SINGAPORE POLYTECHNIC

2015/16 SEMESTER ONE EXAMINATION

DASE/DCEG/DEEE/DCPE/DESM/DES/DEB/DME/DBEN/DARE/DMRO
DARCH/DIT/DBIT/DISM/DDA/DVEMG

3rd Year Full-Time

PHYSICS Time allowed : 2 hours

Instructions to Candidates:

1. The examination rules set out on the last page of the answer booklet are to be complied with.

2. This paper consists of **THREE sections** printed on 7 pages (inclusive of cover page and formula sheet).

   Section A: 5 multiple-choice questions, 2 marks each. Answer these questions in the MCQ answer sheet of the answer booklet.

   Section B: 7 questions, 10 marks each. The total mark of the questions in this section is 70 marks. You may answer as many questions as you wish. The marks from all questions you answered will be added, but the maximum mark you may obtain from this section is **50 marks**.

   Section C: 3 questions, total mark is 40.
   Answer all three questions in this section.

3. Write your name, admission number and seat number on the formula sheet.

4. All answers are to be written in the answer booklet provided.

5. All answers must be to the appropriate number of significant figures.

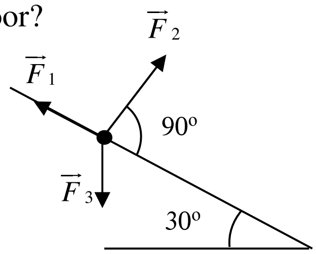
6. Take acceleration due to gravity, $g = 9.80 \text{ m/s}^2$.

7. Except for sketches, graphs and diagrams, no solution is to be written in pencil. Failure to comply will result in loss of marks.

Section A (10 marks)

Answer ALL multiple choice questions on the MCQ answer sheet of the answer booklet. No marks will be deducted for incorrect answers.

A1. Three forces $\vec{F}_1$, $\vec{F}_2$ and $\vec{F}_3$ act on an object placed on a tilted floor as shown in the figure. $\vec{F}_3$ acts vertically downwards. If the forces have magnitudes such that $|\vec{F}_1| = 1.0\,\text{N}$, $|\vec{F}_2| = 8.0\,\text{N}$ and $|\vec{F}_3| = 7.0\,\text{N}$, what is the magnitude of the net force $\vec{F}_{\text{Net}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3$ parallel to the tilted floor?



a) 2.5 N
b) 5.1 N
c) 6.0 N
d) 7.8 N

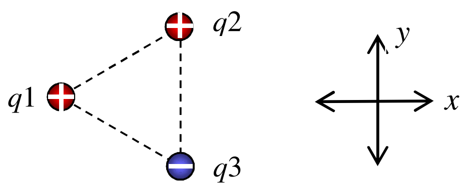
A2. Object A has a position given by $\vec{r}_A = 3.00t\hat{i} + 1.00t^2\hat{j}$. Object B has a position given by $\vec{r}_B = 4.00t\hat{i} - 1.00t^2\hat{j}$. What is the distance between A and B at time t = 3.00 s?

a) 34.6 m
b) 15.0 m
c) 18.2 m
d) 3.46 m

A3. A ball P is dropped out of the window of a moving car. At the same time a ball Q is dropped from a stationary truck from the same height. Neglect air resistance. Which of the following is correct?

a) Ball P will have a greater speed when it hits the road.
b) Ball Q will have a greater speed when it hits the road.
c) Balls P and Q will both reach the road at the same speed.
d) We cannot compare their speeds as more information is required.

A4. Three point charges lie at the vertices of an equilateral triangle as shown in the figure. All three charges have the same magnitude. Taking right as $+x$ and up as $+y$, the net electric force that charges $q2$ and $q3$ exert on $q1$ is in the



a) $+x$-direction.
b) $-x$-direction.
c) $+y$-direction.
d) $-y$-direction.

A5. Lenz's law is a consequence of the law of conservation of

a) induced current. b) charge.
c) linear momentum. d) energy.

<u>Section B</u> (50 marks)

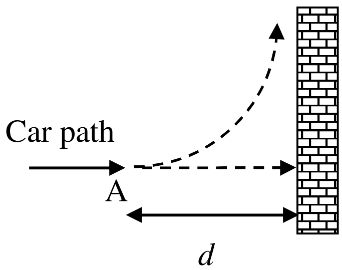
The total mark of the questions in this section is 70 marks. You may answer as many questions as you wish. The marks from all questions you answered will be added, but the maximum mark you may obtain from this section is 50 marks.

B1. A car of mass 1400 kg is approaching a wall with speed $v_0 = 35$ m/s as shown in the below figure. It begins to slow down when it reaches a point A which is at a distance of $d = 107$ m from the wall.

a) (i) Find the force needed to bring the car to stop just before it hits the wall. You may assume that this force is constant.
(ii) Instead if the car slows down solely due to kinetic friction from point A, at what speed will the car hit the wall? The coefficient of kinetic friction is $\mu_k = 0.40$ from point A to the wall.

b) Suppose at point A, the driver decides to take the curved path shown of radius 107 m while maintaining the speed of $v_0 = 35$ m/s, what is the net force on the car?

