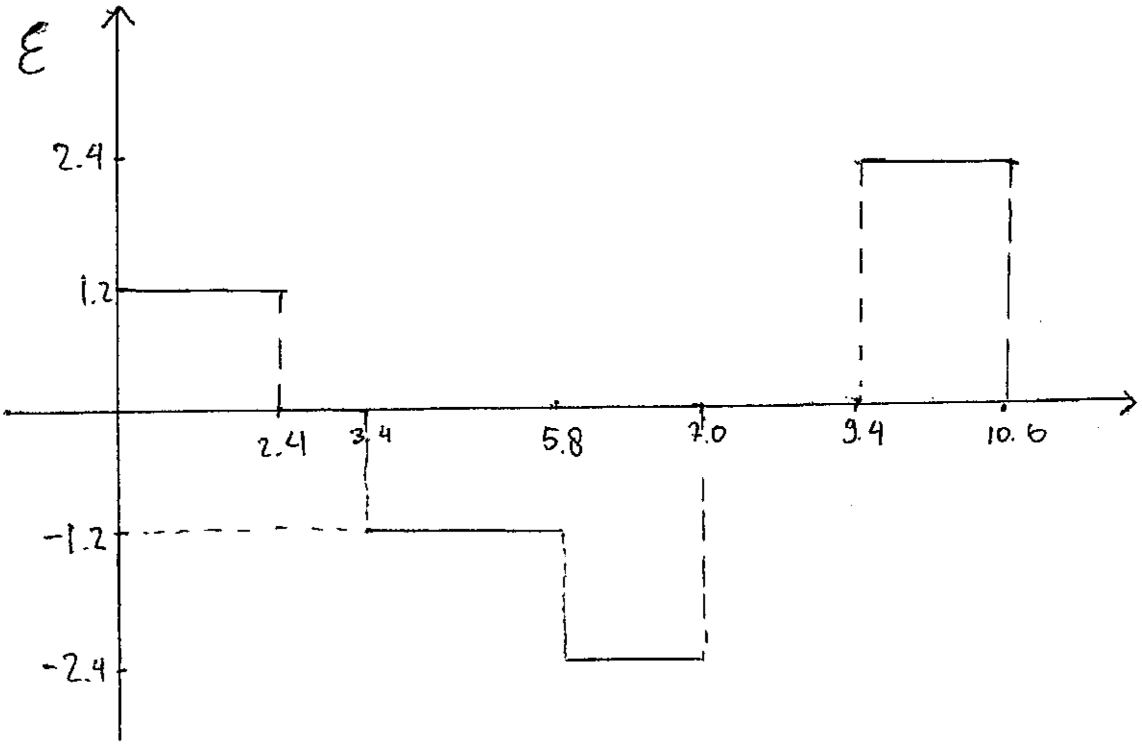
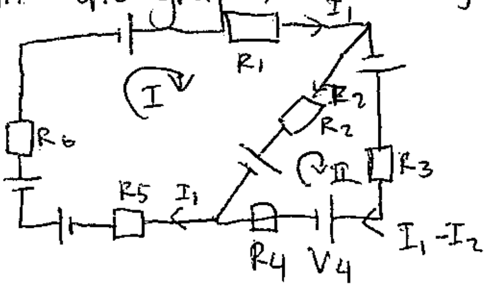


iii. From the graph, max emf is 2.4V, in interval 9.4 → 10.6

Q6.



a. Using Kirchoff Law:

$$\sum V_{enclosed} = 0$$

Loop I :

$$V_1 - I_1R_1 - I_2R_2 - V_2 - I_1R_5 + V_5 + V_6 - I_1R_6 = 0$$

Loop II :

$$V_3 - (I_1 - I_2)R_3 - V_4 - (I_1 - I_3)R_4 + V_2 + I_2R_2 = 0$$

subtitute the values we get:

Loop I : $1 - I_1 - 2I_2 - 2 - 5I_1 + 5 + 6 - 6I_1 = 0$ ... (1)

Loop II : $3 - 3I_1 + 3I_2 - 4 - 4I_1 + 4I_2 + 2 + 2I_2 = 0$ ... (2)

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Using (1).

$1 - I_1 - 2I_2 - 2 - 5I_1 + 5 + 6 - 6I_1 = 0$

$-12I_1 + 10 - 2I_2 = 0$

$\frac{5 - I_2}{6} = I_1 \ldots (3)$

Using (2)

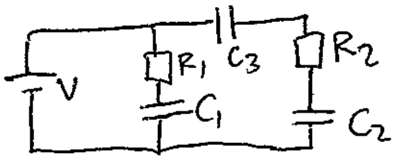
$3 - 3I_1 + 3I_2 - 4 - 4I_1 + 4I_2 + 2 + 2I_2 = 0$

$-7I_1 + 1 + 9I_2 = 0 \ldots (4)$

Substitute (3) to (4)

$9I_2 + 1 - \frac{7 \cdot 5}{6} + \frac{7I_2}{6} = 0$

$54I_2 + 6 - 35 + 7I_2 = 0 \longrightarrow I_2 = \frac{29}{61} A$

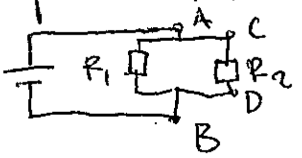
b. 

