NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER I EXAMINATION 2016-2017

PH1011 - Physics

Nov/Dec 2016 Time Allowed: 2.5 Hours

SEAT NUMBER: | | | | | |

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

INSTRUCTIONS TO CANDIDATES

1. This question and answer booklet contains **EIGHT (8)** questions and comprises of **SEVENTEEN (17)** printed pages.

2. Answer **ALL EIGHT (8)** questions. All workings must be clearly shown.

3. Total 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 (15)	2 (10)	3 (15)	4 (10)	5 (15)	6 (15)	7 (10)	8 (10)	Total (100)
Marks									

/15

Q1 (15 marks)

A ball with mass m is launched horizontally at a height H from the ground (Figure 1). The horizontal displacement at the first bounce is $\frac{4}{3}H$ and the maximum height after the bounce is $\frac{9}{16}H$. The duration of the contact between the ball and the ground is t.

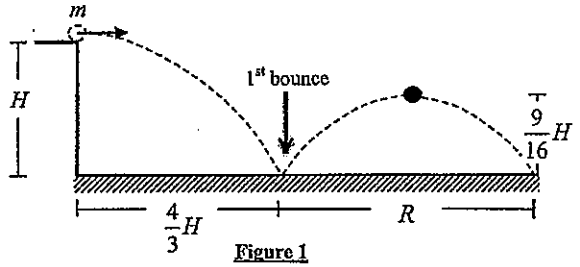


Figure 1

(a) At the first bounce, derive an expression for the vertical average force acting on the ball.

ANS: _____

Note: Question No. 1 continues on Page 3

(b) Find R, the horizontal distance between the first and second bounce.

ANS: _____

(c) Assuming during each bounce, the horizontal momentum does not change. What is the minimum number of bounces it takes to reach a height less than $\frac{H}{10}$?

ANS: _____

/10

Q2 (10 marks)

As shown in Figure 2(a), a cube of mass M is fully submerged under the water and is attached by a string from the bottom of the container. The density of the cube is half the density of the water and the side of the cube is L. Initially, the surface of the water is at the same level ($y = 0$) of the top surface of the cube. The density of the water is ρ. You can neglect drag forces.

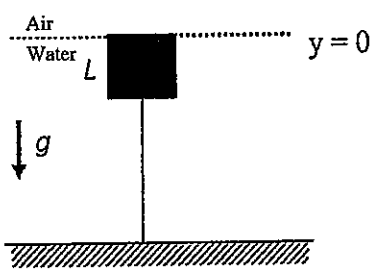


Figure 2(a)

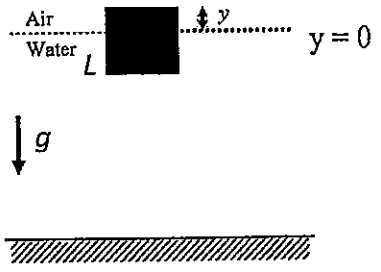


Figure 2(b)

(a) After the string is cut, using Newton's second law, write down the acceleration of the cube as a function of y. See Figure 2(b).

ANS: _____

Note: Question No. 2 continues on Page 5

(b) What will be the largest displacement y of the cube when the string is cut?

ANS: _____

(c) What will be the largest speed of the cube when it is travelling upward?

ANS: _____

/15

Q3 (15 marks)

(a) Three blocks A, B, and C are doing one dimensional elastic collision. B and C are initially stationary, and A is moving to the right at a velocity v (Figure 3(a)). Blocks A and B have the same mass and block C has double the mass of block A. There is no friction in any contact surfaces. Find the velocities of A, B, and C after all the collisions.

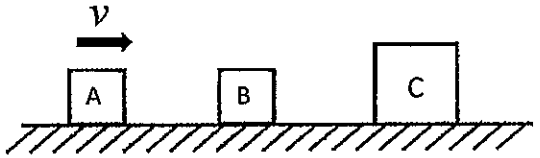


Figure 3(a)

ANS: _____

ANS: _____

ANS: _____

Note: Question No. 3 continues on Page 7

(b) Two masses, $3M$ and M are separated by distance a on the x-axis as shown in Figure 3(b).

(i) Determine the neutral point along the x-axis.

ANS: _____

(ii) Sketch the gravitational potential energy between the two masses in Figure 3(b). Label the neutral point clearly.

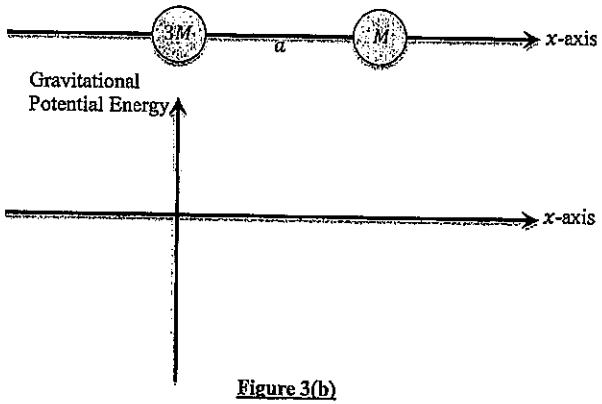


Figure 3(b)

/10

Q4 (10 marks)

(a) Consider a uniform rod of mass M and length l, pivoted at one end, rotating in a horizontal plane with constant angular velocity ω.

(i) Show that its rotational KE is $\frac{1}{6}Ml^2\omega^2$.

(ii) Derive the KE of the same rod by considering the total KE of all infinitesimally small elements of the rod (small slices of the rod).

ANS: _____

Note: Question No. 4 continues on Page 9

(b) A 3 kg magnetic disc of radius 10 cm is spinning at 65 rpm about the fixed axis through the centre of the disc as shown in Figure 4(b). A solid iron sphere of mass 0.5 kg, radius 5 cm is attracted to the edge of the disc and they rotate together. Find the angular velocity of the system now.

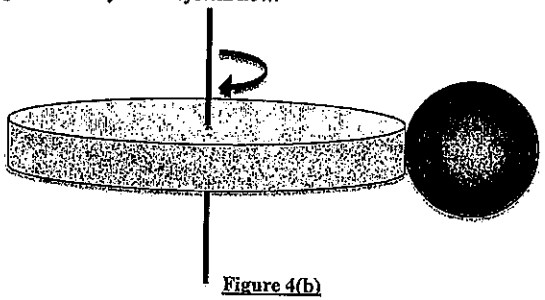


Figure 4(b)

ANS: _____

/15

Q5 (15 marks)

The *PV* diagram shown in Figure 5 is called the Brayton cycle which is made up of two adiabatic processes and two isobaric processes. Assume that ideal gas is being used in this cycle.

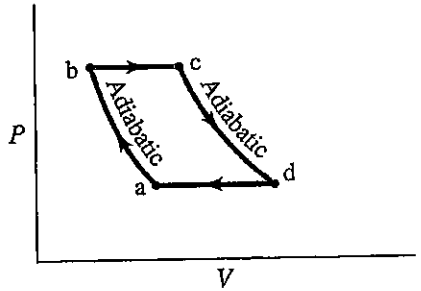


Figure 5

(a) Assuming that we do not know if the ideal gas is monoatomic or diatomic, show that the efficiency of the Brayton cycle is $e = 1 - \left(\frac{p_b}{p_a}\right)^{\frac{1-\gamma}{\gamma}}$. Hint: This is not easy to show.

Note: Question No. 5 continues on Page 11

(b) Suppose now we know that there are 2 moles of monoatomic ideal gas, $P_a = 1$ atm, $V_a = 0.05\,\mathrm{m}^3$, $P_b = 1.3$ atm and $V_d = 0.07\,\mathrm{m}^3$. Determine the change in internal energy ΔU, heat exchange Q and work done by gas W for two of the processes in the Brayton cycle. Use the space below to show your working neatly.

	ΔU	Q	W
Process a to b			
Process b to c			

(c) Determine v_{rms} of the ideal gas at point d of the cycle, given that the molar mass of the ideal gas is 28 g/mol.

ANS: _____

/15

Q6 (15 marks)

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

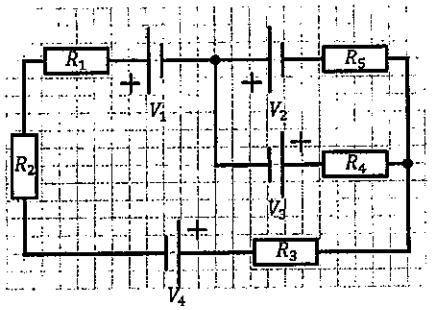


Figure 6(a)

Current through resistor R_2: _____

Note: Question No. 6 continues on Page 13

(b) Consider a RC circuit in Figure 6(b) with a 15 V source, $R_1 = 10\ \Omega$ and $R_2 = 20\ \Omega$. The capacitors have capacitances $C_1 = 1\ \mu$F and $C_2 = 2\ \mu$F. Switch S has been closed for a long time.

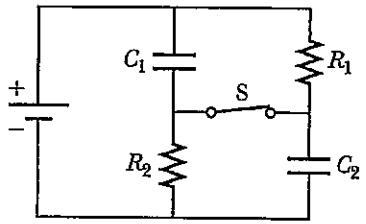


Figure 6(b)

(i) Find the current passing through R_2.

ANS: _____

(ii) Now switch S is opened and after a long time, C_1 and C_2 are charged to new values. Find the change in energy stored in C_1.

ANS: _____

/10

Q7 (10 marks)

(a) Consider a non-uniformly charged insulating sphere of radius R, total charge Q. The volume charge density varies linearly as r, i.e. $\rho(r) = \rho_0 r$ where ρ_0 is a constant. By using Gauss Law or otherwise, determine the E field for

(i) $r > R$

ANS: _____

(ii) $r < R$

ANS: _____

(iii) Sketch the E field from $r = 0$ to $r > R$

Note: Question No. 7 continues on Page 15

(b) Show that the magnetic field at the centre of a square of side a, carrying current I, is $B = \frac{2\sqrt{2}\mu_0 I}{\pi a}$.

/10

Q8 (10 marks)

Consider a rod of length L held by 3 conducting wires, is spinning about the z-axis as shown in Figure 8(a). The rod is spinning at constant angular velocity ω at a distance r from the z-axis. The rod-wire closed circuit has a total resistance R.

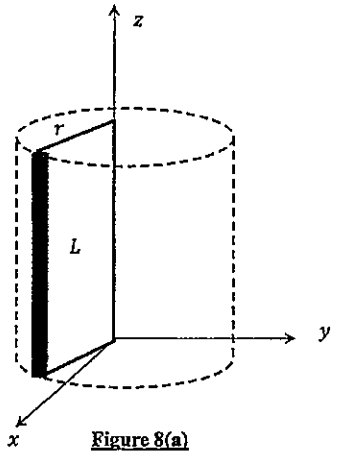


Figure 8(a)

(a) A constant magnetic field B is applied in the positive y direction. Give an expression for the induced current in the rod-wire closed circuit.

ANS: _____

Note: Question No. 8 continues on Page 17

(b) Now, instead of a constant magnetic field B applied in the positive y direction, imagine the z-axis is a wire carrying current I in the positive z-direction as shown in Figure 8(b). Give an expression for the induced current in the rod-wire closed circuit.

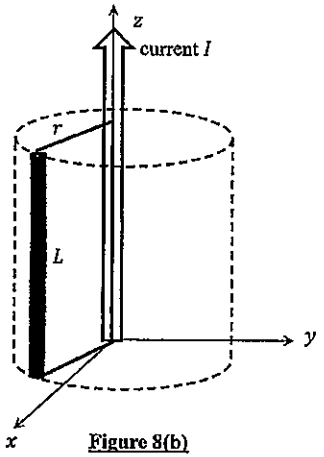


Figure 8(b)

ANS: _____

(c) Now, instead of a wire carrying current I in the positive z-direction, imagine a (polar) radial magnetic field with a constant magnitude B as shown in Figure 8(c). Give an expression for the induced current in the rod-wire closed circuit.

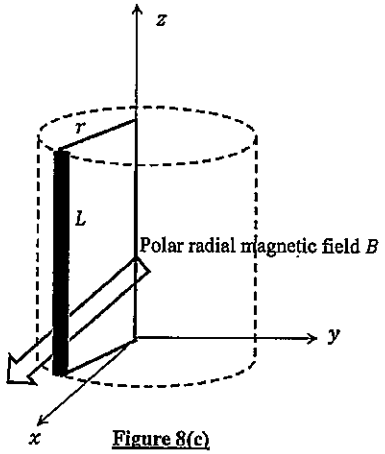


Figure 8(c)

ANS: _____

- End of Paper -

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17 SEM 1	

1a.

To find the vertical force acting on the ball, we can use the formula : $F\Delta t = m(V'-V)$.

F is the average force acting on the ball, Δt is the duration of the contact between the ball and the ground, V' is the velocity right after the ball bounces, V is the velocity right before the ball bounces, and m is the mass of the ball.

Now, we need to find the value of V' and V first.

We can find the value of V by considering the vertical motion before the first bounce and by using this formula: $V_t^2 = V_0^2 + 2as$. Since the ball doesn't have initial vertical velocity, $V_0=0$. And a=g, s=H.

$V_t^2 = V_0^2 + 2as$

$V^2 = 2gH$

$V = \sqrt{2gH}$

We can find the value of V' by considering the vertical motion after the first bounce until it reaches the highest point and by using this formula: $V_t^2 = V_0^2 + 2as$. The ball has initial velocity, $V_0=V'$, but doesn't have velocity at the highest point $V_t=0$. And a=g, s= 9/16 H.

$V_t^2 = V_0^2 + 2as$

$0=V'^2-2g\frac{9}{16}H$

$V'^2=\frac{9}{8}gH$

$V'=\sqrt{\frac{9}{8}gH}=\frac{3}{4}\sqrt{2gH}$

Now we can find F, but since this equation is vector equation, we need to consider which direction is positive. We assume that velocity in Y+ direction is positive. So, V is negative and V' is positive:

$F\Delta t = m(V'-V)$

$Ft=m(\frac{3}{4}\sqrt{2gH} - (-\sqrt{2gH}))$

$F=\frac{m}{t}(\frac{7}{4}\sqrt{2gH})$

$\mathbf{F=\frac{7m}{4t}\sqrt{2gH}}$

b. To find R, we need to find the horizontal velocity of the ball. It can be found by considering the motion before the first bounce. First, we need to find the time needed from right after the ball is launched until right before the first bounce (by considering the vertical motion). Then, we can find the horizontal velocity (by considering the horizontal motion). We can find the time needed by using this formula: $S=V_0t+\frac{1}{2}at^2$.

S=H, $V_0=0$, a=g.

$S=V_0t+\frac{1}{2}at^2$

$H=\frac{1}{2}gt^2$

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

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17 Sem 1	

We can find the horizontal velocity by considering the horizontal motion. Since there is no horizontal acceleration, we use this formula: $S=V_xt$. $S=\frac{4}{3}H$, $t=\sqrt{\frac{2H}{g}}$

$S=V_xt$

$\frac{4}{3}H=V_x\sqrt{\frac{2H}{g}}$

$V_x=\frac{4}{3}H\sqrt{\frac{g}{2H}}$

$V_x=\frac{2\sqrt{2}}{3}\sqrt{gH}$

Next, we need to find the time needed from right after the first bounce until right before the second bounce. The time needed is twice as the time needed to reach the highest point

$T=\frac{2V'}{g}$

$T=\frac{2\,x\,3/4\,\sqrt{2gH}}{g}$

$T=\frac{6}{4}\sqrt{\frac{2H}{g}}$

Now, we can find R by considering the horizontal motion after the first bounce.

$S=V_xT$

$R=\frac{2\sqrt{2}}{3}\sqrt{gH}\;x\;\frac{6}{4}\sqrt{\frac{2H}{g}}$

R=2H

c. The highest height before the first bounce $H_0=H$, the highest height after the first bounce $H_1=H$. The relation between these highest height is $H_{n+1}=e^2H_n$. Where e is the elasticity. By this relation, we can find the elasticity:

$e=\sqrt{\frac{H1}{H0}}$

$e=\sqrt{\frac{9}{16}}=\frac{3}{4}$

We can find H_2 and so on until H_n:

$H_2 = e^2H_1$

$H_2 = \frac{9}{16}\frac{9}{16}H$

$H_2 = \frac{81}{256}H$

$\underline{H_n = e^{2n}H_1}$

$H_4 = \frac{9}{16}^8 H = 0.10011H$

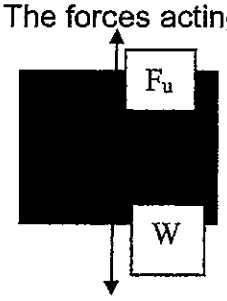
$H_5 = \frac{9}{16}^{10} H = 0.056H$

Now we can find the highest height after n bounces. And we can find that the minimum number of bounces it takes to reach a height less than H/10 is **5 bounces** ($H_5 = 0.056$ H, H_4 is still more than 0.1H)

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics	
Year / Semester : AY16/17Sem1	

2a. The forces acting on the cube are Weight and Upthrust force



$F_u = \rho g v'$

$W = Mg$

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

Where ρ = density of water and v' = the volume of cube which is in the water

$v' = L^3(1-\frac{y}{L})$

By using the Newton's second law we can find the acceleration as a function of y:

$F = Ma$

$Fu - W = Ma$

$\rho g L^3(1-\frac{y}{L}) - Mg = Ma$

$a = \frac{\rho g L3 (1-\frac{y}{L}) - Mg}{M}$

$a = \frac{\rho g L3 (1-\frac{y}{L})}{M} - g$

We can simplify this equation by substituting $M = \frac{1}{2}\rho L^3$

$a = \frac{\rho g L3 (1-\frac{y}{L})}{\frac{1}{2}\rho L^3} - g$

$a = 2g(1-\frac{y}{L}) - g$

$a = g - 2g\frac{y}{L}$

b. The largest displacement occurs when a=0.

$0 = g - 2g\frac{y}{L}$

$y = \frac{L}{2}$

c. The largest speed of the cube occurs when a=0 ($y=\frac{L}{2}$). Now we need to find the formula for the velocity.