(10 marks)



B2. A wave on a string is described by $y(x,t) = (5.00)\cos\left(\frac{\pi x}{8} - 4\pi t\right)$, where x and y are in centimetres and t is in seconds.

a) What is the transverse speed for a point at $x = 6.00$ cm when $t = 0.250$ s?
b) What is the maximum transverse speed of a point on the string?
c) What is the minimum transverse speed of a point on the string?

(10 marks)

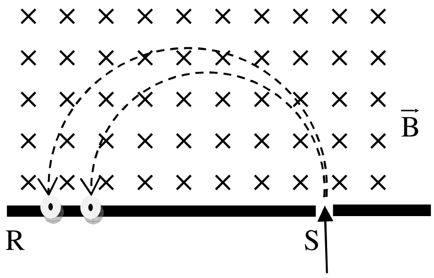
B3. A 3.0 kg mass is connected to a massless spring and undergoes simple harmonic motion according to the equation $x = 5.0\cos\left(\frac{\pi t}{3} - \frac{\pi}{4}\right)$ where $t \geq 0$. All the quantities have SI units.

a) At what value of x is the potential energy equal to half of the total energy?
b) From its initial position, how long does the mass take to reach the equilibrium position?

(10 marks)

B4. In the below figure, two singly ionized atoms pass through slit S each with a speed of 7.00×10^5 m/s. They then enter a uniform magnetic field of magnitude 0.070 T pointing into the page. They move in circular paths and strike a photographic plate RS each leaving a dot on the plate. One atom has a mass of 1.67×10^{-27} kg, while the other has a mass of 8.35×10^{-27} kg. Find the distance between the dots.

(10 marks)



B5. Two objects A and B, each of mass 3.00 kg, collide. The velocity of A before the collision is $\mathbf{u}_A = (5.00\,\mathbf{i} + 8.00\,\mathbf{j})$ m/s and immediately after the collision is $\mathbf{v}_A = (7.00\,\mathbf{i} + 1.00\,\mathbf{j})$ m/s. The velocity of B before the collision is given as $\mathbf{u}_B = (2.00\,\mathbf{i} - 3.00\,\mathbf{j})$ m/s.

a) Find the velocity of B immediately after the collision in terms of unit vectors **i** and **j**.

b) Is the collision elastic or inelastic? Support your answer with calculations.

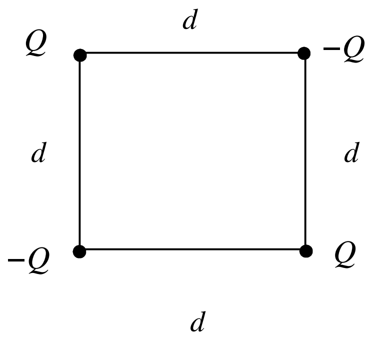
(10 marks)

B6. The time taken by an object to cover a distance is suspected to depend on mass, distance and acceleration raised to different exponents. Determine a possible formula for time using dimensional analysis.

(10 marks)

B7. Four point charges of the same magnitude Q are located at the four corners of a square of side d such as shown in the below figure. Calculate the work done in assembling these charges, each starting from infinity.

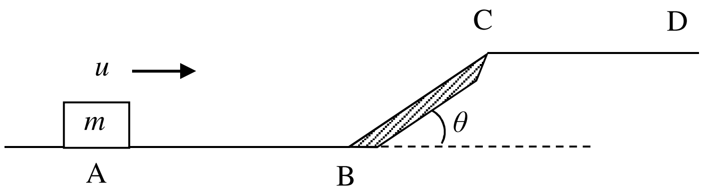
(10 marks)



Section C (40 marks)

Answer all THREE questions in this section.

C1. In the below figure, an object of mass m on a flat frictionless surface AB, moves with a speed of u. It then encounters an incline BC. The incline is rough where the coefficient of kinetic friction is μ_k. After the object reaches the top of the incline, it continues to move on a second flat frictionless surface CD. The length of BC is d and that of CD is x, the angle of inclination is θ and the acceleration due to gravity is g.



a) What is the work done by friction?
b) What is the speed of the object at point D?
c) What is the magnitude of the linear momentum of the object at point D?

(15 marks)

C2. A point charge $q = -9.00$ nC is located at the origin. The electric field due to this charge is $\mathbf{E} = (7.80\ \mathbf{i} + 10.4\ \mathbf{j})$ N/C at a certain point X. [1nC = 10^{-9} C].

a) Find the coordinates of point X.
b) Find the electric potential at point X.

(15 marks)

C3. An object of mass m is placed on a weighing scale inside an elevator. The scale reading increases when the elevator is accelerating up with magnitude a, while there is no change in the scale reading when the elevator moves up with constant speed v. Explain these observations with suitable calculations.