$V = 15 V$, $R_1 = 200\Omega$, $R_2 = 100\Omega$

$C_1 = 1\mu F$, $C_2 = 2\mu F$, $C_3 = 3\mu F$

(i). when $t = 0$

capacitors behave just like cables

so 

$V_{AB} = V_{CD}$

so $V_{AB} = V_{CD} = V = I_2 \cdot R_2$

$I_2 = \frac{15}{100} = 0.15 A$

ii. Fully charged, so V_1 at $C_1 = V$

$\frac{Q_1}{C_1} = V_1 = V$

Energy capacitor $= \frac{1}{2} CV^2$

$= \frac{1}{2} C_1 V^2$

$= \frac{1}{2} \cdot 10^{-6} \cdot 15^2$

$= 1.125 \cdot 10^{-4}$ Joule

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NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2016-2017

PH1012 – Physics A

Nov/Dec 2016 Time Allowed: 2½ Hours

SEAT NUMBER: | | | | |

MATRICULATION NUMBER: | | | | | | | | | |

INSTRUCTIONS TO CANDIDATES

1. This question and answer booklet contains **SIX (6)** questions and comprises **SEVENTEEN (17)** pages.

2. Answer **ALL SIX (6)** 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** (20)	**3** (15)	**4** (15)	**5** (20)	**6** (10)	**Total** (100)
Marks							

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Q1 (20 marks) **/20**

(a) An object A with mass 5.0 g has velocity $\vec{u}_A$ at time t:

$$\vec{u}_A(t) = [(5.0 + 3.0t)\hat{\imath} + (11.0 - 2.0t^2)\hat{\jmath}]\ \mathrm{m/s}$$

for $t = 0.0$ s to $t = 2.0$ s. As shown in Figure 1(a), at time $t = 0.0$ s, object A is at the origin of the $x - y$ coordinate system. At $t = 2.0$ s, object A collides with object B which is originally at rest at point X. The mass of object B is 2.0 g.

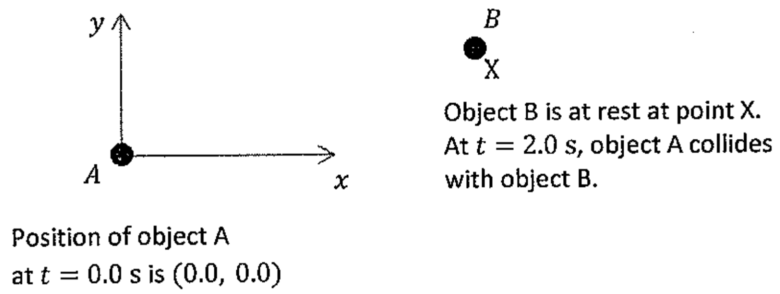


Figure 1(a)

Immediately after the collision, object B moves off with $\vec{v}_B = (9.0\,\hat{\imath} + 3.0\,\hat{\jmath})$ m/s.

i. Determine the momentum and kinetic energy of object A at $t = 2.0$ s just before the collision.

ANS: ________________

____

ii. Determine the momentum of object A immediately after the collision.

ANS: ________________

Note: Question No. 1 continues on Page 3

iii. Determine if the collision is elastic or inelastic. Marks will only be awarded for correct working.

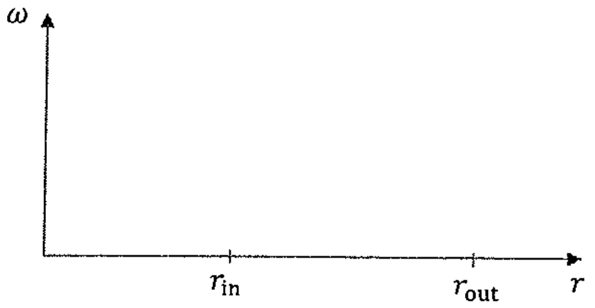
ANS: Elastic / Inelastic

iv. Determine the position of point X in vector form.

ANS: _______________

(b) The outside radius of the playing area of an optical blu-ray disc is $r_{out} = 5.88$ cm, and the inside radius is $r_{in} = 2.55$ cm. When viewing movies, the disc rotates and the reading laser moves slowly in the radial direction to read the tracks. The disc rotates such that it maintains a constant tangential velocity of 4.90 m/s relative to the laser.

i. Determine the maximum angular velocity ω_{max} of the disc in revolutions per minute. Using the axis below, sketch to show how the angular velocity ω of the disc needs to vary from r_{in} to r_{out} so that the tangential velocity relative to the laser is kept constant.



ANS: _______________

Note: Question No. 1 continues on Page 4

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/9

ii. After reading the outer-most track at $r_{\text{out}} = 5.88$ cm, the disc comes to a stop in 2.8 s. Determine the average angular acceleration in rad/s^2 and the total angular displacement of the disc during this time.

ANS: ______________

____

iii. Figure 1(b) shows a schematic sketch of the tracks where data is recorded. In the figure, the pitch (or width) of the tracks has been greatly exaggerated. Given that the track pitch is 320 nm, determine the estimated total length of track that passed under the laser (from r_{in} to r_{out}) when the whole blu-ray disc is played. Determine also the time taken to read the whole disc.

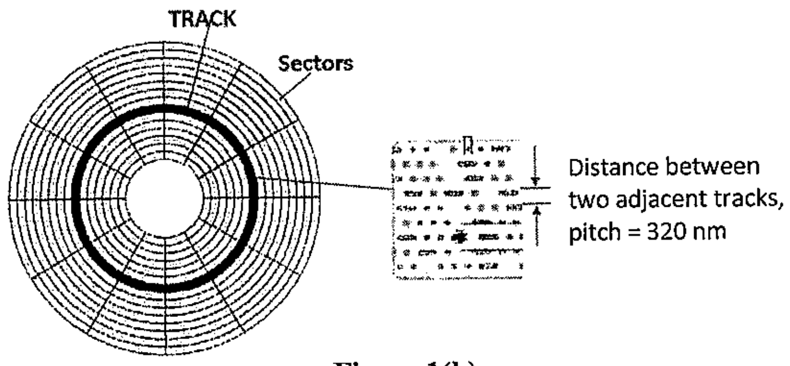


Figure 1(b)

ANS: ______________

____

Q2 (20 marks) /20

In the 2016 Rio Olympics, Joseph Schooling won the first ever gold medal for Singapore in the 100 m butterfly competition. We will do a simplified analysis of competitive swimming.