As we know that $a = \frac{dV}{dt} = \frac{dV}{dy}\frac{dy}{dt} = \frac{dV}{dy}V$

$a = g - 2g\frac{y}{L}$

$\frac{dV}{dy}V = g - 2g\frac{y}{L}$

$VdV = (g - 2g\frac{y}{L})dy$

Integrate both sides:

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17 Sem 1	

$$\int_0^{V_t} V dV = \int_0^{y} (g - 2g\frac{y}{L}) dy$$

$$\frac{V_t^2}{2} = gy - 2g\frac{y^2}{2L}$$

$$= gy - g\frac{y^2}{L}$$

$$V_t^2 = 2gy(1-\frac{y}{L})$$

$$V_t = \sqrt{2gy(1-\frac{y}{L})}$$

Now we substitute $y=\frac{L}{2}$. <u>This is when the velocity is maximum</u>

$$V_t = \sqrt{2g\frac{L}{2}(1-\frac{L}{2L})}$$

$$\mathbf{V_t = \sqrt{gL/2}}$$

3. Assume the mass of block A and B are M. Then the mass of block C is 2M. Because the collision between blocks is elastic, e=1.
Firstly, A will collide with B. We can use these formula to find each block's velocity after the collision:

$$MV_A+MV_B=MV_A'+MV_B'$$
$$V=V_A'+V_B'.....(1)$$

$$e = \frac{-(V_A'-V_B')}{V_A-V_B}$$
$$1=\frac{-(V_A'-V_B')}{V}$$
$$V=-V_A' + V_B'....(2)$$

From the equations above, we get $V_B'=V$ and $V_A'=0$.
Secondly, B will collide with C.

$$MV_B+2MV_C=MV_B'+2MV_C'$$
$$V=V_B'+2V_C'.....(3)$$

$$e = \frac{-(V_B'-V_C')}{V_B-V_C}$$
$$1=\frac{-(V_B'-V_C')}{V}$$
$$V=-V_B' + V_C'$$

From the equations above, we get $V_B'=\frac{-1}{3}V$, $V_C'=\frac{2}{3}V$. We can see that <u>block B will still have velocity</u> after the second collision and it will move toward block A. So <u>there will be third collision</u> (between block B and block A)

*<u>"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"</u>*

Third collision between A and B.

$MV_A'+MV_B'=MV_A''+MV_B''$

$-\frac{1}{3}V=V_A''+V_B''$

$e = \frac{-(V_B'' - V_A'')}{V_B' - V_A'}$

$1=\frac{-(V_B'' - V_A'')}{\frac{-1}{3}V}$

$\frac{1}{3}V = V_B'' - V_A''$

From the equations above, we get $V_B''=0$, $V_A''=\frac{-1}{3}V$.
So after all the collisions, The velocity of each blocks are:
Velocity of A = $\frac{-1}{3}$ V (Moves to the left)
Velocity of B = 0
Velocity of C = $\frac{2}{3}$ V (Moves to the right)

3bi. The neutral point is where the gravitational field is zero. This means the gravitational field by 3M is equal to the gravitational field by M. Let the distance between 3M and the neutral point is x.

$\frac{G3M}{x^2}=\frac{GM}{(a-x)^2}$

$3(a-x)^2 = x^2$

$3a^2 - 6ax + 3x^2 = x^2$

$0=2x^2-6ax+3a^2$

From the equation above we can get **$x = \frac{a}{2}(3-\sqrt{3})$**

bii. The gravitational potential energy is given by this equation:

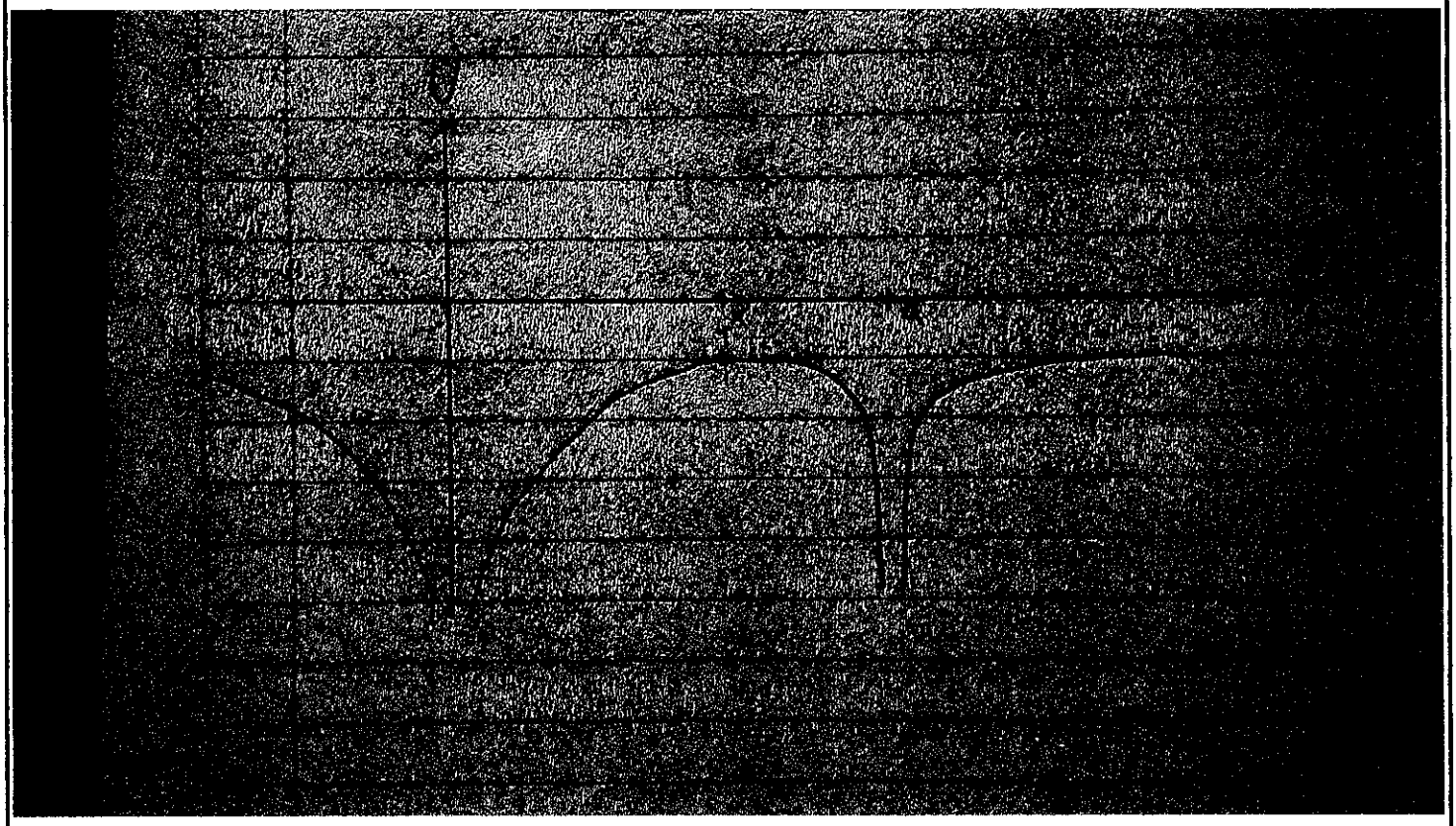
$$U = \frac{-G3Mm}{r^2} - \frac{GMm}{R^2}$$

$$U = -GMm\left(\frac{3}{r^2} + \frac{1}{(a-r)^2}\right)$$

The gravitational potential energy at critical point is max. The graph is shown below

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics I	
Year / Semester : AY16/17Sem1	



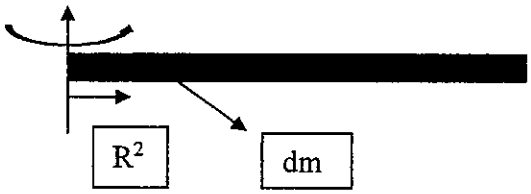
"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17Sem1	

4ai. The Inertia of a uniform rod of mass M and length L pivoted at the one end is $I=\frac{1}{3}ML^2$
The Kinetic energy of the rod is only the rotational kinetic energy, $KE=\frac{1}{2}I\omega^2$

$KE=\frac{1}{2}I\omega^2$
$KE=\frac{1}{2}\frac{ML^2}{3}\omega^2$
$KE=\frac{ML^2}{6}\omega^2$ **Proven**

aii. $KE=\frac{1}{2}I\omega^2 \rightarrow dKE=\frac{1}{2}\omega^2 dI$



Where $dI = R^2\,dm$.
$dKE=\frac{1}{2}\omega^2 R^2\,dm$
$KE=\frac{1}{2}\omega^2 \int_0^L R^2\,dm$
$KE=\frac{1}{2}\omega^2 \frac{L^3}{3}$
$KE=\frac{ML^2}{6}\omega^2$

4b. The inertia of the system before the iron sphere is attached:
$I_0 = I_{disk}$
$I_0 = \frac{mr^2}{2}$
$I_0 = \frac{3x0.1^2}{2} = 0.015\ kg/m^2$

The inertia of the system after the iron sphere is attached:
$I' = I_{disk} + I_{sphere} + MD^2$
$I' = 0.015 + \frac{2MR^2}{5} + M(r+R)^2$
$I' = 0.015 + \frac{2x0.5x0.05^2}{5} + 0.5x(0.15)^2$
$I' = 0.015 + 0.0005 + 0.01125$
$I' = 0.02675\ kg/m^2$

Now, we can find the angular velocity after the sphere is attached by using the conservation of angular momentum:
$I_0\omega_0 = I'\omega'$
$0.015 \times 65 = 0.02675 \times \omega'$
$\omega' = 36.45\ rpm$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17 Sem 1	

5a. The efficiency(η) formula is W_{net}/Q_{in}. To find efficience, we need to find each work done by a single process and find the positive heat (Q_{in}). We can get Q_{in} from process b→c.

Process a → b (adiabatic)

$$W_1 = \frac{-1}{\gamma-1}(P_bV_b - P_aV_a)$$

Process b → c (isobaric)

$$W_2 = P_b(V_c - V_b)$$
$$Q_{in} = nC_p(T_c - T_b)$$

Process c → d (adiabatic)

$$W_3 = \frac{-1}{\gamma-1}(P_cV_c - P_dV_d)$$

Process d → a (isobaric)

$$W_4 = P_a(V_a - V_d)$$

Now we substitute all variables and find the effieciency:

$$\eta = \frac{W_{net}}{Q_{in}}$$
$$\eta = \frac{W_1+W_2+W_3+W_4}{Q_{in}}$$
$$\eta = \frac{\frac{-1}{\gamma-1}(P_bV_b-P_aV_a)+P_b(V_c-V_b)+\frac{-1}{\gamma-1}(P_cV_c-P_dV_d)+P_a(V_a-V_d)}{nC_p(T_c-T_b)}$$
$$\eta = \frac{1}{\gamma-1}\frac{-P_bV_b+P_aV_a+\gamma P_bV_c-\gamma P_bV_b-P_bV_c+P_bV_b-P_cV_c+P_cV_d+\gamma P_aV_a-\gamma P_aV_d-P_aV_a+P_aV_d}{nC_p(T_c-T_b)}$$

$$\eta = \frac{\gamma}{\gamma-1}\frac{P_bV_c - P_bV_b + P_aV_a - P_aV_d}{nC_p(T_c-T_b)}$$

Subtitute $\gamma = \frac{C_p}{C_v}$

$$\eta = \frac{\frac{C_p}{C_v}}{\frac{C_p}{C_v}-1}\frac{P_bV_c - P_bV_b + P_aV_a - P_aV_d}{nC_p(T_c-T_b)}$$

$$\eta = \frac{C_p}{C_p-C_v}\frac{P_bV_c - P_bV_b + P_aV_a - P_aV_d}{nC_p(T_c-T_b)}$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subtitute $C_p - C_v = R$

$$\eta = \frac{P_bV_c - P_bV_b + P_aV_a - P_aV_d}{\mathrm{nR}(T_c - T_b)}$$

Subtitute ideal gas equation $PV = nRT$ *for the denominator.* $P_cV_c = nRT_c$ and $P_bV_b = nRT_b$

$$\eta = \frac{P_bV_c - P_bV_b + P_aV_a - P_aV_d}{P_cV_c - P_bV_b}$$

Because from process $a \rightarrow d$ *is isobaric,* $P_c = P_b$

$$\eta = \frac{P_bV_c - P_bV_b + P_aV_a - P_aV_d}{P_b(V_c - V_b)} \ldots(1)$$

From the adiabatic process (a→b and c→d), we can find the relation between V_a *and* V_b, *and between* V_c *and* V_d

$PV^\gamma = constant$

$Vd = (\frac{P_c}{P_d})^{\frac{1}{\gamma}}V_c = (\frac{P_b}{P_a})^{\frac{1}{\gamma}}V_c$ ....(2) → $P_d = P_a$ and $P_c = P_b$ (from isobaric process)

$Va = (\frac{P_b}{P_a})^{\frac{1}{\gamma}}V_b$.....(3)

Subtitute (2) and (3) to (1)

$$\eta = \frac{P_bV_c - P_bV_b + P_a(\frac{P_b}{P_a})^{\frac{1}{\gamma}}V_b - P_a(\frac{P_b}{P_a})^{\frac{1}{\gamma}}V_c}{P_b(V_c - V_b)}$$

$$\eta = \frac{P_a(\frac{P_b}{P_a})^{\frac{1}{\gamma}}V_b - P_a(\frac{P_b}{P_a})^{\frac{1}{\gamma}}V_c}{P_b(V_c - V_b)} + 1$$

$$\eta = \frac{\frac{P_a}{P_b}(\frac{P_b}{P_a})^{\frac{1}{\gamma}}V_b - \frac{P_a}{P_b}(\frac{P_b}{P_a})^{\frac{1}{\gamma}}V_c}{(V_c - V_b)} + 1$$

$$\eta = \frac{(\frac{P_b}{P_a})^{\frac{1}{\gamma}-1}V_b - (\frac{P_b}{P_a})^{\frac{1}{\gamma}-1}V_c}{(V_c - V_b)} + 1$$

$$\eta = \frac{(\frac{P_b}{P_a})^{\frac{1-\gamma}{\gamma}}V_b - (\frac{P_b}{P_a})^{\frac{1-\gamma}{\gamma}}V_c}{(V_c - V_b)} + 1$$

$$\eta = \frac{-(\frac{P_b}{P_a})^{\frac{1-\gamma}{\gamma}}(V_c - V_b)}{(V_c - V_b)} + 1$$

$$\eta = 1 - (\frac{P_b}{P_a})^{\frac{1-\gamma}{\gamma}}$$

Proven

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17Sem1	

5b. γ for monoatomic is $\frac{5}{3}$. Assume 1 atm = 1.01 x 10^5

Firstly, we need to know V_b and V_c. We can find them from ideal gas equation for adiabatic process. (note that for isobaric process, $P_d = P_a$ and $P_c = P_b$)

We also need to find T_b *and* T_c.

$$Vb = (\frac{P_a}{P_b})^{\frac{1}{\gamma}} V_a$$

$$Vb = (\frac{1 \, x \, 1.01 \, x \, 10^5}{1.3 x \, 1.01 \, x \, 10^5})^{\frac{3}{5}} \, x \, 0.05$$

Vb = 0.0427 m^3

$$T_b = \frac{P_b V_b}{nR}$$

$$T_b = \frac{1.3x1.01x10^5x0.0427}{2x8.314}$$

$$T_b = 337.17 \, K$$

$$Vc = (\frac{P_d}{P_c})^{\frac{1}{\gamma}} V_d$$

$$Vb = (\frac{1 \, x \, 1.01 \, x \, 10^5}{1.3 \, x \, 1.01 \, x \, 10^5})^{\frac{3}{5}} \, x \, 0.07$$

Vc = 0.0598 m^3

$$T_c = \frac{P_c V_c}{nR}$$

$$T_c = \frac{1.3x1.01x10^5x0.0598}{2x8.314}$$

$$T_c = 472.2 \, K$$

Process a→b (adiabatic)

Q=0

$$W = \frac{-1}{\gamma - 1}(P_b V_b - P_a V_a)$$

$$W = \frac{-1}{\frac{5}{3} - 1}(1.3 \, x1.01x10^5x0.0427 - 1x1.01x10^5x0.05)$$

W= -834.765 J

$$\Delta U = -W$$

$$\Delta U = 834.765 \, J$$

Process b→c (isobaric)

$$W = P_b(V_c - V_b)$$

$$W = 1.3x1.01x10^5(0.0598 - 0.0427)$$

W = 2245.23 J

$$\Delta U = nC_v(T_c - T_b)$$

$$\Delta U = 2x\frac{3}{2}(472.2 - 337.17)$$

$$\Delta U = 405.09 \text{ J}$$

$$Q = nC_p(T_c - T_b)$$

$$Q = 2x\frac{5}{2}(472.2 - 337.17)$$

Q = 1012.725 J

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17Sem1	

5c. First we need to find T_d:

$T_d = \frac{P_d V_d}{nR}$

$T_d = \frac{1x1.01x10^5x0.07}{2x8.314}$

$T_d = 425.19\ K$

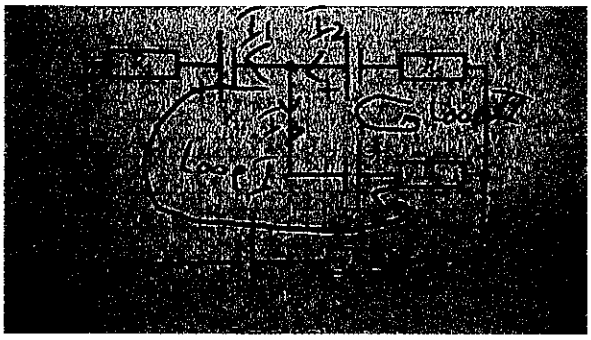
Now we can find the V_{RMS}

$V_{RMS} = \sqrt{\frac{3RT_d}{M}}$

$V_{RMS} = \sqrt{\frac{3x8.314x4 \quad .19}{28x10^{-3}}}$

$\boldsymbol{V_{RMS} = 615.43\ m/s}$

6a.



$I_2 = I_1 + I_3$....(1)

Loop I:

$1\text{-}I_1 - 2I_1 + 4\text{-}3I_1 + 4I_3 - 3 = 0$

$2=6I_1 - 4I_3$

$1=3I_1 - 2I_3$.....(2)

Loop II:

$2+3\text{-}4I_3 - 5I_2 = 0$

$5=5I_2 + 4I_3$.....(3)

Subtitute (1) to (3):

$5=5I_1 + 9I_3$....(4)

From (4) and (2) we can find I_3 *and* I_1 by eliminating them.