(10 marks)

***** End of Paper *****

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Formula sheet

Name: ________________________ Admin. No.: _______________ Seat No.: ________

Kinematics

$$v_x = v_{0x} + a_x t$$
$$v_x{}^2 = v_{0x}{}^2 + 2a_x(x - x_0)$$
$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$
$$\vec{v} = \frac{d\vec{r}}{dt}, \quad \vec{a} = \frac{d\vec{v}}{dt}$$
$$y = (\tan\theta)x - \left(\frac{g}{2v^2\cos^2\theta}\right)x^2$$

Dynamics

$$\vec{F} = m\frac{d\vec{v}}{dt} = m\vec{a},\ F = \mu N$$
$$a = \frac{dv}{dt},\ a = \frac{v^2}{r}, F = m\frac{v^2}{r}$$
$$\vec{J} = \int \vec{F}dt = \Delta\vec{p}$$
$$W = \int \vec{F}.\,d\vec{r},\ W_{net} = K_f - K_i$$
$$KE = \frac{1}{2}mv^2,\ PE = mgh$$
$$PE = \frac{1}{2}kx^2, P = \frac{W}{t},\quad P = \frac{dW}{dt}$$

Linear momentum

$$m_1\vec{u}_1 + m_2\vec{u}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$$
$$\vec{p} = m\vec{v}$$

Static electricity

$$F = k\frac{q_1q_2}{r^2},\ k = \frac{1}{4\pi\varepsilon_o}$$
$$F = qE$$
$$V = k\frac{q}{r}, U = qV$$
$$\Phi_E = \oint \vec{E}.d\vec{A} = \frac{q}{\varepsilon_o}$$
$$V = Ed, W = qV, E = \frac{kq}{r^2}$$

Current electricity

$$Q = It \quad V = IR$$
$$P = VI = I^2R = \frac{V^2}{R}$$

Magnetism & electromagnetism

$$\vec{F} = q\vec{v}\times\vec{B} \qquad \vec{F} = i\vec{L}\times\vec{B}$$
$$e.m.f. = -N\frac{d\Phi_B}{dt} = (\vec{v}\times\vec{B})\cdot\vec{l}$$
$$\Phi_B = BA$$

Thermodynamics

$$\Delta U = Q - W$$
$$W = \int pdV$$
$$Q_V = nC_V\Delta T \quad \text{const vol}$$
$$Q_p = nC_p\Delta T \quad \text{const pressure}$$
$$Q = mC\Delta T$$
$$Q = mL$$

Ideal Gas

$$pV = nRT$$
$$pV^\gamma = c \text{ (adiabatic)}$$
$$\gamma = \frac{C_p}{C_V},\ C_p - C_v = R$$
$$W = pV\ln\frac{V_2}{V_1} = nRT\ln\frac{V_2}{V_1}$$
$$W = \frac{1}{\gamma - 1}(p_1V_1 - p_2V_2)$$

Rotational Motion

$$\omega = \frac{d\theta}{dt},\quad \alpha = \frac{d\omega}{dt}$$
$$\omega = \omega_0 + \alpha t$$
$$\omega^2 = \omega_0{}^2 + 2\alpha(\theta - \theta_0)$$
$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$
$$I = \sum_i^n m_i r_i{}^2,\ I = \int r^2dm,\ K = \frac{1}{2}I\omega^2$$

SHM & waves

$$T = \frac{1}{f} \quad v = f\lambda \quad \omega = 2\pi f$$
$$\omega = \frac{2\pi}{T} \quad k = \frac{2\pi}{\lambda}$$
$$\omega = \sqrt{k/m} \quad \omega = \sqrt{g/L}$$
$$x = A\cos(\omega t + \phi)$$
$$x = A\sin(\omega t + \phi)$$
$$y(x,t) = A\cos(\omega t \pm kx)$$
$$y(x,t) = A\sin(\omega t \pm kx)$$
$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$$

Circuits

$$R = R_1 + R_2 + R_3 + \ldots \quad \text{series}$$
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots \quad \text{parallel}$$
$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots \quad \text{series}$$
$$C = C_1 + C_2 + C_3 + \ldots \quad \text{parallel}$$
$$Q = CV \qquad U = \frac{1}{2}CV^2$$

Constants

Charge on electron/proton
$e = -1.60\times10^{-19}$ / 1.60×10^{-19} C

Coulomb's constant
$k = 8.988\times10^9$ N m^2 C^{-2}

Ideal gas constant
$R = 8.314$ J mol^{-1} K^{-1}

Mass of proton
$m_p = 1.67\times10^{-27}$ kg

Mass of electron
$m_e = 9.11\times10^{-31}$ kg

Permeability of free space
$\mu_o = 4\pi\times10^{-7}$ N A^{-2}

Permittivity of free space
$\varepsilon_o = 8.85\times10^{-12}$ C^2 N^{-1} m^{-2}

Speed of light in vacuum
$c = 3.00\times10^8$ m s^{-1}