(a) First, the starting dive as shown in Figure 2(a). Consider the swimmer with his center of mass 1.20 m above the surface of the water. He jumps off the diving block with horizontal velocity $v_x = 4.90\ \text{m/s}$ and downward vertical velocity $v_y = -1.15\ \text{m/s}$.

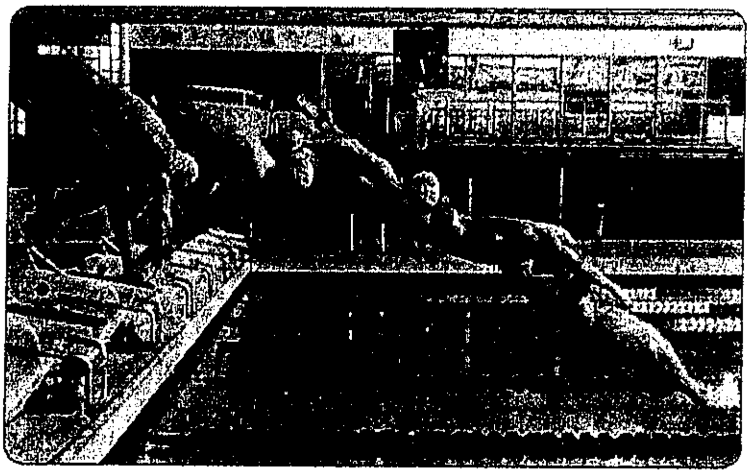


Figure 2(a)

Courtesy of AIS Movement Science, Australian Institute of Sport.

i. Determine the horizontal displacement of the center of mass of the swimmer from the starting block to where his center of mass just enters the water.

ANS: ______________

ii. Determine the velocity (in vector form) of the center of mass of swimmer where his center of mass just enters the water.

ANS: ______________

Note: Question No. 2 continues on Page 6

10

20

Next, we will do some simplified analysis of the butterfly stroke, particularly the forces and motion in the horizontal direction. For our simplified analysis, we will focus on three main actions (listed as I, II and III) of each cycle of the stroke as shown in Figure 2(b) and the variation of the horizontal velocity of the swimmer with respect to the pool. The six segments of the velocity variation are labelled A to F.

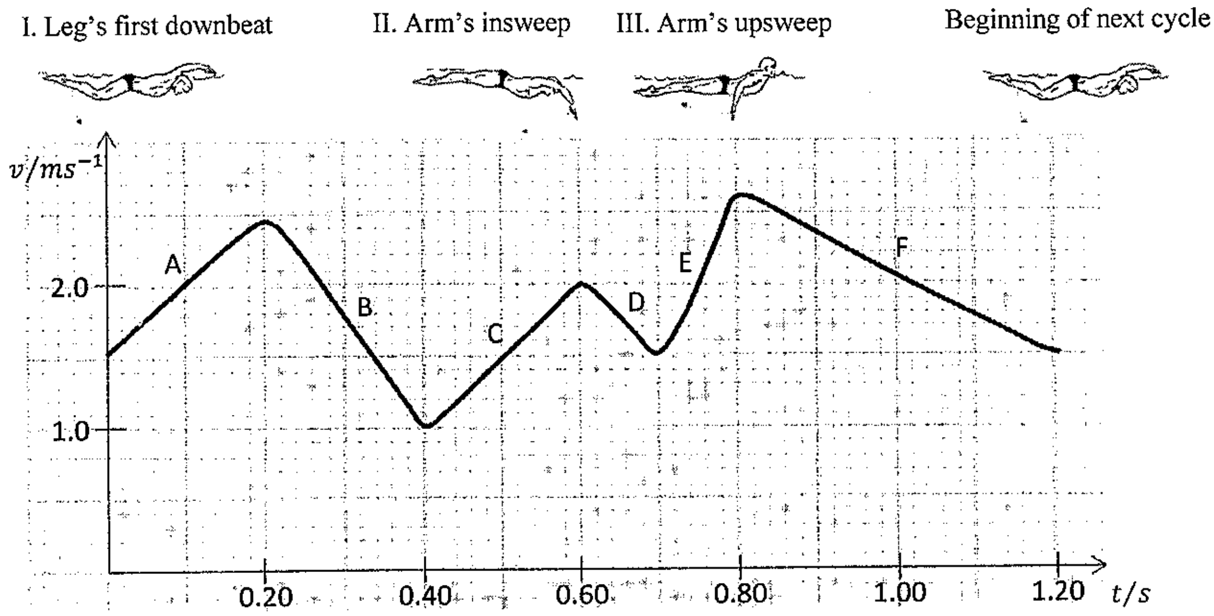


Figure 2(b)

(b) We will first study the kinematics of the swimmer.

i. Determine the average acceleration of the swimmer in the first 0.20 s (segment A) in the cycle of the stroke.

ANS: ________________

ii. Write down the segment (A to F) where the average forward acceleration is the largest.

ANS: ______

iii. Determine the average velocity of the swimmer in the first 0.40 s (segment A & B) in the cycle of the stroke.