$15=15I_1 + 27I_3$...(4)

$5 = 15I_1 - 10I_3$...(2)

$10=37I_3$

$I_3 = \frac{10}{37}$ A ....(5)

Subtitute (5) to (4):

$5I_1 = 5 - 9x\frac{10}{37}$

$5I_1 = \frac{185-9}{37}$

$I_1 = \frac{19}{37}$ A...(6)

Subtitute (5)&(6) to (1)

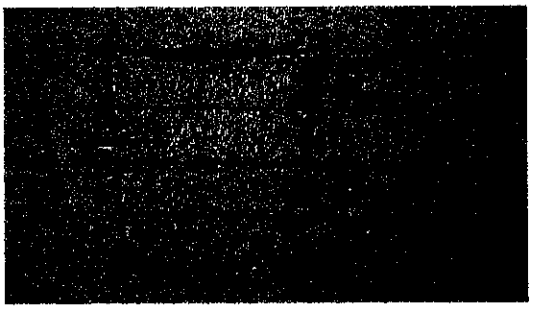
$I_2 = \frac{29}{37}$A

The current passing through R_2 is $\boldsymbol{I_1 = \frac{19}{37} A}$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17 Sem 1	

6bi. After all the capasitors are charged (for a long time). There will be no current passing through both capasitors. The circuit can be simplified:



We can simply find the current in the circuit.

$I = \frac{V}{R_1+R_2}$

$\mathbf{I = \frac{15}{30} = 0.5A}$

The current passing through R_2 is the same as I because this is series circuit.

bii.

Before switch S is opened, The potential difference in C_1 is the same as the potential difference in R_1 which is $V_1=IxR_1=0.5x10=5V$.

After switch S is opened for a long time, The potential difference in C_1 is the same as the potential difference in the battery (ε). $V_1'=15V$

Now, we can find the change in energy stored in C_1.

$$\Delta E = \frac{1}{2}C_1{V_1}'^2 - \frac{1}{2}C_1{V_1}^2$$
$$\Delta E = \frac{1}{2}C_1({V_1}'^2 - {V_1}^2)$$
$$\Delta E = \frac{1}{2}x1x10^{-6}(15^2 - 5^2)$$
$$\Delta E = \frac{1}{2}x10^{-6}x200$$
$$\mathbf{\Delta E = 10^{-4}J}$$

7ai. At r>R, $q_{in} = Q$

$$\oint EdA = \frac{q_{in}}{\epsilon_0}$$
$$E \times 4\pi r^2 = \frac{Q}{\epsilon_0}$$
$$E = \frac{Q}{4\pi r^2 \epsilon_0}$$

ii. This is insulating sphere, so the charge is distributed with the volume charge density $\rho_{(r)} = \rho_0 r$. We need to find the charge function with respect to r.

$dq = \rho dV$

The dV for a sphere is $4\pi r^2 dr$

$$q = \int_0^r \rho_0 r 4\pi r^2 dr$$
$$q = 4\pi\rho_0 \int_0^r r^3 dr$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

$q=4\pi\rho_0\frac{r^4}{4}$

$q=\pi\rho_0 r^4$

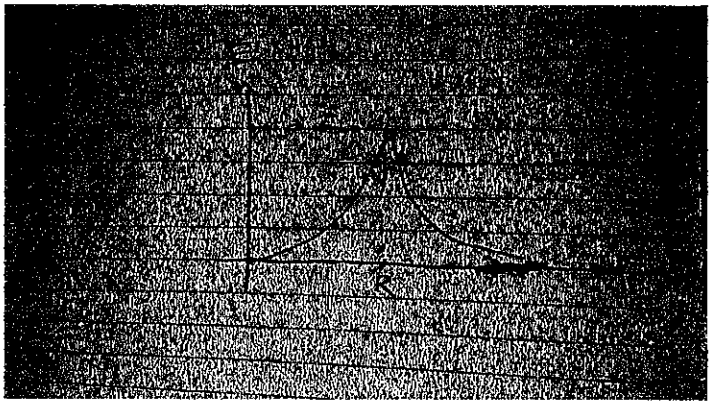
Now, we can find the electric field at r<R.

$\oint EdA \quad \frac{q_{in}}{\epsilon_0}$

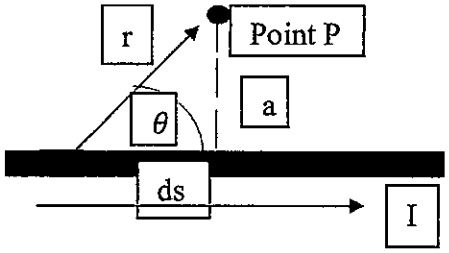
$E4\pi r^2=\frac{\pi\rho_0 r^4}{\epsilon_0}$

$E=\frac{\rho_0 r^2}{\epsilon_0}$

iii.



b.



First, we need to find the magnetic field from a short rod at P by using Biot-Savart law:

$d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{i|ds|\sin\theta}{r^2}\hat{k}$

The ds's direction is in x axis, so $|ds| = d$

$d\mathbf{B} = \frac{\mu_0}{4\pi}\frac{i\,si}{r^2}dx$

We need to change all the variables with the same single variable. Here we use θ

$\frac{a}{r} = \sin\theta$

$r = a\csc\theta$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

$\frac{a}{-x} = \tan\theta$

$x = -a\cot\theta$

$dx \quad -ad(\cot\theta) = -a(-\csc^2\theta\ d\theta) = a\csc^2\theta\ d\theta$

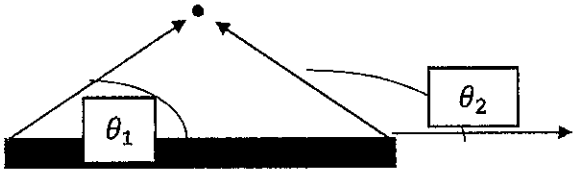
Next we substitute these variables into d**B**

$$\mathbf{dB} = \frac{\mu_0}{4\pi}\frac{i\,\mathrm{sl}}{r^2}dx$$

$$\mathbf{dB} = \frac{\mu_0}{4\pi}\frac{i\sin}{(a\csc\theta)^2}\,a\csc^2\theta\ d\theta$$

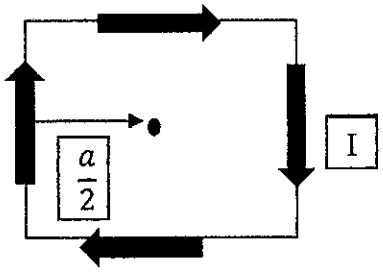
$$\mathbf{dB} = \frac{\mu_0 i\ \sin}{4\pi a}\,d\theta$$

To integrate the equation above, we need to determine the lower limit and higher limit. Here we use *θ_1 as the lower limit and θ_2 as the high limit*



$$B=\frac{\mu_0 i}{4\pi}\int_{\theta_1}^{\theta_2}\sin\theta\,d\theta$$

$$B=\frac{\mu_0 i}{4\pi a}(\cos\theta_1 - \cos\theta_2)$$



Now, if there are 4 rods which have length *a* carrying current *I*, the Magnetic field at the centre of a square is

$$B = 4x\ \frac{\mu_0 i}{4\pi\frac{a}{2}}(\cos 45^o - \cos 135^o)$$

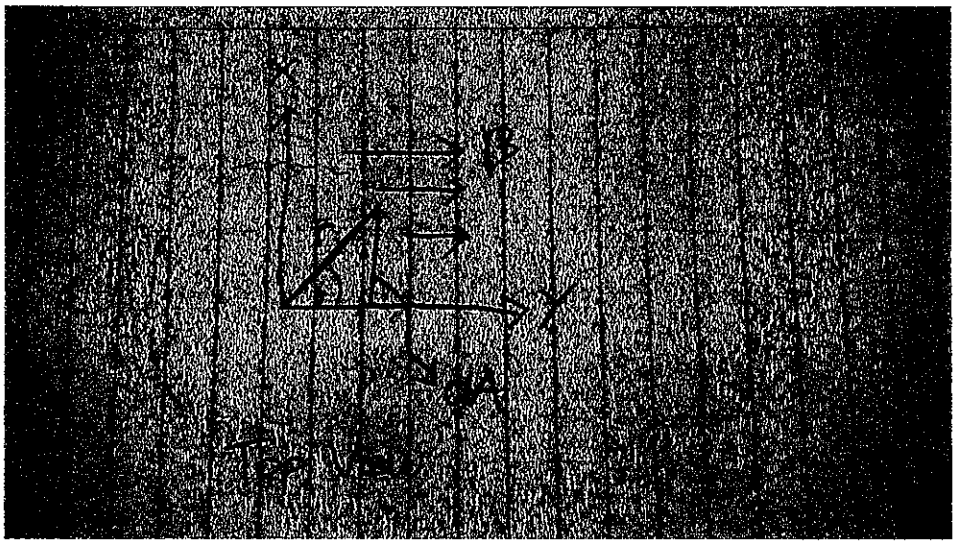
$$B = \frac{2\mu_0 i}{\pi a}\left(\frac{\sqrt{2}}{2}+\frac{\sqrt{2}}{2}\right)$$

$$B = \frac{2\sqrt{2}\mu_0 i}{\pi a}$$ **shown**

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics I	
Year / Semester : AY16/17Sem1	

8a.



To find the induced current, we can use this equation:

$$I = \frac{\varepsilon}{R}$$

Where

$$\varepsilon = \frac{-d\Phi}{dt} \text{ and } d\Phi = BdA$$

In this question $A = rL \sin\theta$ and $\theta = \omega t$. (note that after t second, the wire will cover $\theta = \omega t$)
So :

$A = rL\sin \omega t.$
$dA = rL\, d\sin \omega t$
$= rL\cos \omega t\, d\omega t$
$= rL\omega \cos \omega t\, dt.$

Next,

$d\Phi = BdA$
$d\Phi = Br \quad \cos \omega t\, dt$

Then,

$$\varepsilon = \frac{-d\Phi}{dt}$$
$$\varepsilon = BrL\omega \cos \omega t \frac{dt}{dt}$$
$$\varepsilon = BrL\omega \cos \omega t$$

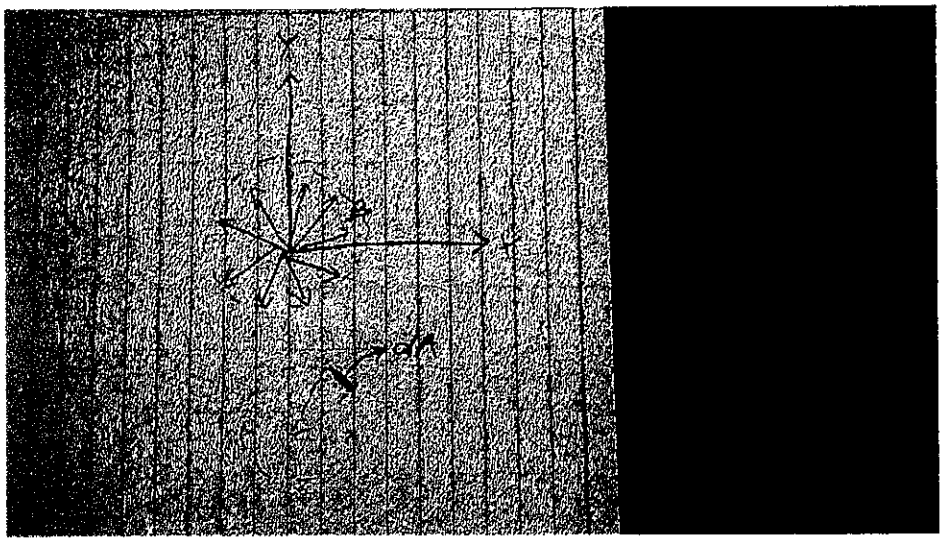
Finally we can find the induced current.

$$I = \frac{\varepsilon}{R}$$
$$\mathbf{I} = \frac{\boldsymbol{BrL\omega \cos \omega t}}{R}$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

8b. In this case, there is no cross-sectional area. So there won't be induced current **I=0**

c.



In this case, the cross sectional area is the arc length times L.

$A = rL\theta$

$A = rL\omega t$

$dA = rL\omega dt$

Next,

$d\Phi = BdA$

$d\Phi = BrL\omega dt$

Then,

$\varepsilon = \frac{-d\Phi}{dt}$

$\varepsilon = BrL\omega \frac{dt}{dt}$

$\varepsilon = BrL\omega$

Finally we can find the induced current.

$I = \frac{\varepsilon}{R}$

$\mathbf{I = \frac{BrL\omega}{R}}$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER I EXAMINATION 2017-2018

PH1011 - Physics

November 2017 Time Allowed: 2.5 HOURS

SEAT NUMBER: | | | | | |

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

INSTRUCTIONS TO CANDIDATES

1. This question and answer booklet contains **EIGHT (8)** questions and comprises of **SEVENTEEN (17)** printed pages.

2. Answer **ALL EIGHT (8)** questions. All workings must be clearly shown.

3. Total 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 (10)	2 (10)	3 (15)	4 (15)	5 (15)	6 (15)	7 (10)	8 (10)	Total (100)
Marks									

/10

Q1 (10 marks)

Usually a simple analysis of the motion of an object in two dimensions can provide us with some basic insights into the problems that we need to solve. Here, you will analyze two rather different problems. In both cases, ignore the effects of air resistance.

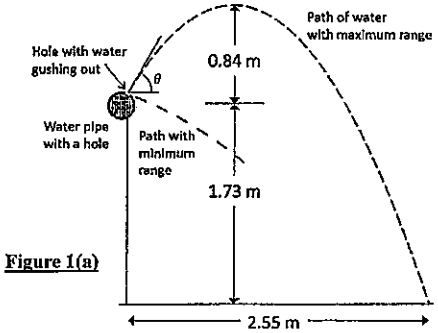


Figure 1(a)

(a) Bursting of water pipes can happen due to long-term corrosion or careless drilling by the workers. Figure 1(a) shows the cross-section of a punctured water pipe and the trajectory of water gushing out of the hole. We will focus on studying the path of the water that gives the maximum range.

i) Using the information provided in Figure 1(a), determine the vertical component of the velocity of the water coming out of hole that gives the path with maximum range.

ANS: _____

ii) Using the information provided in Figure 1(a), determine the magnitude and the angle θ of the velocity of the water coming out of hole that follows the path that gives maximum range.

ANS: _____

Note: Question 1 continues on page 3

(b) This year, there has been many treats to world peace because of missile tests. Missiles differ from usual projectile motion because there is an additional propelling force on the missile. We will do a basic analysis of missiles. Here we will regard the missile as a point object.

Figure 1(bi)

Figure 1(bii)

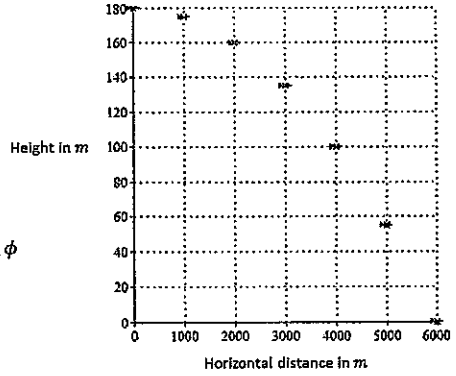


Figure 1(c)

As shown in Figure 1(bi), if the missile is projected horizontally from a cliff of height 180 m but the propulsion is not turned on, the position of the missile is given in Figure 2(c) at intervals of 1 s for the first 6 s.

i) However, usually fuel is burnt to propel the missile as shown in Figure 1(bii). If the propulsion provides a constant acceleration of 40 m/s^2, determine the angle ϕ such that the missile will fly at a constant height.

ANS: _____

ii) Based on your answer in part b(i) and same initial horizontal velocity in Figure 1(c), determine the horizontal distance the missile (with propulsion) travelled in the first 6 s.

ANS: _____

/10

Q2 (10 marks)

A block B with mass $2m$ is initially at rest on a frictionless ground. Another block A with mass m is moving on top of the block B with initial velocity v to the right. The kinetic friction between the contact surface of A and B is μ_k.

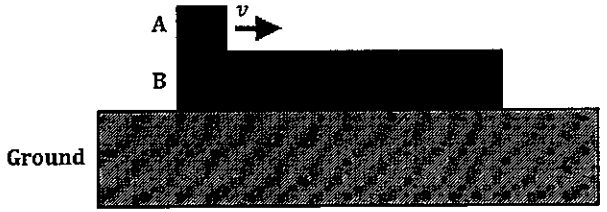


Figure 2

(a) After a while, block A and B will travel at the same velocity v_f. Assuming the length of block B is enough for A not to fall off, show that $v_f = \frac{1}{3}v$.

Note: Question 2 continues on page 5

(b) Determine the time it takes for both blocks to reach v_f.

ANS: _____

(c) Find the minimum length of block B for block A not to fall off.

ANS: _____

/15

Q3 (15 marks)

(a) An external force is applied to an object with mass 2 kg at $t = 0$ which is initially at rest on a frictionless surface. The figure below shows the acceleration-time graph of the object.

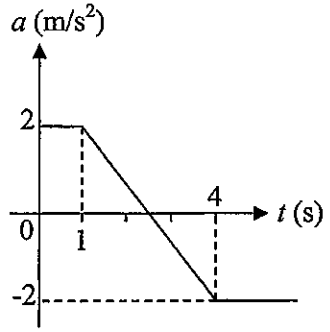


Figure 3

(i) What is the impulse of the object from $t = 0$ to $t = 4$ s?

ANS: _____

(ii) What is the net work done by the external force on the object during $t = 0$ to $t = 4$ s?

ANS: _____

Note: Question 3 continues on page 5

(b) An experiment is performed in deep space with two uniform spheres, one with mass 22.0 kg and the other with mass 101.0 kg. They have equal radii, $r = 0.20$ m. The spheres are released from rest with their centres 25.0 m apart. They accelerate towards each other because of their mutual gravitational attraction. You can ignore all gravitational forces other than that between the two spheres.

(i) When their centres are 20.0 m apart, find the speed of each sphere.

ANS: _____

(ii) When their centres are 20.0 m apart, find the magnitude of the relative velocity with which one sphere is approaching the other.

ANS: _____

(iii) How far from the initial position of the centre of the 22.0-kg sphere do the surfaces of the two spheres collide?

ANS: _____

/15

Q4 (15 marks)

(a) A bead of mass m is suspended on one arm of a Y-shape pole. When the pole rotates around the vertical axis at an angular velocity ω, the bead maintains a distance h from the center of the pole. Ignore friction for this question.

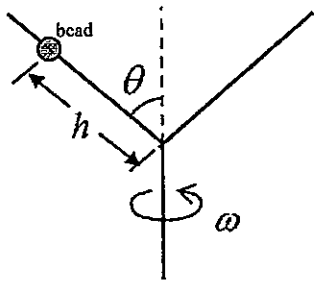


Figure 4(a)

(i) Derive an expression for the normal force on the bead.

ANS: _____

(ii) Derive an expression for ω.

ANS: _____

Note: Question 4 continues on page 9

(b) A mobile elevated working platform as shown in Figure 4(b) consists of three parts: a car, an arm, and a platform. The distance between the front and the back wheels is a. The mass of the car is M and its center of mass is located at the top of the front wheel. The arm, assuming uniform, has a mass of $\frac{M}{8}$ and its pivot point is located at the top of the back wheel. The platform and the engineer have a total mass of $\frac{M}{4}$ and their centre of mass is assumed to be at the end of the arm. When the arm is tilted at 30° from the vertical axis, what will be the maximum working distance of the extensible arm before the platform topples?

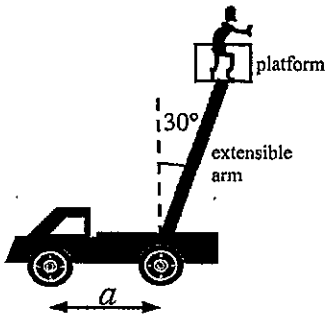


Figure 4(b)

ANS: _____

Note: Question 4 continues on page 10

(c) Consider two identical, uniform rods each of length L and mass m forming a symmetrical T-shaped pendulum, pivoted at one end as shown in Figure 4(c).

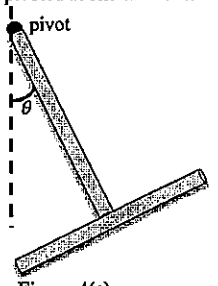


Figure 4(c)

(i) Show that the moment of inertia about the pivot is $\frac{17}{12}mL^2$.

(ii) The pendulum is released at some angle θ (less than 90°). Show that, at the position when $\theta = 0$, the angular velocity of the pendulum is $\omega = \sqrt{\frac{36g(1-\cos\theta)}{17L}}$.

ANS: _____

/15

Q5 (15 marks)

(a) A laboratory vacuum pump attained a pressure of 9.05×10^{-13} atm in a sealed chamber. Air contains mostly N_2 molecules, so the air can be treated as a diatomic ideal gas.

i) At a temperature of 295.0 K, how many molecules are present in a volume of 1.05 cm^3?

ANS: _____

ii) What is the average translational kinetic energy of the air molecules?

ANS: _____

iii) What is the average internal energy of the air molecules?

ANS: _____

(b) Nine moles of an ideal, diatomic gas go through cycle *abc* as shown below in Figure 5. For this gas, the molar heat capacity at constant pressure is $c_P = 29.1$ J mol^{-1} K^{-1}. Process *ca* is at constant pressure, process *ab* is at constant volume and process *bc* is adiabatic. The temperatures of the gas in states *a*, *b* and *c* are $T_a = 300$ K, $T_b = 600$ K and $T_c = 492$ K.

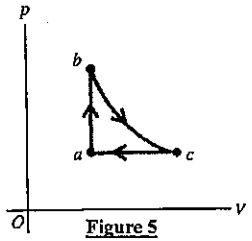


Figure 5

i) Write down the relationship between the ideal gas constant *R*, the molar heat capacity at constant pressure c_P and the molar heat capacity at constant volume c_V.

ANS: _____

Note: Question 5 continues on page 12

ii) Fill in the blanks for each of the quantities in each process. Include the calculations in that cell. Leave your answers in units of kJ (kilo-joules).

	Work done by the gas (kJ)	Heat supplied to the gas (kJ)	Change in internal energy of the gas (kJ)
Process *ab* (constant volume)			
Process *bc* (adiabatic)			
Process *ca* (constant pressure)			

iii) From your results in the table, calculate the efficiency of this cycle.

ANS: _____

/15

Q6 (15 marks)

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

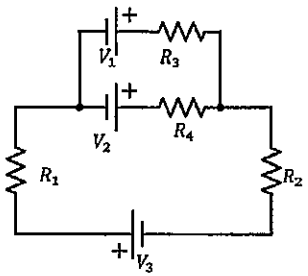


Figure 6(a)

Current through resistor R_3: _____

Note: Question 6 continues on page 14

(b) Consider a RC circuit in Figure 6(b) with $V = 15$ V, $R_1 = 10\,\Omega$ and $R_2 = 20\,\Omega$. The capacitors have capacitances $C_1 = 1\,\mu$F, $C_2 = 2\,\mu$F and $C_3 = 3\,\mu$F.

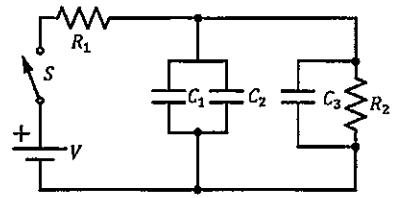


Figure 6(b)

(i) Immediately after switch S is closed, find the current passing through R_1.

ANS: _____

(ii) Switch S has been closed for a long time, find the energy stored in C_3.

ANS: _____

/10

Q7 (10 marks)

(a) As shown in Figure 7(ai), a finite line of charge length L with the right end at $x = 2$ m has a uniform charge density of λ C/m.

Figure 7(ai)

(i) Show that the electric potential due to the finite line of charge at any point x (greater than $x = 2$ m) is given by $V = \frac{\lambda}{4\pi\epsilon_0} \ln\left(\frac{x-2+L}{x-2}\right)$.

ANS: _____

(ii) As shown in Figure 7(aii), a point charge of $4\,\mu$C and mass 1.5 kg held at $x = 5$ m is released from rest. Given that $L = 100$ m and $\lambda = 3\,\mu$C/m, find its velocity when it is at $x = 12$ m.

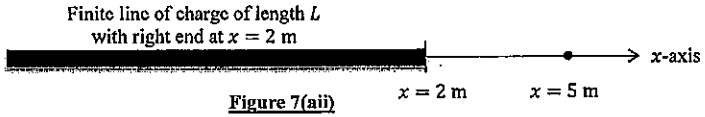


Figure 7(aii)

ANS: _____

Note: Question 7 continues on page 16

(b) Consider the electric field inside a uniformly charged ring. 2 Students gave the following explanations:

Student 1: Using Coulomb's law, it can be shown that the E-field is not zero except at the centre of the ring.

Student 2: If Gauss's law is used with a concentric cylindrical Gaussian surface as shown in Figure 7(b), there is no charge enclosed and hence E-field is entirely zero within the plane of the ring.

Which student is correct?

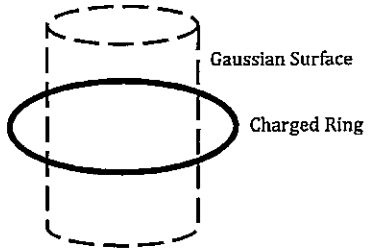


Figure 7(b)

Circle the correct explanation: Student 1 or Student 2

Give a SHORT reason why the other explanation is incorrect:

_____

_____

_____

/10

Q8 (10 marks)

As shown in Figure 8(a), two horizontal conducting rails, in a uniform magnetic field, is connected to a circuit on the left. The circuit consists of a capacitor charged to a potential difference of V_0. A frictionless conducting rod of mass m, length L and resistance R is placed perpendicularly onto the track. The switch S is then turned to the right and the rod slides to the right.

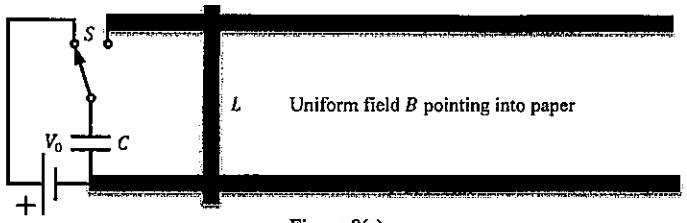


Figure 8(a)

Derive expressions for the maximum velocity of the rod and the remaining charge in the capacitor.

ANS: _____

ANS: _____

----- End of Paper -----

November 2017

Subject Code : PH 1011	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics	
Year / Semester : 1 / 1	

1 a)(i) V_y (vertical component of the velocity):

$$V_{y\,final}^2 = V_{y\,initial}^2 + 2gh$$

$$0 = V_{y\,initial}^2 + 2gh_{max}$$

$$V_{y\,initial}^2 = 2gh_{max}$$

$$V_{y\,initial}^2 = 2(9.8)(0.84) = 16.46$$

$$V_{y\,initial} = \underline{4.06\ m/s}$$

(ii) Vertical component:

$$h = V_{y\,initial}\,t - \frac{1}{2}gt^2$$

$$-1.73 = 4.06t - 4.9t^2$$

$$t = 1.14\ s$$

Horizontal component:

$$x = V_x \cdot t$$

$$V_x = \frac{x}{t} = \frac{2.55}{1.14} = 2.24\ m/s$$

$$\tan\theta = \frac{V_y}{V_x} = \frac{4.06}{2.24} = 1.81 \Leftrightarrow \theta = \tan^{-1}(1.81) = 61.1^\circ$$

$$|V| = \sqrt{V_x^2 + V_y^2} = \sqrt{4.06^2 + 2.24^2} = \underline{4.64\ m/s}$$

b) (i) To fly in a constant height:

$$a_y = g$$

$$a\sin\phi = g$$

$$\sin\phi = \frac{g}{a} = \frac{9.8}{40} = 0.245$$

$$\phi = \sin^{-1}0.245 = \underline{14.2^\circ}$$

(ii) Initial horizontal velocity:

Before propulsion turned on:

$$x = V_x t \Leftrightarrow V_x = \frac{x}{t} = \frac{6000}{6} = 1000\ m/s$$

After propulsion turned on:

$$x = V_{x\,initial}\,t + \frac{1}{2}a_x t^2$$

$$x = V_{x\,initial}\,t + \frac{1}{2}a\cos\phi\, t^2$$

$$x = 1000(6) + \frac{1}{2}(40)\cos 14.2(36)$$

$$x \simeq \underline{6700\ m}$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics	
Year / Semester : 1 / 1	

2 a) Since there is no external force act on the systems (A and B), the linear momentum is conserved.

CoLM:

$$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$$

$$mV + 2m(0) = mv_f + 2mv_f$$

$$V = v_f + 2v_f = 3v_f \quad \rightarrow \quad v_f = \frac{1}{3}V$$

b) For object A:

$$F\Delta t = m_A(v_f - v_i)$$

$$-f_k \Delta t = m_A\left(\frac{1}{3}V - v\right)$$

$$-\mu_k m_A g \Delta t = m_A\left(\frac{1}{3}V - v\right)$$

$$\Delta t = \frac{2v}{3\mu_k g}$$

c) For A:

$$\Sigma F = m_A a_A$$

$$-f_k = m_A a_A$$

$$-\mu_k m_A g = m_A a_A$$

$$a_A = -\mu_k g$$

For B:

$$\Sigma F = m_B a_B$$

$$f_k = m_B a_B$$

$$\mu_k m g = 2m a_B$$

$$a_B = \frac{1}{2}\mu_k g$$

$$a_{A,B} = a_A - a_B = -\mu_k g - \frac{1}{2}\mu_k g = -\frac{3}{2}\mu_k g$$

The minimum length of B for A not to fall:

$$v_{f_A} = v_{f_B}$$

$$v_{f_{A,B}}^2 = v_{i_{A,B}}^2 + 2a_{A,B}s$$

$$0 = V^2 + 2\left(-\frac{3}{2}\mu_k g\right)s$$

$$-V^2 = -3\mu_k g s$$

$$s = \frac{V^2}{3\mu_k g}$$

"This suggested solution was done by a student with grade A or above"

MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH 1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics	
Year / Semester : 1 / 1	

3 a) (i) Impulse (t:0 to t:4):

$I = \int_0^4 F \cdot dt$ — The area under the a-t curve

$I = m\int_0^4 a \cdot dt$

$I = 2\left(2(1) + \frac{1}{2}(2)(1.5) - \frac{1}{2}(2)(1.5)\right)$

$I = 2(2 + 0 + 0) = \underline{\underline{4 \text{ Ns}}}$

(ii) Work done (t:0 to t:4):

$W = \Delta KE$

$W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 \quad (v_i = 0)$

$W = \frac{1}{2}m\left(v_i + \int_0^4 a\,dt\right)^2$

$W = \frac{1}{2}(2)(2)^2 = \underline{\underline{4 \text{ J}}}$

b) (i) Since there is no external force act on systems, than linear momentum is conserved.

CoLM: ($v_A, v_B = 0$)

$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$

$-m_A v_A' = m_B v_B'$

$v_A' = -\left(\frac{m_B}{m_A} v_B'\right) = -\frac{101}{22} v_B' = -4.59 v_B' \quad (1)$

COE:

$U = U' + KE_A' + KE_B'$

$-G\frac{m_A m_B}{r_i^2} = -G\frac{m_A m_B}{r_f^2} + \frac{1}{2}m_A v_A'^2 + \frac{1}{2}m_B v_B'^2$

$G m_A m_B\left(\frac{1}{r_f^2} - \frac{1}{r_i^2}\right) = \frac{1}{2}m_A v_A'^2 + \frac{1}{2}m_B v_B'^2$

$6.67\times10^{-11}(22)(101)\left(\frac{1}{20^2} - \frac{1}{25^2}\right) = \frac{22}{2}v_A'^2 + \frac{101}{2}v_B'^2$

$1.33\times10^{-10} = 11 v_A'^2 + 50.5 v_B'^2 \quad (2)$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH 1011	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics	
Year / Semester : 1 / 1	

36)(i) Cont'd. By subsituting (1) to (2):

$$1.33\times10^{-10} = 11(-4.59\,v_{B'})^2 + 50.5\,v_{B'}^2$$

$$1.33\times10^{-10} = 231.76\,v_{B'}^2 + 50.5\,v_{B'}^2$$

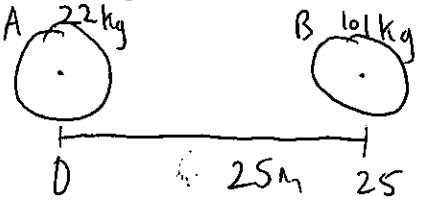
$$v_{B'}^2 = 4.7\times10^{-13}$$

$$v_{B'} = \underline{6.86\times10^{-7}\ m/s}\ ,\quad v_{A'} = -4.59(6.86\times10^{-7}) = \underline{-3.15\times10^{-6}\ m/s}$$ (opposite direction)

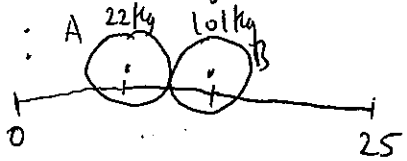
(ii) $|v_{BA}| = |v_B - v_A| = 6.86\times10^{-7} - (-3.15\times10^{-6}) = \underline{3.84\times10^{-6}\ m/s}$

(iii) Since both object are in rest initially, the CoM doesn't change

Initial :



Final :



$$COM_i = COM_f$$

$$\frac{m_A x_A + m_B x_B}{\cancel{m_A + m_B}} = \frac{m_A x'_A + m_B x'_B}{\cancel{m_A + m_B}}$$

$$22(0) + 101(25) = 22(x) + 101(0.4 + x)$$

$$2525 = 22x + 40.4 + 101x$$

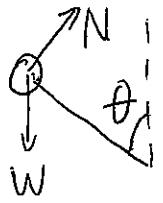
$$2484.6 = 123x$$

$$x = \underline{20.2\ m}$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH 1011	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics	
Year / Semester : 1 / 1	

4 a) (i)



Vertical component:

$$N_y = W$$

$$N\sin\theta = mg$$

$$N = \frac{mg}{\sin\theta}$$

(ii) Horizontal Component:

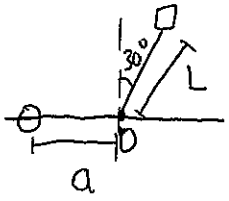
$$N_x = m\omega^2 r$$

$$N\cos\theta = m\omega^2 h\sin\theta$$

$$\frac{mg\cos\theta}{\sin\theta} = m\omega^2 h\sin\theta$$

$$\omega = \sqrt{\frac{g\cot\theta}{h\sin\theta}}$$

b)



The maximum working distance; (Pivot at the back wheel)

$$\Sigma\tau = 0$$

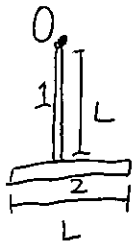
$$-W_{car}a + W_{worm}\frac{L}{2}\sin 30^\circ + W_{platform}L\sin 30^\circ = 0$$

$$-Mga + \frac{M}{8}g\frac{L}{2}\frac{1}{2} + \frac{M}{4}gL\frac{1}{2} = 0$$

$$\frac{L}{32} + \frac{L}{8} = a$$

$$L = \frac{32}{5}a = 6.4a$$

c) (i)



Moment of Inertia (Pivot at O):

$$I_O = I_1 + I_2$$

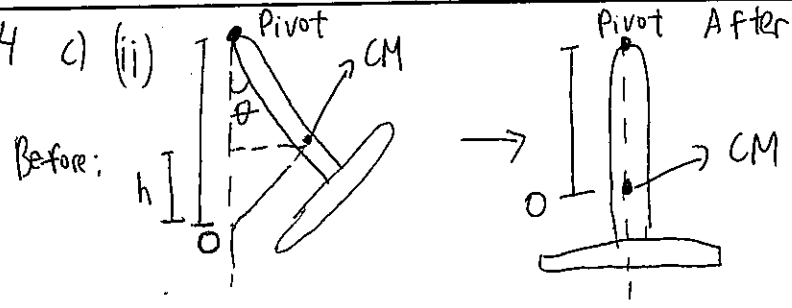
$$= \frac{1}{3}ML^2 + \left(\frac{1}{12}ML^2 + ML^2\right)$$

$$= \frac{17}{12}ML^2$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH 1011	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics	
Year / Semester : 1 / 1	

4 c) (ii)