ANS: ________________

Note: Question No. 2 continues on Page 7

(c) We use a simple model considering just two horizontal forces acting on the swimmer. Firstly, the forward propulsive force $F_p = v_{rel}\frac{dm_w}{dt}$ where v_{rel} is the speed of the water moving backwards relative to the body when pushed by the limbs (arms or legs) and $\frac{dm_W}{dt}$ is the mass of water pushed backwards per unit time. Secondly, the drag force $F_D = \frac{1}{2}C_D\rho Av^2$ where C_D is the drag coefficient dependent on the shape of the object with frontal area A moving through a fluid of density ρ at velocity v. (Here, we excluded the effects of other types of drag.) Thus, the horizontal force F_x on the swimmer can be written as

$$F_x = F_P - F_D = v_{rel}\frac{dm_w}{dt} - \frac{1}{2}C_D\rho Av^2.$$

i. For a swimmer of mass 74 kg, using Figure 2(b) or otherwise, determine the value of $\frac{dm_w}{dt}$ at $t = 0.5$ s. You are also given that $C_D = 0.30$, $A = 0.20\ \text{m}^2$, $v_{rel} = 4.5$ m/s and the density of water $\rho = 1000$ kg /m^3.

ANS: ______________

ii. Determine the propulsive power of the swimmer at $t = 0.5$ s.

ANS: ______________

iii. By analyzing the three main actions, I, II and III, circle the physical quantity (or quantities) listed below which is/are constant in time over the cycle of a stroke.

C_D $\qquad\qquad$ ρ $\qquad\qquad$ A $\qquad\qquad$ v_{rel}

21

Q3 (15 marks) /15

As shown in Figure 3, a wooden block **C** of mass m_C is connected to a light inextensible cable that goes round a pulley **B** and is connected to steel block **A** of mass m_A. The friction between the cable and the pulley is negligible here. Block **C** moves with acceleration a up a rough inclined plane at an angle θ to the horizontal. At this instance shown in Figure 3, the angle ϕ (subtended by PQO) between the cable and the inclined plane is ϕ_1. We denote the vertical height OP as h and length PQ as l. The coefficient of kinetic friction between block **C** and inclined plane is $\mu_k = 0.40$.

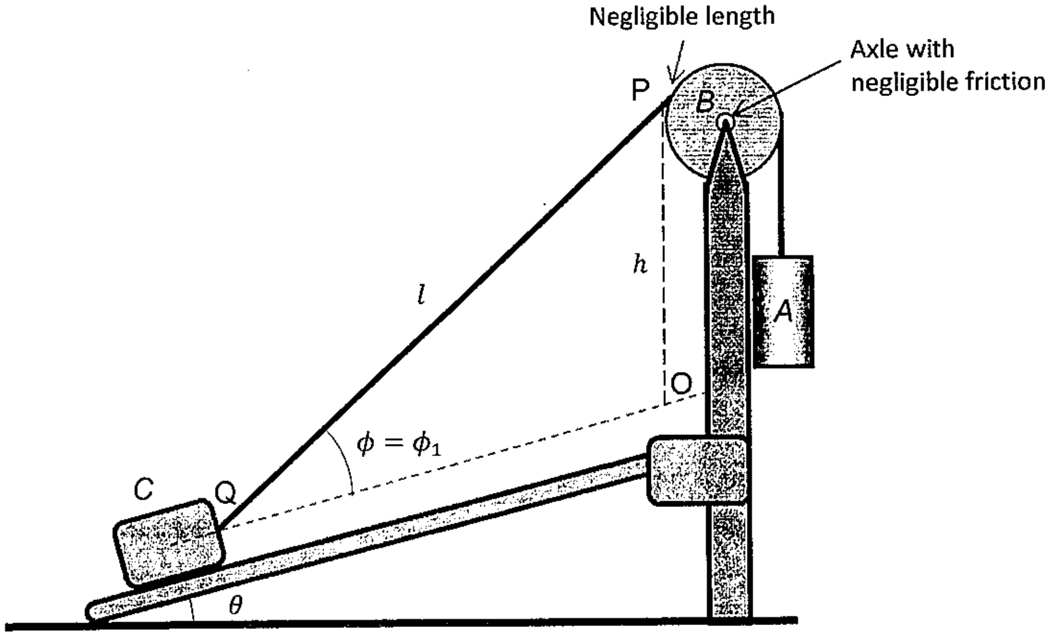


Figure 3

i. The tension in the cable connected to block **C** is denoted as F_T. Write down the components of F_T along the inclined plane $F_{T||}$ and perpendicular to it $F_{T\perp}$.

ANS: $F_{T||}$ = ____________; $F_{T\perp}$ = ____________

ii. Apply Newton's second law to block **A** and block **C** (along and perpendicular to the inclined plane). Leave your answers in symbols.

Block **A**:

Block **C** ($\perp$ to inclined plane):

Block **C** ($||$ to inclined plane):

Note: Question No. 3 continues on Page 9

iii. Given that $m_A = 100$ kg, $m_B = 20$ kg, $m_C = 40$ kg and the angles $\theta = 15°$ and $\phi_1 = 25°$, calculate the acceleration a of the blocks at this instance.

This part was too difficult and was voided. The marks allocated for this part were re-distributed to other parts and students who made sensible attempts for this part were given bonus marks.

ANS: ______________

iv. If the friction between the cable and the pulley is significant and cannot be neglected, the pulley will rotate (without slipping) at angular acceleration α. Label the tension for the side of cable connected to block **C** as F_{TC} and the tension for the side connected to block **A** as F_{TA}. If the moment of inertia of the pulley is I_B and its radius r_B, apply Newton's second law (rotational motion) for pulley **B**.

Pulley **B**:

Write down the relationship between α and a.

v. As block **C** moves up the inclined plane, the angle ϕ will increase. Determine the relationship between instantaneous velocity v_A of block A and $\frac{d\phi}{dt}$ in terms of the variables provided. (Note that the length of the cable from point P to the pulley is negligible.)