Center of Mass (from the pivot):

$$CM = \frac{ML + M\frac{L}{2}}{2M} = \frac{3}{4}L$$

$$h = CM - CM\cos\theta = \frac{3}{4}L - \frac{3}{4}L\cos\theta$$

Conservation of energy (CoE):

$$mgh = \frac{1}{2}Iw^2$$

$$2Mg\left(\frac{3}{4}L - \frac{3}{4}L\cos\theta\right) = \frac{1}{2}\left(\frac{17}{12}ML^2\right)w^2 \iff 4Mg\left(\frac{3}{4}L\right)(1-\cos\theta) = \frac{17}{12}ML^2w^2$$

$$\frac{36g(1-\cos\theta)}{17L} = w^2$$

$$w = \sqrt{\frac{36g(1-\cos\theta)}{17L}}$$

5 a) (i) Ideal gas equation: $PV = nRT$

$$9.05\times10^{-13}(1.01\times10^{5})(1.05\times10^{-6}) = \frac{N}{N_a}8.314(295)$$

$N = 2.36\times10^{7}$ molecules

(ii) Average kinetic energy: (1 molecule)

$$KE = \frac{3}{2}K_B T = \frac{3}{2}(1.38\times10^{-23})(295) = 6.11\times10^{-21}\ \text{J}$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH 1011	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics	
Year / Semester : 1 / 1	

5 a) (iii) Internal energy : $U = \frac{5}{2} N k_B T = \frac{5}{2}(236\times10^{7})(1.38\times10^{-23})(295)$

$= 2.4\times10^{-13}$ J

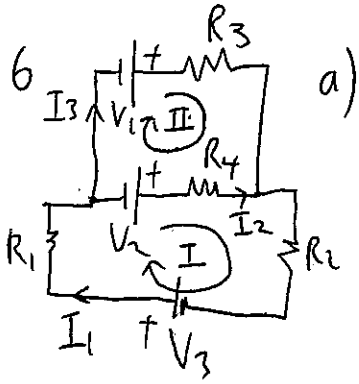
b) (i) $R = c_p - c_v$ (for ideal gas)

(ii)

	Work done by the gas (kJ)	Heat Supplied to the gas (kJ)	Change in Internal energy (kJ)
Process ab constant volume	$W = 0$	$Q = nc_v(T_b - T_a)$ $= 9(\frac{5}{2})(8.314)(300) = 56$	$\Delta U = Q$ $= 56$
Process bc adiabatic	$W = -nc_v(T_c - T_b)$ $= -9(\frac{5}{2})(8.314)(-108) = 20.2$	$Q = 0$	$\Delta U = -W$ $= -20.2$
Process ca Constant pressure	$W = nR(T_a - T_c)$ $= 9(8.314)(-192)$ $= -14.4$	$Q = nc_p(T_a - T_c)$ $= 9(\frac{7}{2})(8.314)(-192)$ $= -50.4$	$\Delta U = Q - W$ $= -50.4 + 14.4$ $= -36$

(iii) $\eta = \frac{W_{net}}{Q_{input}} = \frac{20.2 - 14.4}{56} \times 100\% = 10.4\%$

6 a)



Kirchoff rule 1 :

$I_1 = I_2 + I_3 \iff 0 = -I_1 + I_2 + I_3$ (1)

Kirchoff rule 2 :

Loop 1 :

$V_3 + V_2 - I_2R_4 - I_1R_2 - I_1R_1 = 0$

$5 = 3I_1 + 4I_2$ (2)

Loop 2: $V_1 - I_3R_3 + I_2R_4 - V_2 = 0$

$-1 = 3I_3 - 4I_2$ (3)

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH 1011	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics	
Year / Semester : 1 / 1	

6 a) Cont'd By solving (1), (2), (3), we get $I_3 = 0.39$ A

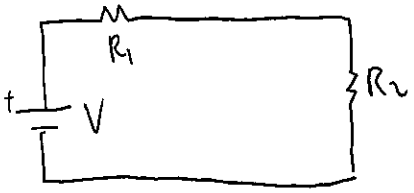
b)(i) When switch S is just closed:

The capacitor can act as a wire. Hence, there is no current passing R_2.

The current passing R_1: $I = \frac{V}{R_1} = \frac{15}{10} = 1.5$ A

(ii) When switch S is closed for a long time:

There is no current (charge) passing the capacitor. Hence, we can redraw the circuit as below:

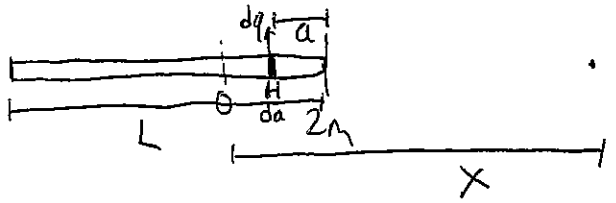


$$I = \frac{V}{R_1 + R_2} = \frac{15}{10+20} = 0.5\text{ A}$$

$$V \text{ at } C_3 = V \text{ at } R_2 = IR_2 = 0.5(20) = 10\text{ V}$$

Energy stored at $C_3 = \frac{1}{2}C_3V^2 = \frac{1}{2}(3\times10^{-6})(100) = 1.5\times10^{-4}$ J

7 a)(i)



$$dV = K\frac{dq}{r} = \frac{1}{4\pi\varepsilon_0}\frac{\lambda\, da}{x-2\pi a}$$

$$V = \int dV$$

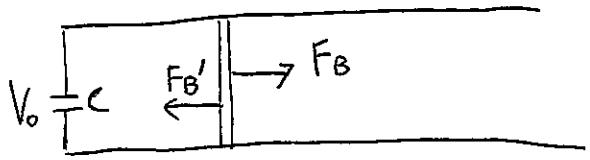
$$= \int_0^L \frac{1}{4\pi\varepsilon_0}\frac{\lambda}{x-2\pi a}\,da$$

$$= \frac{\lambda}{4\pi\varepsilon_0}\ln\frac{x-2\pi L}{x-2}$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH 1011	Suggested Solution Brought to You by Materials Science and Engineering Club
Subject Name : Physics	
Year / Semester : 1 / 1	

8



Newton 2nd law:

$$\Sigma F = ma$$

$$F_B - F_B' = ma$$

$$BIL - BI'L = m\frac{dv}{dt}$$

$$I = I_0 e^{-\frac{t}{RC}} = \frac{V_0}{R} e^{-\frac{t}{RC}}$$

$$I' = \frac{\varepsilon_{induced}}{R} = \frac{BvL}{R}$$

Since we want to find maximum velocity, then $\frac{dv}{dt} = 0$

$$BIL = BI'L$$

$$I = I'$$

$$\frac{V_0}{R} e^{-\frac{t}{RC}} = \frac{BvL}{R} \iff e^{-\frac{t}{RC}} = \frac{BvL}{V_0} \quad (1)$$

Conservation of Energy:

$$\frac{1}{2}CV_0^2 = \frac{1}{2}mv^2 + \frac{1}{2}CV^2$$

$$C(V_0^2 - V^2) = mv^2$$

$$CV_0^2\left(1 - e^{-\frac{2t}{RC}}\right) = mv^2 \quad (2)$$

Substitute (1) to (2):

$$\frac{CV_0^2\left(1 - \frac{B^2v^2L^2}{V_0^2}\right)}{m} = v^2$$

$$v_{max} = \sqrt{\frac{CV_0^2 - CB^2v^2L^2}{m}}$$

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

Subject Code : PH 1011	**Suggested Solution Brought to You by Materials Science and Engineering Club**
Subject Name : Physics	
Year / Semester : 1 / 1	

7 a) (ii) Conservation of Energy (CoE):

$$U = U' + KE'$$

$$qV = qV' + KE'$$

$$q(V - V') = \frac{1}{2}mv^2$$

$$q\left(\frac{\lambda}{4\pi\varepsilon_0}\left(\ln\frac{x-2+L}{x-2} - \ln\frac{x'-2+L}{x'-2}\right)\right) = \frac{1}{2}mv^2$$

$$4\times10^{-6}\left(\frac{3\times10^{-6}}{4\pi\varepsilon_0}\left(\ln\frac{5-2+100}{5-2} - \ln\frac{12-2+100}{12-2}\right)\right) = \frac{1}{2}(1.5)v^2$$

$$v = 0.404 \text{ m/s}$$

7 b) Student 1 is correct

Student 2 is wrong. There is no charge enclosed so the "total electric flux" is zero. However, the E-field in a particular plane of the Gaussian surface itself is not zero

"This suggested solution was done by a student with grade A or above.
MSE Club specifically disclaims any responsibility for any errors in the answers given. Caveat lector"

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER I EXAMINATION 2018-2019

PH1011 - Physics

November 2018 Time Allowed: 2.5 HOURS

SEAT NUMBER: | | | | | |

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

INSTRUCTIONS TO CANDIDATES

1. This question and answer booklet contains **EIGHT (8)** questions and comprises of **SEVENTEEN (17)** printed pages.

2. Answer **ALL EIGHT (8)** questions. All workings must be clearly shown.

3. Total 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 (10)	2 (15)	3 (10)	4 (15)	5 (15)	6 (15)	7 (10)	8 (10)	Total (100)
Marks									

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

/10

Q1 (10 marks)

A block of mass $m = 0.5$ kg sits on the top of a large plate with mass $M = 1.5$ kg as shown in Figure 1. The contact surface of the plate and the ground is frictionless and the coefficients of the static and kinetic friction between m and M are $\mu_s = 0.9$ and $\mu_k = 0.5$, respectively. The system is originally at rest and now an external force $F(t) = 2t$ N (where t is time in seconds) is used to pull the block. Until the block starts to slide, after which F is maintained at the value in part (a). We also assume that the plate is long enough that the block does not fall off the plate.

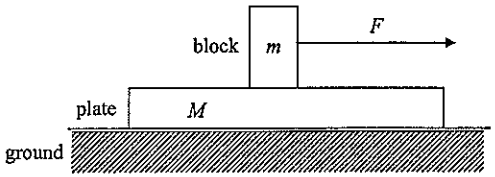


Figure 1

(a) Calculate the external force F at the moment just before the block starts to slide on the plate.

ANS: _____

(b) Calculate how far the plate will travel relative to the ground 1 s after the block slips.

Note: Question 1 continues on page 3

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

ANS: _____

(c) Calculate how far the block will travel relative to the ground 1 s after the block slips.

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

/15

Q2 (15 marks)

Ground-based air defence systems play an important part in ensuring the safety and security against any possible attacks from the air. For example, a few of such systems were deployed during the Trump-Kim summit held in Singapore on 12 June this year.

As shown in Figure 2(a), a particular air defence system consists of an interceptor missile that can be launched from a Mobile Firing Unit (MFU). Actual systems will require very precise engineering involving interceptor missiles that can lock on targets but here, we will only deal with very simplified analysis. We assume that the interceptor missile can be programmed to fly in a straight line at a constant speed of $v_I = 1360$ m/s for up to 15.0 km for the given altitudes. In your calculations, you can ignore the effects of air resistance and the height of the MFU.

(a) A hostile aircraft is flying at a constant speed of $v_H = 580$ m/s at a constant height of 6.0 km in the direction of the MFU. If the hostile aircraft is to be hit by the interceptor missile at 15.0 km from the MFU as shown in Figure 1(a), determine the horizontal distance x_1 of the aircraft to the MFU when the interceptor missile has to be launched and the angle θ that it has to be launched.

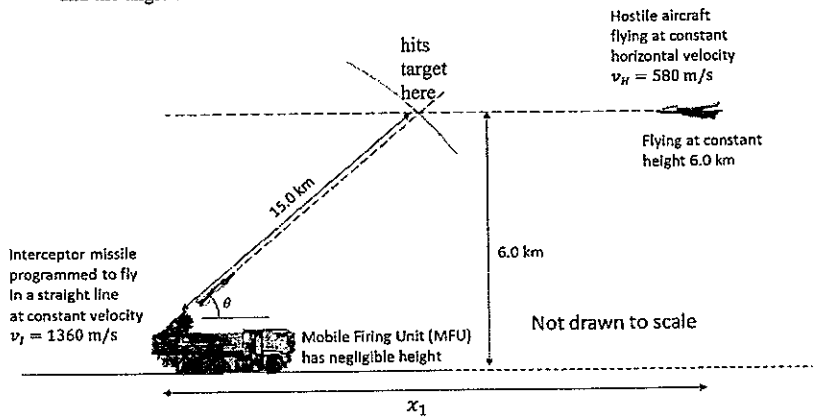


Figure 2(a)

ANS: _____

ANS: _____

Note: Question 2 continues on page 5

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(b) As shown in Figure 2(b), a shell (projectile) is fired by a big artillery gun from an unknown location of horizontal distance x_2 from the MFU. The shell is observed to have a maximum height of 18.4 km. The shell was successfully intercepted at 15.0 km away, at a height of 7.1 km. The velocity of the shell when it is hit is given as $\vec{v}_S = (-250\,\hat{\imath} - 470\,\hat{\jmath})$ m/s. Determine x_2.

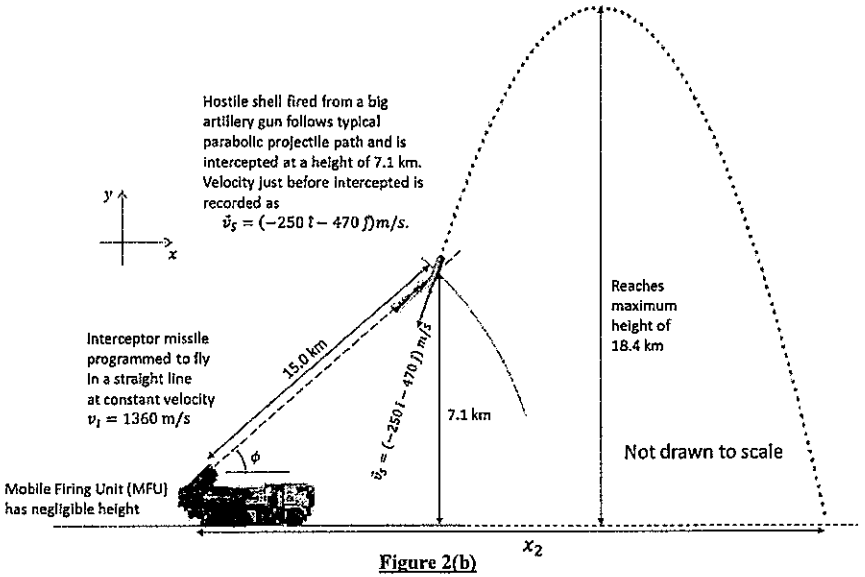


Figure 2(b)

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

/10

Q3 (10 marks)

(a) A cannon is rigidly attached to a carriage, which can move along horizontal rails, but is connected to a post by a large spring, initially unstretched and with force constant. $k = 2 \times 10^4$ N/m, as shown in Figure 3(a). The cannon fires a 200 kg projectile at a velocity of 125 m/s directed 45.0° above the horizontal.

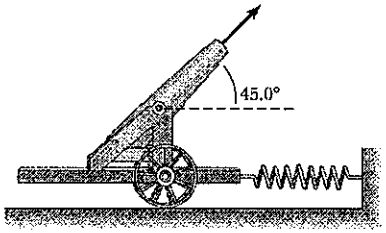


Figure 3(a)

i) If the mass of the cannon and its carriage is 5000 kg, find the recoil speed of the cannon.

ANS: _____

ii) Determine the maximum extension of the spring.

ANS: _____

Note: Question 3 continues on page 7

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

iii) Find the maximum force the spring exerts on the carriage.

ANS: _____

(b) A binary system consists of two stars of equal mass that revolve in a circular orbit about their centre-of-mass midway between them as shown in Figure 3(b). Assume the orbital speed of each star is $|\vec{v}| = 220$ km/s and the orbital period of each star is 14.4 days. Find the mass M of each star.

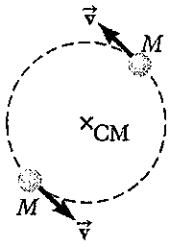


Figure 3(b)

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

/15

Q4 (15 marks)

(a) Two masses, $m_A = 35$ kg and $m_B = 38$ kg, are connected by a rope that hangs over a pulley as shown in Figure 4(a). The pulley is a uniform cylinder of radius 0.381 m and mass 3.1 kg. Initially m_A is on the ground and m_B rests 2.5 m above the ground. If the system is released , determine the speed of m_B just before it hits the ground. Assume the pulley is frictionless and string does not slip on the cylinder.

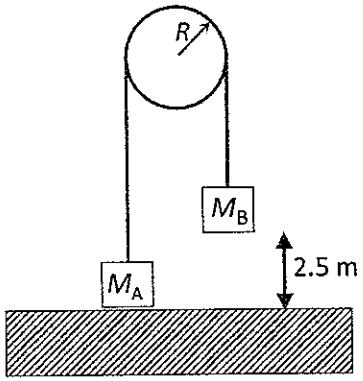


Figure 4(a)

ANS: _____

Note: Question 4 continues on page 9

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(b) A thin, hollow spherical shell of mass M and radius R, rotates about a vertical axis on frictionless bearings. A light cord passes around the equator of the shell, over a pulley, and is attached to a small object of mass m, as shown in Figure 4(b). The moment of inertia of the pulley is I and its radius is r. The moment of inertia of the spherical shell about the axis passing through its centre is $\frac{2}{3}MR^2$. The cord does not slip on the pulley or spherical shell.

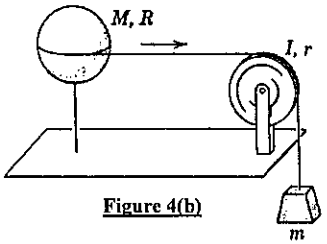


Figure 4(b)

The system is released from rest. The object's linear acceleration is a and the angular acceleration of the pulley is α_p and the angular acceleration of the spherical shell is α_s. Derive expressions for the linear and angular accelerations, a, α_p and α_s, in terms of the given parameters m, M, r, R, I and g.

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

/15

Q5 (15 marks)

A so-called *air-standard diesel* cycle is shown in Figure 5 which is made up of two adiabatic processes, an isobaric process and an isochoric process. Assume 6 moles of an ideal diatomic gas undergoes this cycle, and the values $V_1 = 0.3\ \text{m}^3$, $V_2 = 0.1\ \text{m}^3$, $V_C = 0.2\ \text{m}^3$ and $P_A = 1.00$ atm.

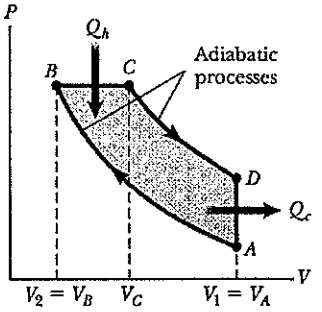


Figure 5

(a) Show that the pressure of the gas at B is $P_B = 4.66$ atm.

(b) Show that the pressure of the gas at D is $P_D = 2.64$ atm.

Note: Question 5 continues on page 11

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(c) Fill in the blanks for each of the quantities in each process. Include the calculations in that cell.

	Work done by the gas (J)	Heat supplied to the gas (J)	Change in internal energy of the gas (J)
Process *AB*			
Process *BC*			
Process *CD*			
Process *DA*			

(d) Calculate the efficiency of this engine.

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

/15

Q6 (15 marks)

Figure 6(a) shows a circuit where $V_1, V_2, V_3, V_4 = 1\text{ V}, 2\text{ V}, 3\text{ V}, 4\text{ V}$ 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_6.

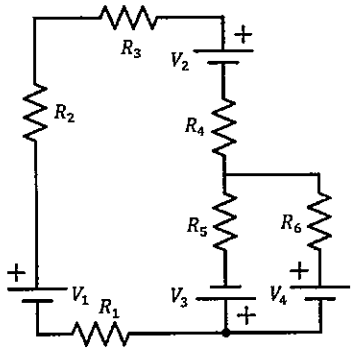


Figure 6(a)

Current through resistor R_6: _____

Note: Question 6 continues on page 13

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(b) Consider a RC circuit in Figure 6(b) with $V = 15$ V, $R_1 = 10\ \Omega$ and $R_2 = 20\ \Omega$. The capacitors have capacitances $C_1 = 1\ \mu$F and $C_2 = 2\ \mu$F and are initially uncharged.

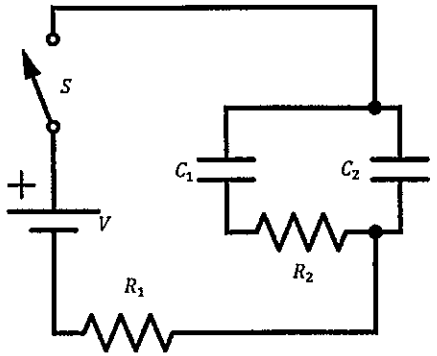


Figure 6(b)

(i) Immediately after switch S is closed, find the current passing through R_1.

ANS:_____

(ii) After the capacitors are fully charged, C_2 is first removed from the circuit and the battery is replaced with a wire (switch S remains closed). Calculate the time it takes for the potential difference of C_1 to become 2 V.

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

/10

Q7 (10 marks)

(a) A uniformly charged insulating rod of length 14.0 cm is bent into the shape of a semicircle as shown in Figure 7(a). The rod has a total charge of $-7.50\ \mu$C. Find the magnitude and direction of the electric field at O, the centre of the semicircle.

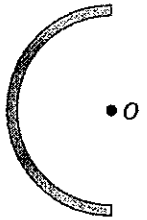


Figure 7(a)

ANS: _____

Note: Question 7 continues on page 15

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(b) Consider the magnetic field created by a toroid as shown in Figure 7(b).

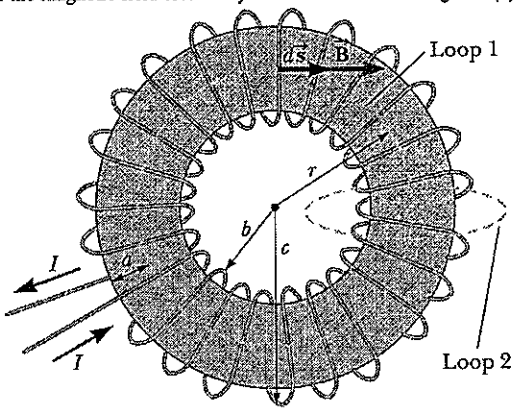


Figure 7(b)

If an Amperian loop of $r < b$ (in the plane of the toroid) is chosen, state the values of the LHS and RHS of Ampere's law separately and give a brief explanation why you give the values of the LHS and RHS as such. (Hint: think about if there is magnetic field in the plane of the toroid for $r < b$ and $r > c$.)

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

/10

Q8 (10 marks)

(a) Shown in Figure 8(a) is a simple device for measuring the magnitude B of a magnetic field, a uniform conducting rod (length $d = 1.0$ m, mass $m = 150$ g) hangs from a friction-free pivot and is oriented so that its axis of rotation is aligned with the direction of the magnetic field to be measured. Thin flexible wires (which exert negligible force on the rod) carry a current $I = 12$ A, which causes the rod to deflect an angle θ with respect to the vertical, where it remains at rest.

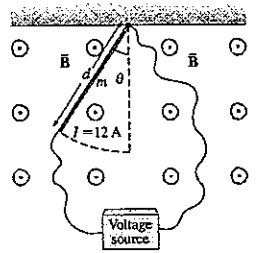


Figure 8(a)

(i) If $\theta = 22°$, determine B.

ANS: _____

(ii) What is the largest magnetic field magnitude that can be measured using this device?

ANS: _____

Note: Question 8 continues on page 17

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(b) Two parallel rails with negligible resistance are 10.0 cm apart and are connected by a resistor of resistance $R_3 = 5.00\ \Omega$. The circuit also contains two metal rods having resistances of $R_1 = 10.0\ \Omega$ and $R_2 = 15.0\ \Omega$ sliding along the rails (Figure 8(b)). The rods are pulled to the right at constant speeds of $v_1 = 4.00$ m/s and $v_2 = 2.00$ m/s, respectively. A uniform magnetic field of magnitude $B = 0.0100$ T is applied perpendicular to the plane of the rails. Determine the current in R_3.

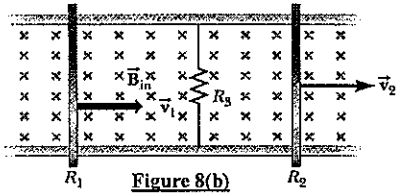


Figure 8(b)

ANS: _____

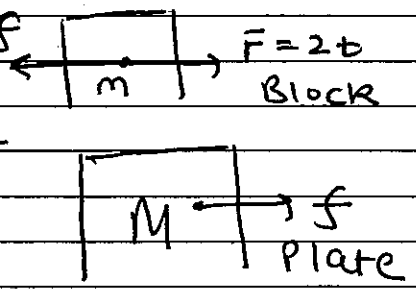
----- End of Paper -----

PH-1011 18-19 SEM-1

Q.1 • first thing to note is that both blocks will start moving immediately with the same acceleration.

• Friction opposes sliding, if both blocks move with same accn, friction is considered static.

Free body diagrams –



$2t - f = 0.5a$ – (1) $f = 1.5a$ – (2)

Solving 1, 2 : $\boxed{a = t}$ – (A)

Maximum possible accn of plate $= \frac{f_{max}}{M} = \frac{\mu mg}{M}$

$= 2.94 m/s^2$ – (B)

Compare (A) and (B), After 2.94 seconds both blocks won't be able to move with same accn since the maximum accn of plate is $2.94 m/s^2$

a) At $t = 2.94s$, plate starts sliding

$f = 2t = 5.88N$

This ques is tricky. Equating $\boxed{2t = \mu mg}$ will give the WRONG ANSWER.

b) Once blocks start sliding, μ_s becomes μ_K (Kinetic friction)

Acceleration of block $= \frac{5.88 - (0.5 \times m \times g)}{0.5}$

f becomes constant $= 2.855 m/s^2$

Acceleration of plate $= \frac{0.5 \times 0.5 \times g}{1.5}$

$= 1.6333 m/s^2$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

☆Before sliding begins, both block and plate have same acceleration and velocity.

$a = t \Rightarrow \frac{dv}{dt} = t \Rightarrow \int_0^V dv = \int_0^{2.94} t\,dt$

$v = \left[\frac{t^2}{2}\right]_0^{2.94} = 4.3218 \text{ m/s}$

This v is the initial velocity when plate starts sliding.

$S_2 = ut + \frac{1}{2}at^2$ [For plate]

$= 4.3218 \times 1 + \frac{1}{2} \times 1.6333 \times (1)^2 = 5.138 \text{ m}$

S_1 = Distance travelled before plate and block start sliding.

Before they start sliding together

$v = \frac{dx}{dt} = \frac{t^2}{2} \Rightarrow \int_0^{S_2} dx = \int_0^{2.94} \frac{t^2}{2} dt$

$S_1 = \left[\frac{t^3}{6}\right]_0^{2.94} = 4.235 \text{ m}$

$\boxed{S_{TOT} = S_1 + S_2 = 9.373 \text{ m}}$

c) Distance travelled by block

$= S_1 + S_2$ [S_1 = same as part b]

$S_2 = 4.3218 \times 1 + \frac{1}{2} \times [\text{[illegible]} + 2.855] \times (1)^2$

[block acen relative to plate = 2.855 m/s²
plate acen relative to gnd = 1.6333 m/s²
block acen relative to gnd = 1.6333 + 2.855]

$S_2 = \text{[illegible]}\ 5.7493 \text{ m}$

$\boxed{\text{[illegible]}}$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2lW2C32

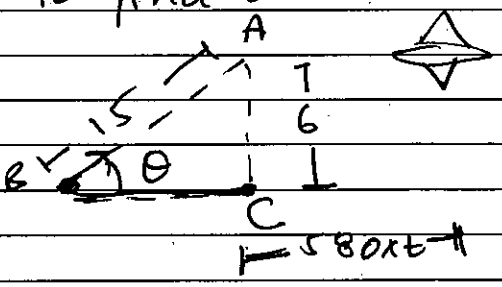
$S_{TOTAL} = S_1 + S_2$

$= 4.235 + 5.7493$

$= 19.984m$

* This was probably the toughest ques in the paper

Q.2 a) Use trigonometry to find θ



$AB = 15 \quad AC = 6$

$\sin\theta = \frac{6}{15} \quad \cos\theta = \frac{\sqrt{189}}{15}$

$\theta = \sin^{-1}\left(\frac{6}{15}\right) = 23.57°$

- Time taken by missile to reach 6000m

$t = \frac{6000}{1360\sin\theta}$ [$1360\sin\theta$ = Vertical velocity]

- Distance travelled by aircraft in same time $= 580 \times t = \frac{580 \times 6000}{1360\sin\theta}$

- Horizontal distance travelled by missile $= 15000\cos\theta = BC$

$x_1 = BC + 580 \times t$

$= 15000 \times \frac{\sqrt{189}}{15} + \frac{580 \times 6000 \times 15}{1360 \times 6}$

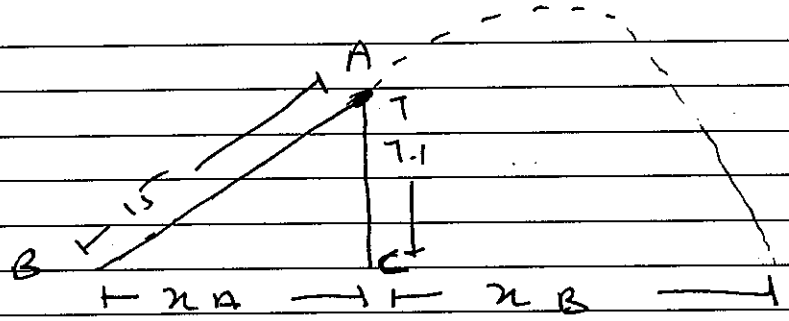
$= 13747 + 6397$

$= 20.144km$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

6)



$x_2 = x_A + x_B$

$x_A = \sqrt{15^2 - 7.1^2}$ km (Pythagoras)

$= 13.213$km

$\vec{V_S} = -250\hat{i} - 470\hat{j}$ [Given]

Horizontal velocity remains constant.

Thus $u_H = -250$m/s

- Let vertical launch velocity be u_V
- Max Height $= \frac{u_V^2}{2g} = 18400 \Rightarrow u_V = 600.83$m/s

- Vertical velocity just before impact $= -470$ m/s

Time taken, $-470 = 600.83 - 9.81t$

$\boxed{t = 109.155}$

- $x_B = 250 \times t = 27.2875$km

$x_2 = x_A + x_B$

$= 40.5$km

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

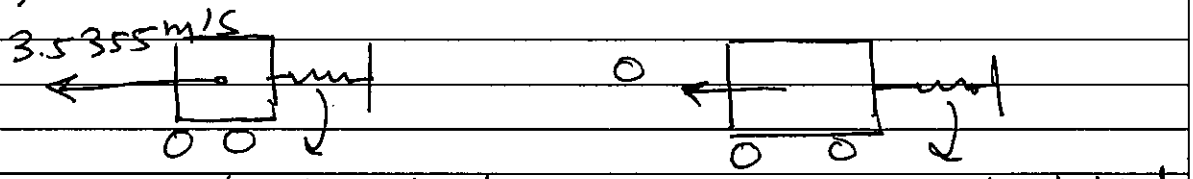
Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2lW2C32

Q.3 a) Momentum is conserved horizontally.

$5000 \times V_{RECOIL} = 200 \times 125 \times \cos 45°$

$V_{RECOIL} = 3.5355 \text{ m/s}$

b) INITIAL FINAL



Energy $= \frac{1}{2}mv^2$ Energy $= \frac{1}{2}kx^2$

Conserving energy

$\frac{1}{2}mv^2 = \frac{1}{2}kx^2 \Rightarrow x = \sqrt{\frac{2m}{k}} \times v$

$\boxed{x = 1.76775 \text{ m}}$

c) Max force $= kx_{max}$

$= 2 \times 10^4 \times 1.76775 \text{ N}$

$= \boxed{35.355 \text{ kN}}$

Q.3 b) Speed of star, $v = 220 \times 10^3 \text{ m/s}$

Orbital period $= \frac{2\pi r}{v} = 14.4 \times 86400 \text{ sec}$ — (1)

- The mutual gravitational force b/w stars provides the required centripetal force.

PTO

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

$$\frac{G(M)^2}{(2R)^2} = \frac{M \times v^2}{R}$$

$$\Rightarrow M = \frac{4R \times v^2}{G} = \frac{(2 \times v \times 14.4 \times 86400) \times v^2}{\pi \quad\quad\quad\quad\quad\quad G}$$

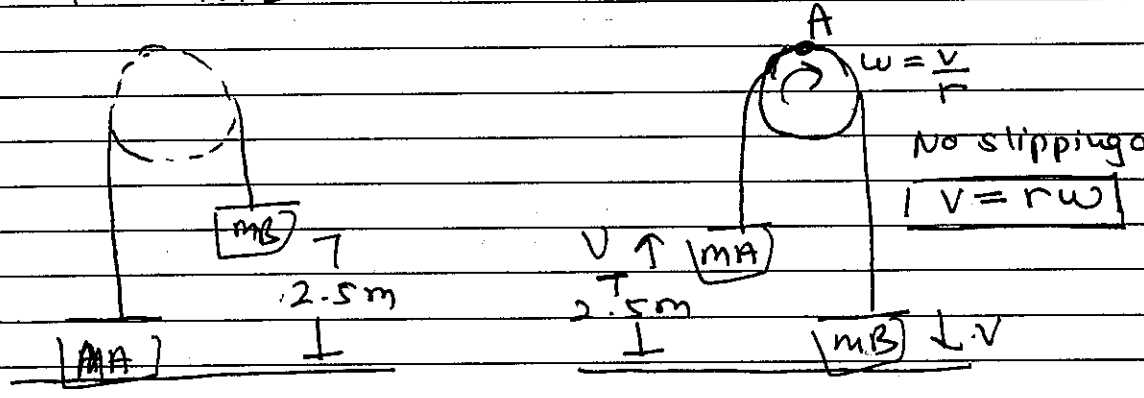
[Using Eqn 1]

$$M = \frac{28.8 \times 86400 \times (220 \times 10^3)^3}{6.67 \times 10^{-11} \times \pi}$$

$$M = 126.43 \times 10^{30} \text{ kg}$$

Q.4 a) Since the length of string is constant, velocity of $M_A = M_B$.