ANS: ______________

22

222

Q4 (15 marks) /15

The indicator diagram for the Carnot heat engine shown in Figure 4 uses 0.120 moles of diatomic gas as a working substance round a cycle: the process **1** → **2** is isothermal at temperature $T_C = 300\ K$; **2** → **3** is adiabatic; **3** → **4** is isothermal at a higher temperature $T_H = 600\ K$; and **4** → **1** is also adiabatic. Here, we know that the volume at state **3** is $V_3 = 6.0 \times 10^{-4}\ \mathrm{m}^3$ and the volume at state **4** is $V_4 = 40.0 \times 10^{-4}\ \mathrm{m}^3$. The molar heat capacity of a diatomic ideal gas at constant volume is $C_V = \frac{5}{2}R$ and at constant pressure is $C_p = \frac{7}{2}R$ where R is the universal gas constant. The ratio $\gamma = \frac{C_p}{C_V} = 7/5$.

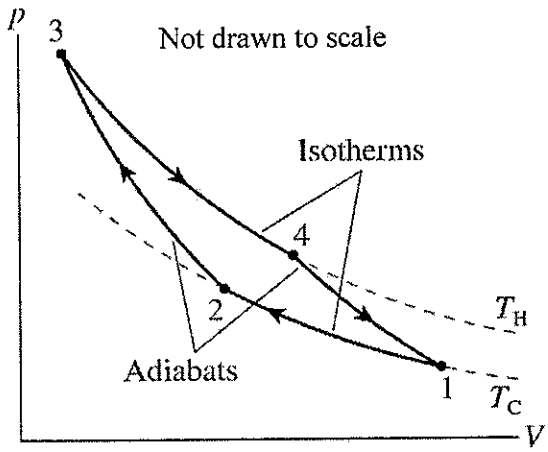


Figure 4

i. Calculate the pressure P_3 at point 3.

ANS: ____________________

ii. The processes for this heat engine include contraction at constant temperature and expansion with no heat loss. Identify these two processes from Figure 4.

Contraction at constant temperature: ____→____;

Expansion with no heat loss: ____→____

Note: Question No. 4 continues on Page 11

iii. Calculate the heat input for the Carnot engine in Figure 4.

ANS: ________________

iv. Determine the volume V_2.

ANS: ________________

v. Calculate the net work done by the gas for one complete cycle $\mathbf{1} \rightarrow \mathbf{2} \rightarrow \mathbf{3} \rightarrow \mathbf{4} \rightarrow \mathbf{1}$ for the heat engine in Figure 4.

ANS: ________________

vi. Determine the algebraic relationship between V_1, V_2, V_3 and V_4 for Carnot engines in general. From there, show that the efficiency η of a Carnot engine is dependent only on T_H and T_C.

ANS: ________________

Q5 (20 marks)

/20

(a) Figure 5(a) shows the cross section of an infinitely long, uniformly charged hollow cylinder of radius R with charge per unit length λ. (You can ignore the thickness of the cylinder.)

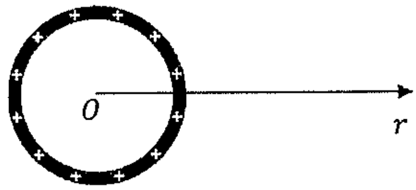


Figure 5(a)

i. Using Gauss's law, determine how the electric field E_{in} inside the cylinder varies along the radial distance r from the center O of the circular cross section to the cylinder, i.e. $r < R$.

ANS: __________

ii. Using Gauss's law, determine how the electric field E_{out} outside the cylinder varies with the radial distance r from the center O, i.e. $r > R$.

ANS: __________

iii. If an object with charge $-q$ and mass m outside the charged cylinder at $r = r_a$ is moving at a constant speed v in a uniform circle centered also at O, determine the speed v of the object in terms of the variables provided.

ANS: __________

Note: Question No. 4 continues on Page 13

(b) A particle of mass $m = 1.2 \times 10^{-8}\ kg$ and charge $q = 84\ \mu C$ is released from rest at line A in the middle of a non-uniform electric field as shown in Figure 5(bi). The particle moves along the center line passing the four lines A, B, C and D. The four lines are spaced equally. The electric potential at the center of line A is $V_A = 0\ V$ and the particle passes line D at $v = 3500\ \mathrm{m/s}$.

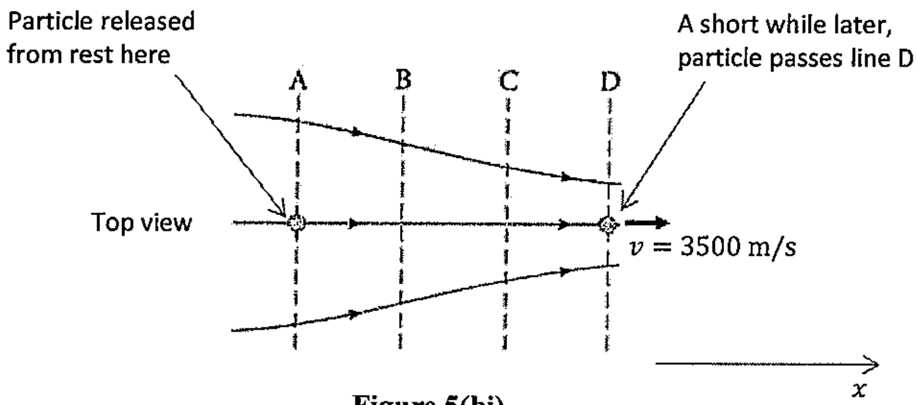
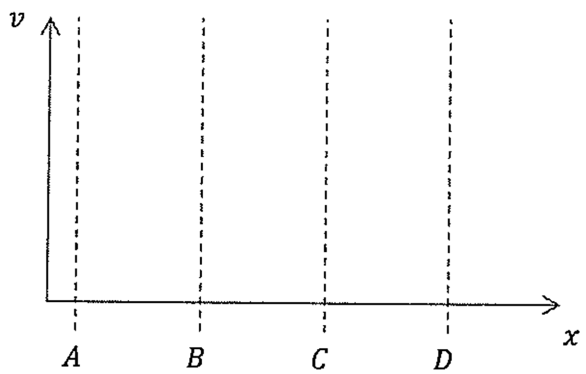


Figure 5(bi)

i. Determine the electric potential V_D at the center of line D.