INITIAL = FINAL



Initial Energy $= m_B \times g \times 2.5$

Final Energy $= m_A \times g \times 2.5 + \frac{1}{2} \times (m_A + m_B) \times v^2 + \frac{1}{2} \times (I_p) \times \omega^2$

m_p = mass of pulley = 3.1 kg

I_p = Inertia of pulley about centre = $\frac{mR^2}{2}$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

Conserving Energy

$$m_B \times g \times 2.5 = m_A \times g \times 2.5 + \frac{1}{2}(m_A + m_B) \times v^2 + \frac{1}{2} \times mR^2 \times \frac{v^2}{R^2}$$

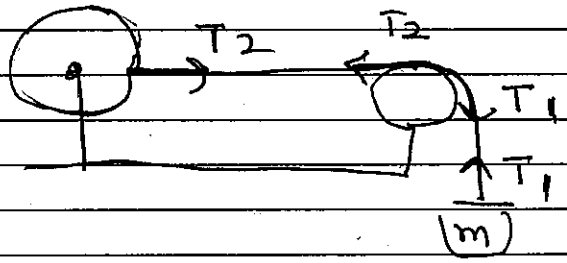
Simplifying,

$$\left[\frac{2(m_B - m_A)g \times 2.5}{m_A + m_B + \frac{m_p}{2}}\right] = v^2 \Rightarrow \boxed{v = 1.4049 \text{ m/s}}$$

x —— x —— x —— x ——

46) since the cord does not slip on pulley or shell

$$\boxed{R\alpha_s = r\alpha_p = a} \quad -(A)$$



Looking at diagram and writing eqns

$$mg - T_1 = ma \quad -(1)$$

$$(T_1 - T_2)r = I\alpha_p \Rightarrow T_1 - T_2 = \frac{I\alpha_p}{r} \quad -(2)$$

$$T_2 R = \frac{2}{3}MR^2 \alpha_s \Rightarrow T_2 = \frac{2}{3}MR\alpha_s \quad -(3)$$

(1) + (2) + (3)

$$mg = ma + \frac{I\alpha_p}{r} + \frac{2}{3}MR\alpha_s$$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

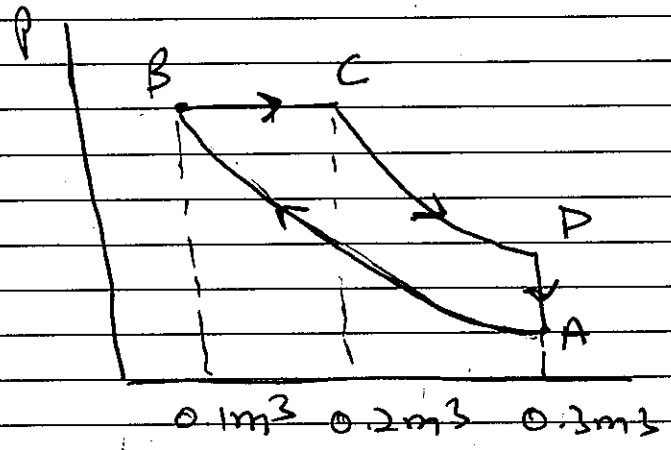
Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

$$mg = ma + \frac{Ia}{r^2} + \frac{2}{3}Ma$$

$$mg = a\left(m + \frac{I}{r^2} + \frac{2}{3}M\right)$$

Ans $a = \dfrac{mg}{\left(m + \frac{I}{r^2} + \frac{2}{3}M\right)}$ Use eqn (A) to derive other relations

Q.5



a) AB is an adiabatic process

$P_A \times V_A^{\gamma} = P_B \times V_B^{\gamma}$ [$\gamma = 1.4$ (Diatomic)]

$P_B = 4.66$ atm

b) $P_b = P_c$ [Isbaric process BC]

CD is an adiabatic process

$P_C \times V_C^{\gamma} = P_D \times V_D^{\gamma} \Rightarrow P_D = 2.64$ atm

- Process AB: Adiabatic

$Q = 0$ [Adiabatic]

$$W = \frac{(P_B V_B - P_A V_A)}{1-\gamma} = \frac{[4.66 \times 0.1 - 0.3 \times 1] \times 101325}{1-1.4}$$

$= -42.04$ kJ

→ Remember to convert atm to kPa

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2lW2C32

for adiabatic, $Q=0 \Rightarrow \Delta U = -W$

Thus, $\Delta U = +42.049\,kJ$

- Process BC: Isobaric

$$W = P(V_C - V_B) = 4.66 \times 101325 \times 0.1$$
$$= 47.217\,kJ$$

$$\Delta U = nC_V(T_C - T_B) = nC_V\left[\frac{P_C V_C}{nR} - \frac{P_B V_B}{nR}\right]$$

[Using ideal Gas Law]

$C_V = \frac{5R}{2} \Rightarrow \Delta U = \frac{n \times 5R}{2 \times nR}[P_C V_C - P_B V_B]$

$$= +118.04\,kJ$$

$$Q = \Delta U + W = 118.04 + 47.217 = 165.261\,kJ$$

- Process CD: Adiabatic

$Q = 0$

$$W = \frac{(P_D V_D - P_C V_C)}{1-\gamma} = \left(\frac{2.64}{-0.4} \times 0.3 - \frac{4.66}{-0.4} \times 0.2\right) \times 101325\,J =$$

$$= 35.463\,kJ$$

$\Delta U = -W = -35.463\,kJ$

- For DA: Isochoric

$W = 0$, $Q = \Delta U$

$$\Delta U = nC_V \Delta T = \frac{5}{2}[P_A V_A - P_D V_D]$$

$$= -124.629\,kJ$$

$Q = -124.629\,kJ$

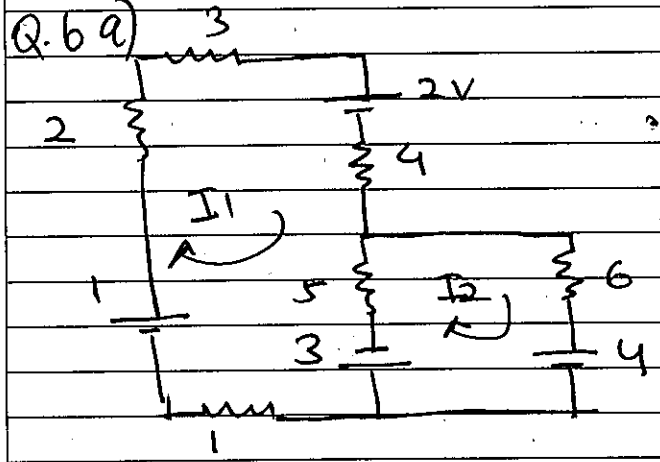
DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

d) Efficiency $= \frac{W_{net}}{Q_{in}} = \frac{47.218 + 35.463 - 42.049}{165.261}$

$= 24.56\%$

Q.69)



- I_1 in loop 1
- I_2 in loop 2
- Apply KVL for both loops and solve.

Loop 1

$(-1)I_1 + 1 - (5)I_1 - 2 - (4)I_1 - 5(I_1 - I_2) + 3 = 0$

$-15I_1 + 5I_2 + 2 = 0 \quad -(1)$

Loop 2

$-3 - 5(I_2 - I_1) - 6I_2 - 4 = 0$

$-11I_2 + 5I_1 - 7 = 0 \quad -(2)$

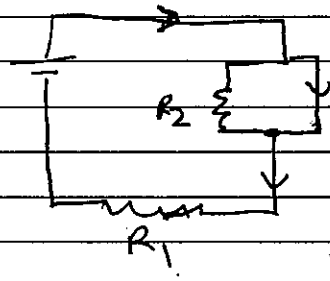
Solve for I_2 to get $\boxed{I_2 = -\frac{19}{28}\ A}$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

6b) Immediately after switch is closed, capacitors act as components with 0 resistance.

Eqv ckt —

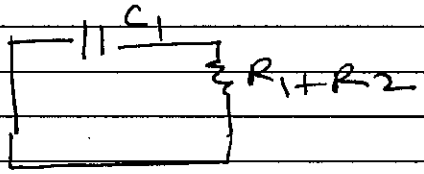


Current flows through the shown path

$I = \frac{V}{R_1} = 1.5A$

* When the capacitors are fully charged, both will have a potential of 15V across them since they are in parallel.

Eqv ckt after C_2 is removed



The discharging eqn for capacitor is given by

$V = 15e^{-t/RC}$ $R = 30$, $C = 10^{-6}$

When $V = 2V$

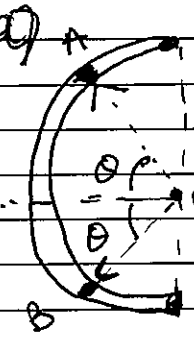
$$\frac{2}{15} = e^{-t/RC} \Rightarrow \log\frac{2}{15} = -\frac{t}{RC}$$

Ans. $t = -RC\log\frac{2}{15} = \boxed{6\ 0.447 \times 10^{-6}\ s}$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

Q.7 a)



Consider 2 pts A and B located symmetrically at angle θ. From observation, the vertical components of electric field of A and B cancel out (see arrows in figure).

Thus, only horizontal components need to added. Consider an element of width dr located at angle θ.

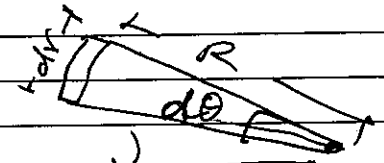
Electric field due to this element

$$\vec{dE} = \frac{K\,dq}{R^2}, \quad dQ = \left(\frac{Q}{\pi R}\right) d\theta$$

$$\vec{dE}_{HORIZONTAL} = \frac{K\,dq}{R^2}\cos\theta$$ [Vertical components get cancelled]

$$\vec{dE_H} = \frac{K Q\,dr}{\pi R^3}\cos\theta \quad -(2)$$

Now, $|dr = R\,d\theta|$ —(1)



$|dr = R\,d\theta|$

Using (1), (2)

$$\vec{dE_H} = \frac{KQ}{\pi r^2}\cos\theta\,d\theta$$

$$\vec{E} = \int_{-\pi/2}^{+\pi/2} \frac{KQ}{\pi r^2}\cos\theta\,d\theta = \frac{KQ}{\pi R^2}\int_{-\pi/2}^{+\pi/2}\cos\theta\,d\theta$$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

$= \frac{KQ}{\pi R^2}[\sin\theta]_{-\pi/2}^{+\pi/2} = \frac{2KQ}{\pi R^2} = \frac{2\times9\times10^9\times-7.5\times10^{-6}}{\pi\times(0.14)^2}$

$= -2.192\times10^6\ N/C\ \hat{i}$

Direction is towards left.

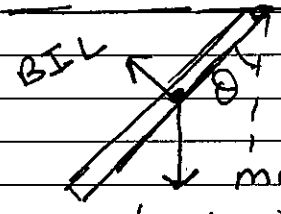
b) $\oint \vec{B}\cdot d\vec{L} = \mu_0 I_{enclosed}$ [Ampere's law]

$I_{enclosed} = 0$ for $r < b$

$\oint \vec{B}\cdot d\vec{L} = 0 \rightarrow \boxed{\vec{B} = 0}$

Magnetic field in toroid for $r < b$ is 0.

Q.8 a) consider the FBD at eqbm.



BIL is the force on wire $L = d$.

balance

We can ~~conserve~~ moment about the hinge point.

$(BId)\times\frac{d}{2} = mg\sin\theta\times\frac{d}{2}$

$\Rightarrow B = \left(\frac{mg\sin\theta}{Id}\right) = 0.0459\ T$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2IW2C32

6) $B = \frac{mg\sin\theta}{Id}$

Since I, d, m, g are constant, B will be largest when $\sin\theta$ is largest.

Thus when $\sin\theta = 1$

$B_{max} = \frac{mg(1)}{Id} = 0.1225\ T$

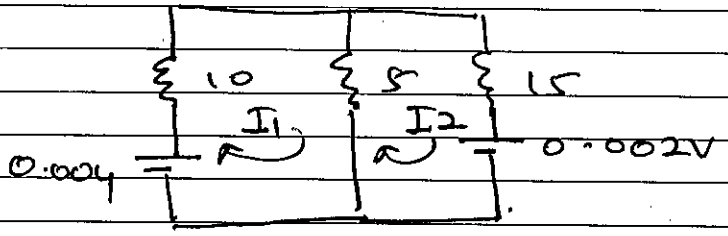
8b) emf in rod 1 $= V_1 BL$

$= \frac{4}{100} \times 1 \times 0.1 = 0.004\ V$

emf in rod 2 $= V_2 BL$

$= \frac{2}{100} \times 1 \times 0.1 = 0.002\ V$

Equivalent circuit becomes



Applying KVL to loop 1

$+0.004 - 10I_1 - 5(I_1 - I_2) = 0 \quad -(1)$

Applying KVL to loop 2

$-5(I_2 - I_1) - 15I_2 - 0.002 = 0 \quad -(2)$

→ Current through R_3 is $(I_2 - I_1)$ upwards.

→ Solve eqn 1, 2 to get the values.

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. MAE Club and Campus supplies are not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistake identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: http://bit.ly/2lW2C32

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER I EXAMINATION 2020-2021

PH1011 - Physics

November 2020 Time Allowed: 2 HOURS

SEAT NUMBER: | | | | | |

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

INSTRUCTIONS TO CANDIDATES

1. This question and answer booklet contains **EIGHT (8)** questions and comprises of **SIXTEEN (16)** printed pages.

2. Answer **ALL EIGHT (8)** questions. All workings must be clearly shown.

3. Total marks for each question are as indicated.

4. This is a **CLOSED BOOK** examination. A 2-page formula sheet is provided for your reference.

5. All your solutions must be written in this booklet within the space provided within each question.

6. This examination paper is NOT ALLOWED to be removed from the examination hall.

For examiners only:

Questions	1 (10)	2 (15)	3 (10)	4 (15)	5 (15)	6 (15)	7 (10)	8 (10)	Total (100)
Marks									

Q1 (10 marks) /10

A ball of mass M and radius r is thrown along a level surface so that initially ($t = 0$) it slides with a linear speed v but does not rotate as shown in Figure 1. As it slides, it begins to spin, and eventually rolls without slipping. The coefficients of static and kinetic friction are μ_s and μ_k respectively and the gravitational acceleration is g.

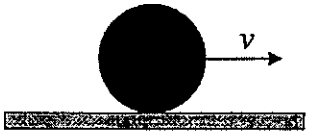


Figure 1

(a) Draw the free-body diagram of the ball as it is slipping.

(b) Write down the translational Newton's second law equation of the ball.

ANS: _____

(c) Write down the rotational Newton's second law of the ball about its centre-of-mass.

ANS: _____

Note: Question 1 continues on page 3

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(d) Derive an expression for the time it takes for the ball to begin rolling without slipping.

ANS: _____

/15

Q2 (15 marks)

A circular frictionless track of radius R is set vertically as shown in Figure 2. Inside the track, a point mass M is launched in the downward direction from a height of R with an initial speed v such that the mass is always in contact with the track throughout. The gravitational acceleration is g.

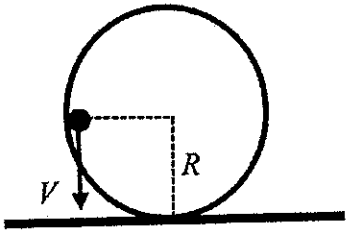


Figure 2

(a) Derive an expression for the minimum speed of the point mass at the top of the circular track.

ANS: _____

(b) Derive an expression for the minimum initial speed v for the point mass to complete the circular motion?

ANS: _____

Note: Question 2 continues on page 5

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(c) Derive an expression for the normal contact force of the point mass at the bottom of the track.

ANS: _____

Q3 (10 marks) /10

As shown in Figure 3, a spring of spring constant k is placed horizontally on the floor. One end of the spring is attached to a solid block of mass M and the other end of the spring is compressed by a sphere of mass m by a distance d. Neglect all the friction and neglect the mass of the spring as well as the mass of the plate between the sphere and the spring.

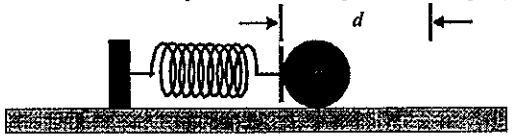


Figure 3

(a) The block is fixed on the floor. Derive an expression for the speed of the sphere when it is at a distance d from the initial position.

ANS: _____

(b) The block is now free to move, derive an expression for the speed of the sphere relative to the floor after it loses the contact with the spring.

ANS: _____

Note: Question 3 continues on page 7

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(c) The block is still free to move. Derive an expression for the distance the block travels when the sphere just loses the contact with the spring.

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

Q4 (15 marks) /15

(a) A large turntable with radius 6.00 m rotates about a fixed vertical axis, initially making one revolution in 8.00 s. The moment of inertia of the turntable about this axis is 1200 kg m^2. You stand, barefooted, at the rim of the turntable (rotating with the initial angular velocity of the turntable) and very slowly walk toward the center, along a radial line painted on the surface of the turntable. Your mass is 70.0 kg. Since the radius of the turntable is large, it is a good approximation to treat yourself as a point mass. Assume that you can maintain your balance by adjusting the positions of your feet. You find that you can reach a point 3.00 m from the center of the turntable before your feet begin to slip. What is the coefficient of static friction between the bottoms of your feet and the surface of the turntable?

ANS: _____

Note: Question 4 continues on page 9

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(b) A ball is thrown horizontally from the top of a cliff with initial speed u (at $t = 0$). At any moment, its direction of motion makes an angle θ to the horizontal. Derive an expression for θ as a function of time t, as the ball follows a projectile's path.

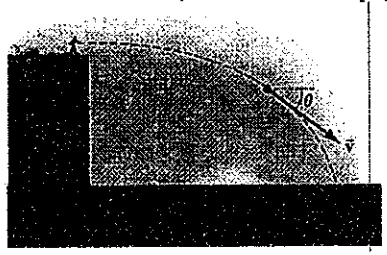


Figure 4(b)

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

Q5 (15 marks) /15

Consider 5 moles of a diatomic ideal gas undergoing the cycle ABCD shown in Figure 5. Process A to B is an isothermal expansion; process B to C is an adiabatic expansion; process C to D is an isobaric compression at 1 atm and process D to A is an isochoric process.
(Take 1 atm = 1.01×10^5 Pa)

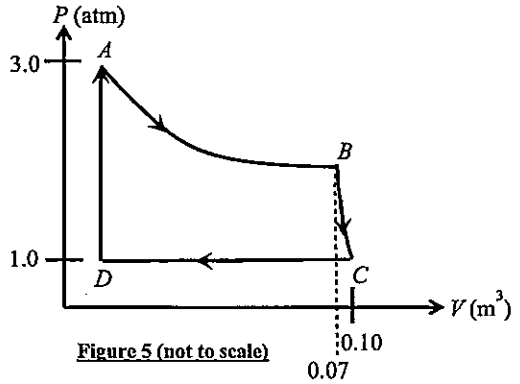


Figure 5 (not to scale)

(a) Show that the temperature of the gas at B is $T_B = 280.36$ K.

(b) Show that the volume of the gas at D is $V_D = 0.0384$ m^3.

Note: Question 5 continues on page 11

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(c) Fill in the blanks for each of the quantities in each process. Include the calculations in that cell.

	Work done by the gas (J)	Heat supplied to the gas (J)	Change in internal energy of the gas (J)
Process *AB*			
Process *BC*			
Process *CD*			
Process *DA*			

(d) Calculate the efficiency of this engine.

ANS: _____

/15

Q6 (15 marks)

(a) Figure 6(a) shows a circuit where $V_1, V_2, V_3, V_4 = 1\,\text{V}, 2\,\text{V}, 3\,\text{V}, 4\,\text{V}$ respectively and $R_1, R_2, R_3, R_4, R_5 = 1\,\Omega, 2\,\Omega, 3\,\Omega, 4\,\Omega, 5\,\Omega$ respectively. Calculate the rate of energy loss in cell V_2.

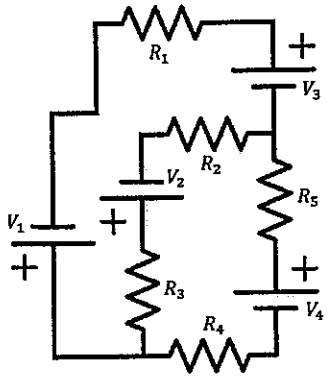


Figure 6(a)

ANS: _____

Note: Question 6 continues on page 13

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(b) Consider a RC circuit shown in Figure 6(b) with $V = 4$ V, $R_1 = 1000\,\Omega$, $R_2 = 2000\,\Omega$, $R_3 = 3000\,\Omega$ and $R_4 = 4000\,\Omega$. The capacitor has capacitance $C = 6\,\mu$F and the capacitor is initially uncharged.

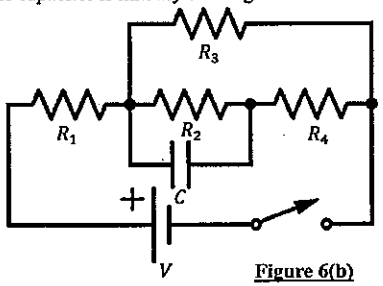


Figure 6(b)

(i) Immediately after the switch is closed, calculate the current passing through resistor R_4.

ANS:_____

(ii) After the circuit is closed for a long time, the switch is opened. Calculate the time it takes for the potential difference across the capacitor to be 30% of its fully charged potential difference.

ANS: _____

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

Q7 (10 marks) /10

(a) An insulating rod having linear charge density $\lambda = 40.0\,\mu$C/m and linear mass density $\mu = 0.100$ kg/m is released from rest on a frictionless surface in a uniform electric field $E = 100$ V/m directed perpendicular to the rod (see Figure 7(a)).

(i) Determine the speed of the rod after it has travelled 2.00 m.

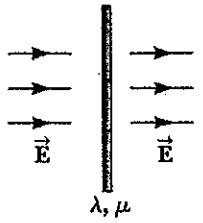


Figure 7(a)
(Top View)

ANS: _____

(ii) Will the speed from the previous part change if the rod is not perpendicular to the field? Give a brief explanation for your answer.

Note: Question 7 continues on page 15

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(b) Conceptual question: Consider 2 scenarios given in Figures 7(b) and 7(c) where we have two conducting spherical shells with a point charge $+Q$ inside.

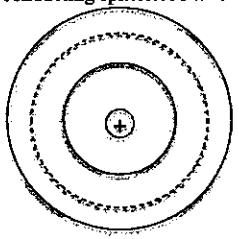


Figure 7(b)

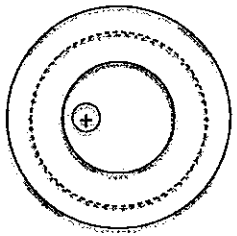


Figure 7(c)

In Figure 7(b), the point charge is in the centre of the conducting shell. We usually choose the spherical Gaussian surface shown as the dashed circle and we will say that "since $E = 0$ in the conducting shell, the total charge on the inner surface of the shell is $-Q$".

In Figure 7(c), the point charge is not in the centre of the conducting shell. Now, briefly explain whether the same conclusion can be made for Figure 7(c). Also, state one difference between the inner surfaces of the two shells.

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

Q8 (10 marks) /10

A long, straight wire of negligible resistance is bent into a V shape, its two arms making an angle α with each other, and placed horizontally in a vertical, homogenous magnetic field of strength B. A rod of total mass m, and resistance R per unit length, is placed on the V-shaped conductor, at a distance x_0 from its vertex A, and perpendicular to the bisector of the angle α (see Figure 8).

The rod started off with an initial velocity v_0 in the direction of the bisector, and away from A. The rod is long enough not to fall off the wire during the subsequent motion, and the electrical contact between the two is perfect while friction between them is negligible.

Show that the rod will stop at $x = \sqrt{x_0^2 + \frac{mv_0R}{B^2 \tan\frac{\alpha}{2}}}$.

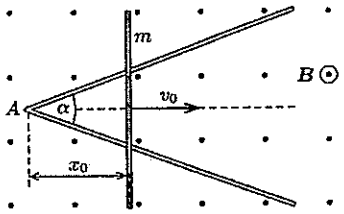
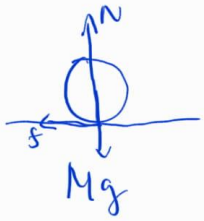


Figure 8
(Top View)

----- End of Paper -----

ATTENTION: The Singapore Copyright Act applies to the use of this document. Nanyang Technological University Library

(1) a)



b) $x: \Sigma F = -\mu_k . N = M . a_x$

$y: \Sigma F = N - Mg = M . a_y = 0 \rightarrow N = Mg$

c) $\Sigma \tau_{CM} = I_{cm} \alpha$

$\mu_k . N = \frac{2}{5} M r^2 \alpha$

d) CoE: $\frac{1}{2}mv^2 = \frac{1}{2}m(v_f)^2 + \frac{1}{2}I(\omega_f)^2$

$Mv^2 = M(v_f)^2 + \frac{1}{2}\cdot\frac{2}{5}M r^2 \left(\frac{v_f}{r}\right)^2$

$v^2 = v_f^2 + \frac{1}{5}v_f^2$

$v_f = v\sqrt{\frac{5}{6}}$

* friction work only converts translational to rotational

$-\mu_k . N = M . a_x$

$-\mu_k M g = M . a_x$

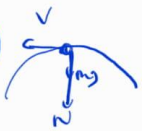
$v_f = u + at$

$u\sqrt{\frac{5}{6}} = u - \mu_k g t$

$t = \frac{u\left(1-\sqrt{\frac{5}{6}}\right)}{\mu_k . g}$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2lW2C32*

(2) a) 

$F_s = mg + N = \frac{mv^2}{R}$

minimum speed → when $N = 0$

$mg = \frac{mv_t^2}{R}$

$v_t = \sqrt{gR}$ //

b) COE: $mgR + \frac{1}{2}mv^2 = mg2R + \frac{1}{2}mv_t^2$

$\frac{1}{2}v^2 = gR + \frac{1}{2}(gR)$

$v^2 = 3gR$

$v = \sqrt{3gR}$

c) COE: $mgR + \frac{1}{2}mv^2 = \frac{1}{2}mv_b^2$ ×2

$2gR + 3gR = v_b^2$

$v_b = \sqrt{5gR}$

$F_s: N - mg = \frac{mv_b^2}{R}$

$N = \frac{m(5gR)}{R} + mg$

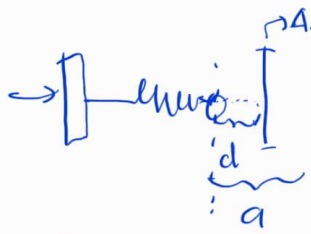
$= 6mg$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2lW2C32*

③ a) When it is at a distance a from the initial position:

Compression = d



Δx of spring when ball is a distance a from initial position = (a − d)

COE: $\frac{1}{2}kd^2 = \frac{1}{2}k(a-d)^2 + \frac{1}{2}mv^2$

$v^2 = \frac{k}{m}(d^2 - (a^2 - 2ad + d^2))$

$v = \sqrt{\frac{k}{m}a(2d-a)}$

b) COLM: $m.v_1 + M.v_2 = 0$

$v_2 = -\frac{m}{M}v_1$

COE: $\frac{1}{2}kd^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}Mv_2^2$

$kd^2 = mv_1^2 + M\frac{m^2}{M^2}v_1^2$

$kd^2 = mv_1^2\left(1 + \frac{m}{M}\right)$

$v_1^2 = \frac{kd^2}{m(1+\frac{m}{M})}$

$v_1 = d\sqrt{\frac{k}{m(1+\frac{m}{M})}}$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2lW2C32*

c) at every instant, COLM still applies. Therefore,

$V_2 = -\frac{m}{M} v_1$ still holds,

V_2 after sphere loses contact: $-\frac{md}{M}\sqrt{\frac{k}{m(1+\frac{m}{M})}}$

$$V_{2f} = -d\sqrt{\frac{k}{\frac{M^2}{m^2}m(1+\frac{m}{M})}}$$

$$V_{2f} = -d\sqrt{\frac{k}{M(1+\frac{M}{m})}}$$

$$\bar{F} = M.\bar{a_2}$$

t = time when sphere lose contact w/ spring

= time when the total displacement of sphere & block = d

$\Delta x = v_0 t + \frac{1}{2}\bar{a}t^2$

$\Delta x_1 = \frac{1}{2}\bar{a_1}t^2$

$\Delta x_2 = \frac{1}{2}\bar{a_2}t^2$

* Since $F_1 = -F_2$

$m\bar{a_1} = -M\bar{a_2}$

$\bar{a_1} = -\frac{M}{m}\bar{a_2}$

at time t:

$|\Delta x_1| + |\Delta x_2| = d$

$\frac{1}{2}\left(\frac{M}{m}\bar{a_2} + \bar{a_2}\right)t^2 = d$

$t = \sqrt{\frac{2d}{\bar{a_2}(\frac{M}{m}+1)}}$

$\bar{a_2} = \frac{v_{2f}}{t}$

$$-d\sqrt{\frac{k}{M(1+\frac{M}{m})}} = \bar{a_2}\sqrt{\frac{2d}{(1+\frac{M}{m})\bar{a_2}}}$$

$()^2$

$$\frac{d^2k}{M} = |\bar{a_2}|^2\frac{2d}{\bar{a_2}} \rightarrow \bar{a_2} = -\frac{kd}{2M}$$

↓ direction

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2lW2C32*

$$V_t^2 = V_0^2 + 2|\bar{a}_2|s$$

$$(V_{2f})^2 = 2\frac{kd}{2M}s$$

$$\frac{d^2k}{M(1+\frac{M}{m})} = \frac{kd}{M}s$$

$$s = \frac{d}{(1+\frac{M}{m})}$$

(4) a) $\frac{1\,rev}{8s} = \frac{2\pi\,rad}{8s} = \frac{\pi}{4}\,rad/s \hookrightarrow \omega_i$

$I = 1200\ kg\,m^2$

$m = 70\ kg$

$r = 6m$

$I_i = 1200 + 70(6)^2$

$I_f = 1200 + 70(3)^2$

COAM: $I_i\omega_i = I_f\omega_f$

$\omega_f = \frac{I_i}{I_f}\frac{\pi}{4} \approx 1.5965\ rad/s$

person: $\Sigma F_y = 0 \rightarrow N - mg = 0$

$N = mg$

$f = \mu_s \cdot N \cdot g = m\omega_f^2 R \quad *R = 3m$

$\mu_s = \frac{\omega_f^2 R}{g} \approx 0.7795$

b) $V_x = u$

$V_y = 0 + at = -gt$

$\tan\theta = \frac{V_y}{V_x} = \frac{-gt}{u} \rightarrow$ IV Quadrant

$\theta = \tan^{-1}\left(\frac{-gt}{u}\right) = -\tan^{-1}\left(\frac{gt}{u}\right)$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2lW2C32*

5) $n = 5$ moles

diatomic $\rightarrow f = 5 \rightarrow \gamma = \frac{f+2}{f} = \frac{7}{5}$

a) $P_C V_C^{\gamma} = P_B V_B^{\gamma}$

$$P_B = P_C \left(\frac{V_C}{V_B}\right)^{\gamma} \approx 1.6476 \text{ atm}$$

$$P_B V_B = nRT_B$$

$$\frac{(1.6476 \times 1.01 \times 10^5)(0.07)}{(5)(8.314)} = T_B$$

$$T_B \approx 280.22 \text{ K} \quad \text{close to } 280.36 \text{ K}$$

b) $V_D = V_A$

$$P_A V_A = P_B V_B$$

$$V_A = V_D = \frac{P_B}{P_A} V_B \approx 0.0384 \text{ m}^3$$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2lW2C32*

c)

	Work done by the gas (J)	Heat supplied to the gas (J)	Change in internal energy of the gas (J)
Process *AB*	$P_A V_A \ln\left(\frac{V_B}{V_A}\right)$ ≈ 6980.7613	$Q = W + \Delta U$ $Q = 6980.7613$	0 (Isothermal)
Process *BC*	$Q = W + \Delta U$ $W = -\Delta U$ $= 3872.0650$	0 (adiabatic)	$\frac{f}{2}(P_C V_C - P_B V_B)$ $= -3872.0650$
Process *CD*	$P(V_D - V_C)$ $= -6217.0580$	$Q = W + \Delta U$ $= -21759.703$	$\frac{f}{2} P(V_D - V_C)$ $= -15542.6450$
Process *DA*	0 (isochoric)	$Q = W + \Delta U$ $= 19414.7100$	$\frac{f}{2} V(P_A - P_D)$ $= 19414.7100$

d) $\eta = \frac{W_{net}}{Q_{in}} = \frac{6980.7613 + 3872.0650 - 6217.0580}{6980.7613 + 19414.7100}$

$\approx 0.17563 = 17.563\ \%$

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2lW2C32*

(6) a) •) $V_4 - (I_1 + I_2)(R_5 + R_4) - I_1 \cdot (R_2 + R_3) + V_2 = 0$

$14 I_1 + 9 I_2 = 6 \quad \ldots (1)$

•) $V_4 - (I_1 + I_2)(R_5 + R_4) + V_3 - I_2 R_1 + V_1 = 0$

$9 I_1 + 10 I_2 = 8 \quad \ldots (2)$

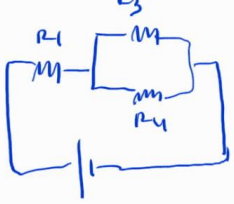
Calculate w/ calculator, we get

$I_1 = -\frac{12}{59}$ A $\quad I_2 = \frac{58}{59}$ A

rate of energy loss in cell V2

$= I_1 \cdot V_2 = \left(\frac{12}{59}\right) 2 = \frac{24}{59}$ W //

b) (i)



$\rightarrow \frac{1}{R_p} = \frac{1}{3000} + \frac{1}{4000} \rightarrow R_p \approx 1714.286$

$I_t = \frac{4}{1000 + R_p} \approx 1.4737 \times 10^{-3}$ A

$V_{parallel} = 4 - I_t R_1$

$I_{R4} = \frac{V_{parallel}}{R_4} = \frac{4 - I_t (1000)}{4000}$

$\approx 6.316 \times 10^{-4}$ A //

(ii)

$\rightarrow \frac{1}{R_p} = \frac{1}{2000} + \frac{1}{7000} \rightarrow R_p \approx 1555.556\ \Omega$

$V = V_0 e^{-\frac{t}{RC}} \rightarrow \frac{3}{10} V_0 = V_0 e^{-\frac{t}{RC}}$

$\ln\left(\frac{3}{10}\right) = -\frac{t}{RC} \rightarrow t = -RC \ln\left(\frac{3}{10}\right)$

≈ 0.01124 s //

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2lW2C32*

(7) a) (i) $\frac{F}{\ell} = \frac{q}{\ell} \cdot E = \lambda E = 40\times10^{-6} \times 100 = 4\times10^{-3}$ N/m

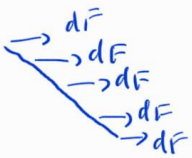
$\frac{m}{\ell} = 0.1$ kg/m

$\frac{F}{\ell} = \frac{m}{\ell} \cdot a \rightarrow a = \frac{4\times10^{-3}\ \text{N/m}}{0.1\ \text{kg/m}} = 4\times10^{-2}\ \text{m/s}^2$

$v_f^2 = v_0^2 + 2ax$

$v_f = \sqrt{0 + 2 \cdot 4\times10^{-2} \cdot 2} = 0.4$ m/s

(ii)



It will not change. With any orientation, the infinitesimal element of the rod will still experience the same infinitesimal force from the magnetic field $\frac{F}{\ell} dl$ since the charge density stays the same. As the mass density doesn't change as well, the acceleration will stay the same.

b) The net Electric field inside the conductor will still be zero as, even though the charges of the inner surface is not distributed homogeneously, the charges on the outer shell will also adapt to it, moving to specific location on the outer shell till there's no net E field. When net E field exists, charges inside conductor will not stay still.

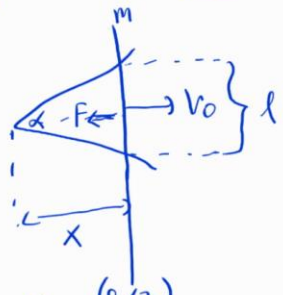
One difference between the inner surfaces:
Figure 7(c)'s inner shell's charges are not distributed homogeneously, unlike figure 7(b)'s inner shell's charges.

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: *http://bit.ly/2IW2C32*

(8)

resistance/unit length : R



$\tan\frac{\alpha}{2} = \frac{(l/2)}{x}$

$l = 2x\tan\left(\frac{\alpha}{2}\right)$

$\mathcal{E} = -\frac{d\Phi}{dt} = -B\frac{dA}{dt} = -B\frac{d\left(x\left(2x\tan\frac{\alpha}{2}\right)/2\right)}{dt}$

$\mathcal{E} = -B\tan\left(\frac{\alpha}{2}\right)\frac{dx^2}{dx}\frac{dx}{dt}$

$\mathcal{E} = -B\tan\left(\frac{\alpha}{2}\right)2x\frac{dx}{dt}$

Resistance $= R\left(2x\tan\left(\frac{\alpha}{2}\right)\right)$

$I = \frac{\mathcal{E}}{R} = \frac{-2B\tan\left(\frac{\alpha}{2}\right)x\frac{dx}{dt}}{R\left(2x\tan\frac{\alpha}{2}\right)}$

$= -\frac{B\frac{dx}{dt}}{R}$

$F = IlxB = ma$

$-\frac{B\frac{dx}{dt}}{R}\,2x\tan\left(\frac{\alpha}{2}\right)B = m\frac{dV}{dt}$

$\int_{x_0}^{x_t} -2x\frac{dx}{dt} = \int_{V_0}^{0}\frac{mR}{B^2\tan\left(\frac{\alpha}{2}\right)}\frac{dV}{dt}$ → since both t is the exact same

$-x^2\Big|_{x_0}^{x_t} = \frac{mR}{B^2\tan\left(\frac{\alpha}{2}\right)}V\Big|_{V_0}^{0}$

$-\left(x_t^2 - x_0^2\right) = \frac{mR}{B^2\tan\left(\frac{\alpha}{2}\right)}(0 - V_0)$

$x_t^2 = x_0^2 + \frac{mR}{B^2\tan\left(\frac{\alpha}{2}\right)}V_0$

$x_t = \sqrt{x_0^2 + \frac{mR}{B^2\tan\left(\frac{\alpha}{2}\right)}V_0}$ shown //

DISCLAIMER: *The solutions are done by students who scored A or above in this subject. Campus supplies is not liable or responsible for any errors in the contents of these solutions. Students are advised to take the solutions as a guide rather than absolute answers to exam paper.*

Should there be any mistakes identified, please proceed to the Facebook link encoded in the QR code to feedback or submit correct answers. The link is: ***http://bit.ly/2IW2C32***