ANS:__________________

ii. Using the axis provided below, sketch to show how the velocity of the particle varies as it passes the four lines.



Note: Question No. 5 continues on Page 14

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iii. The particle passes line D at $v = 3500\ \text{m/s}$ into a wide region of uniform magnetic field with strength $B_o = 2.0\ \text{T}$. After moving in the magnetic field for a duration of time t, the particle leaves the magnetic field passing line D again. Sketch in Figure 5(bii), the path of the particle and determine the duration t it is in the magnetic field.

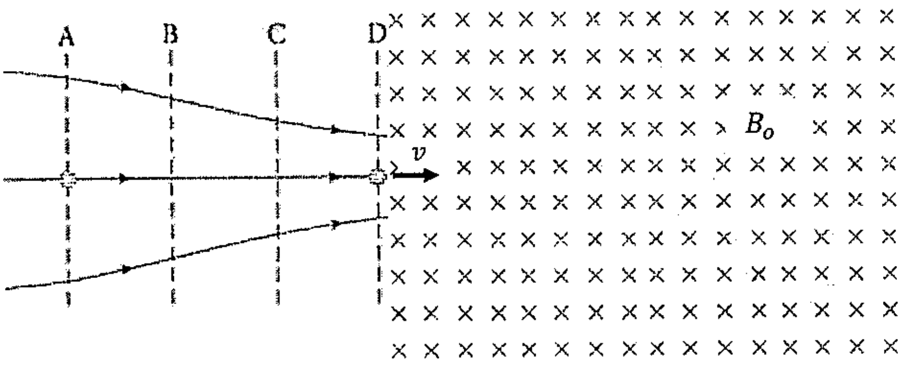

Figure 5(bii)

ANS:_________________

Note: Question No. 5 continues on Page 15

(c) As shown in Figure 5(c), a rectangular curved loop of wire is made up of two bent semi-circular arcs of length $\ell = 950$ mm long connected by two straight sections with width $w = 500$ mm. This rectangular loop is moved at speed $v = 1.20$ m/s into a uniform magnetic field $B = 0.50$ T. One of the sides labeled w is the leading edge of the moving loop, and the magnetic field direction is perpendicular to the plane CDEF.

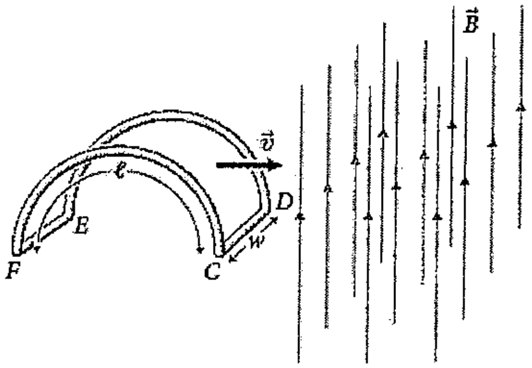

Figure 5(c)

i. Determine the e.m.f. induced in the rectangular loop and the direction of the induced current (circle your answer).

ANS: ____________

Direction of current: Along CDEFC / Along CFEDC

ii. Now the loop is rotated 90° in the plane CDEF such that the curved side CF is leading into the magnetic field moving at the same velocity as before. Determine the e.m.f. induced in the rectangular loop.

ANS: ____________

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Q6 (10 marks)

/10

(a) The circuit as shown in Figure 6(a) has been closed for a long time. It is given that $\mathcal{E} = 80$ V.

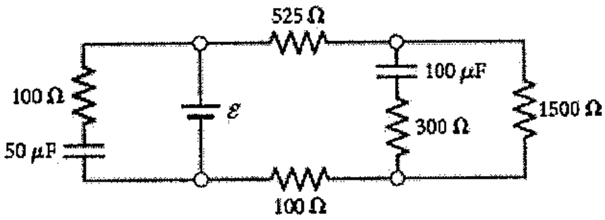

Figure 6(a)

Determine

i. the magnitude of the current through the 100 Ω resistor in the leftmost branch of the circuit;

ANS: __________

ii. the magnitude of the current through the 525 Ω resistor;

ANS: __________

iii. the magnitude of charge on the 50 μF capacitor plate; and

ANS: __________

iv. the magnitude of charge on the 100 μF capacitor plate.

ANS: __________

Note: Question No. 6 continues on Page 17

(b) Windshield wipers use a variable resistor in an RC circuit to control the time interval between successive passes of the wipers. A typical circuit is shown in Figure 6(b). When the switch is closed, the capacitor (which is initially uncharged) begins to charge. A sensor measures the potential difference between points X and Y, triggering a pass of the wipers when the potential difference between X and Y is zero. (Another part of the circuit, not shown, discharges the capacitor at this time so that the cycle can start again.)

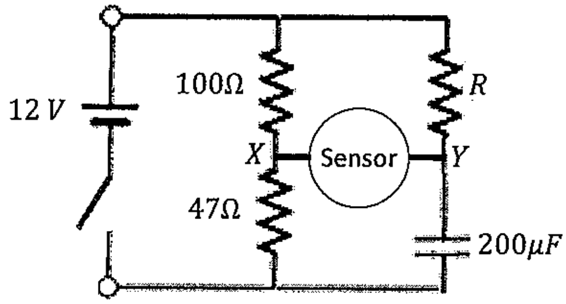

Figure 6(b)

Using the values of the circuit components given in Figure 6(b), determine the value of R such that the time interval of successive passes of the wipers is 4.5s.

ANS: ____________________

- End of Paper -

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Subject Code : PH1012	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : PHYSICS A	
Year / Semester : 2016/17 SEM1	

Question 1 (a) (i)

At t = 2.0s,

$U_A(2) = [5.0 + (3.0)(2.0)]\,i + [11.0 - (2.0)(2.0)^2]\,j$

$= 11.0i + 3.0j = 11.4 m/s;$

Using p=mv;

$p = (5.0x10^{-3} kg)(11.4 m s^{-1})$

$=$ **$0.057 kg m s^{-1}$**;

Using K.E = 1/2(mv²);

$KE = \frac{1}{2}(5.0x10^{-3} kg)(11.4 m s^{-1})^2$

$=$ **0.325 J**

Question 1 (a) (ii)

By COLM $U_A M_A + U_B M_B = V_A M_A + V_B M_B$;

$0.0571 + 0 = V_A M_A + V_B M_B$

$0.0571 = P_A + (9.487)(2x10^{-3})$

$P_A = 0.0381 kg m s^{-1}$

Qustion 1 (a) (iii)

If Collision is elastic, COKE is also observed => $U_A - U_B = -(V_A - V_B)$

$V_A = 7.63 m s^{-1}$; $U_A = 11.4 m s^{-1}$; $V_B = 9.48 m s^{-1}$;

$-(V_A - V_B) = 1.85 m s^{-1}$ =/= U_A

Collision is inelastic

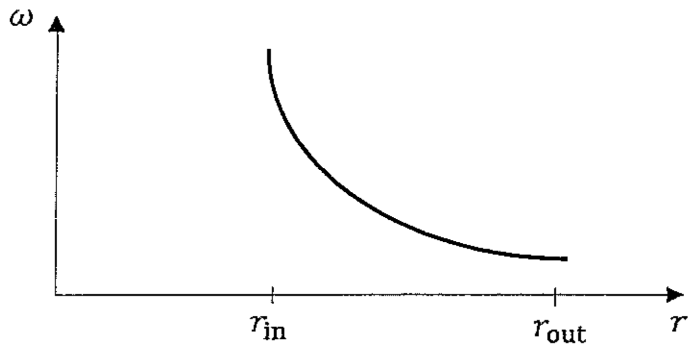
Question 1 (a) (iv)

$x = \int v\, dt$

$x = (5.0t + 1.5t^2)\, i + (11.0t + 0.67t^3)\, j$

$x(2) = 16.0i + 16.67j$ m

Question 1 (b) (i)



$V_{tan} = r\omega$
$V = r/\omega$
Graph of 1/v

Subject Code : PH 1012	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : PHYSICS A	
Year / Semester : 2016/17 SEM 1	

Question 1 (b) (ii)

$\omega = v/r = 83.3$ rad s^{-1}

$\omega_f = \omega_i + \alpha t$

$\alpha = -\omega_i/t =$ **-29.8 rad s^{-2}**

$\theta_f = \theta_i + \omega_i t + 1/2\alpha t^2 =$ **116.4 rad**

Question 1 (b) (iii)

$\Delta r = 3.33$ cm => $r_{avg} = 4.215$cm

No of tracks = n = Δr/pitch = 104062.5

Track length = $n2\pi r_{avg}$ = **2.76×10^4m**

Time = $(n2\pi r_{avg})/v$ = **5264s**

Question 2 (a) (i)

$y_f = y_i + v_y t + 1/2gt^2$

$0 = 1.2 - 1.15t - 4.9t^2$ => t=2.56s OR t=-1.59s(NA)

$x_f = v_x t$ = **12.5m**

Question 2 (a) (ii)

$v_x = 4.9$ i m s^{-1}

$v_y = v_{yi} + at = -26.2$ m s^{-1}

v = (4.9i – 26.2j) m s^{-1}

Question 2 (b) (i)

$a = \Delta v/\Delta t$ = **5.0 m s^{-2}**

Question 2 (b) (ii) ANS: E

Question 2 (b) (iii)

$x = \int v\, dt$

$= (1.5 \times 0.2) + (0.5 \times 1.0 \times 0.2) + (0.5 \times 1.5 \times 0.2) + (1.0 \times 0.2) = 0.74$m

$v_{avg} = x/t$ = **1.85 m s^{-1}**

Question 2 (c) (i)

$F = ma$ => $ma = F_P - F_D$

$(dm_w/dt) = (ma + F_D) / v_{rel}$ = **-93.5 kg s^{-1}**

Questions 2 (c) (ii)

$F_P = v_{rel} \times (dm_w/dt)$ = **-420.8 kg m s^{-2}**

Question 2 (c) (iii) ANS: C_D / ρ

Question 3 (i) ANS: $F_{T\parallel} = F_T\sin(\theta+\Phi)$; $F_{T\perp} = F_T\cos(\theta+\Phi)$

Question 3 (ii)

Block A: $M_a g - T_a = M_a a$;
Block C (perpendicular): $F_N - M_c g\cos\theta = 0$;
Block C (parallel): $F_T - M_c g\sin\theta - \mu_k F_N = M_c a$

Question 3 (iii)

This part was too difficult and was voided.

Question 3 (iv)

Pulley B: $(F_{TC} - F_{TA})(r_B) = I_B\alpha$;
$a = r_B\alpha$

Question 3 (v)

Rate of movement = Rate of change of Φ
$dv_c/dt = d\Phi/dt$
$dv_c = d\Phi$

Question 4 (i)

$P_3V_3 = nRT_3$
$P_3 = (nRT_3)/V_3 =$ **9.97×10^5**

Question 4 (ii)

Contraction at constant temperature (Isothermal Contraction): 1 → 2;
Expansion with no heat loss (Adiabatic Expansion): 4 → 1.

Question 4 (iii)

Heat Input = Q_H; From 1st Law $\Delta U = Q + W$
$\Delta U = 0 \Rightarrow Q_H = -W = -[-nRT\ln(V4/V3)] =$ **1136 J**

Question 4 (iv)

Along Adiabats, $TV^{\gamma-1}$ = constant => $T_3V_3^{\gamma-1} = T_2V_2^{\gamma-1}$
$V_2^{\gamma-1} = (V_3^{\gamma-1})(T_3/T_2) = 0.103$
$V_2 = (0.103)^{1/(\gamma-1)} =$ **33.9×10^{-4} m^3**

Question 4(v)

Adiabatic 1st Law: $\Delta U = W \Rightarrow W = C_V\Delta T$ (W from Ad. Proceeses cancel out)
$W_{net} = W_{34} + W_{41} + W_{12} + W_{23}$
$W_{net} = nRT_H\ln(V4/V3) + nRT_c\ln(V2/V1) =$ **618J**

$T_4V_4^{\gamma-1} = T_1V_1^{\gamma-1}$
$V_1^{\gamma-1} = (V_4^{\gamma-1})(T_4/T_1) = 0.220$
$V_1 = (0.220)^{1/(\gamma-1)} =$ **2.26×10^{-2} m^3**

Question 4 (vi)

Along Adiabats, $TV^{\gamma-1}$ = constant => $T_3V_3^{\gamma-1} = T_2V_2^{\gamma-1}$; $T_4V_4^{\gamma-1} = T_1V_1^{\gamma-1}$

$T4/T1 = (V1/V4)^{\gamma-1}$ – (1)

$T3/T2 = (V2/V3)^{\gamma-1}$ – (2)

(1) = (2); $V1/V4 = V2/V3 \Rightarrow V4/V3 = V1/V2$

$W_{net} = nRT_H\ln(V4/V3) + nRT_c\ln(V2/V1)$

$= nRT_H\ln(V4/V3) - nRT_c\ln(V4/V3)$

$= nR\ln(V4/V3)(T_H - T_C)$

$\eta = W_{net}/Q_H = \sout{nR\ln(V4/V3)}(T_H - T_C)/ \sout{nRT_H\ln(V4/V3)}$

$\eta = (T_H - T_C)/T_H$

Question 5 (a) (i)

Applying Gauss' Law for a conducting shell, **E = 0**

Question 5 (a) (ii)

$E(2\pi rl) = \lambda l/\varepsilon_0$

$E = \lambda/2\pi r\varepsilon_0 = \mathbf{2k\lambda/r}$

Question 5 (a) (iii)

$F_C = F_E \Rightarrow -q(2k\lambda)/r = (mv^2)/r$

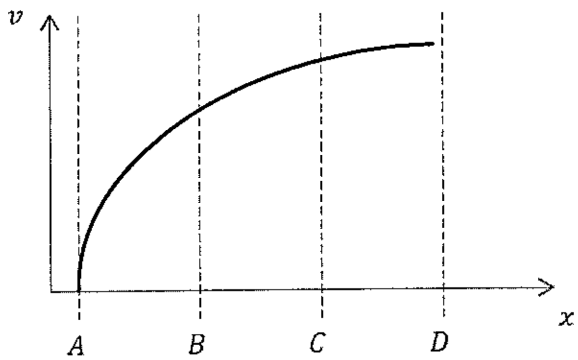
$-q2k\lambda = mv^2 \Rightarrow \mathbf{v = \sqrt{[(-2kq\lambda)/m]}}$

Question 5 (b) (i)

$1/2mv^2 = qV$

$V = (mv^2)/2q =$ **875V**

Question 5 (b) (iii)



$1/2mv^2 = qV$

$v = \sqrt{[(2q/m)(V)]}$

Graph of √v

Question 5 (b) (iii)

$F_B = F_C$ => $qVB = (mv^2)/r$

$r = mv/qB = 0.25m$

Particle moves in a semicircle => arc length = $0.25\pi m$

time = $(0.25\pi)/v$ = **2.24×10^{-4} s**

Question 5 (c) (i)

$\Phi_B = \int B.\, dA = BA\cos\theta$

$= (0.5T)(0.95m)(0.5m)\cos(0) = 0.2375\ T\ m^2$

Time spent in field = 0.95m/v = 0.792s

$\varepsilon = -N(d\Phi_B/dt)$ = **0.3V Along CFEDC**

Question 5 (c) (ii)

Time spent in field = 0.5m/v = 0.417s

$\varepsilon = -N(d\Phi_B/dt)$ = **0.57V**

Question 6 (a) (i)

$I = V/R_{100}$ = **0.8A**

Question 6 (a) (ii)

$I = V/R_{525}$ = **0.152A**

Question 6 (a) (iii)

$\Delta V = 0 \Rightarrow Q = C\Delta V =$ **0**

Question 6 (a) (iv)

$I_1 = I_2 + I_3$

$0.152A = (V/300\Omega) + (V/1500\Omega)$

$V = 38V$

$Q = C\Delta V$ = **3.8×10^{-3}C**

Question 6 (b)

$\Delta V = 0 \Rightarrow V_X = V_Y$

$V_X = \Delta V = (47/147)(12V) = 3.84V$

$\varepsilon = \Delta V(1-e^{-t/RC}) \Rightarrow t/RC = -\ln[1-(\varepsilon/\Delta V)]$

$t/RC = 0.386$

R = **58341Ω**