SINGAPORE POLYTECHNIC

2017/18 SEMESTER ONE EXAMINATION

DASE/DEEE/DCPE/DESM/DES/DEB/DME/DBEN/DARE/DMRO
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 **TWO sections** printed on 5 pages (inclusive of cover page and formula sheet).

   Section A: 5 questions, 14 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 B: 3 questions, total mark is 50.
   Answer all three questions in this section.

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

4. You are allowed ONE A4-sized handwritten formula sheet for reference. Please ensure that you do not have any other reference material or notes with you.

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

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

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

8. 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 (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.

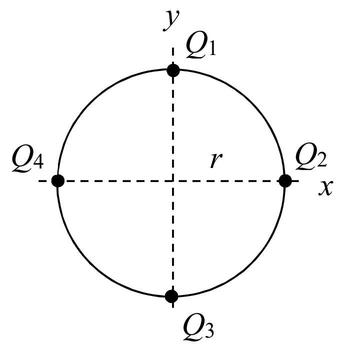
A1. a) Show that if $\boldsymbol{F}$ is force and $\boldsymbol{v}$ is velocity, $\boldsymbol{F} \cdot \boldsymbol{v}$ has the dimension of power.

b) A stationary object of mass 1.0 kg is acted on by a force that is a function of time as $\boldsymbol{F}(t) = (2t\,\mathbf{i} + 3t^2\,\mathbf{j})$ N. What is the instantaneous rate of work done by the force at any time t (in seconds) if the object is at rest initially?

(14 marks)

A2. Four positive charges Q_1, Q_2, Q_3 and Q_4 of magnitude Q are placed on a circle of radius r as shown below.

a) Determine the potential V and electric field $\boldsymbol{E}$ at the centre of the circle.
b) Determine the work required to bring a positive charge q from infinity to the centre of the circle.
c) If the charge of both Q_1 and Q_2 are changed to $-Q$, what is the potential V and electric field $\boldsymbol{E}$ at the centre of the circle?



(14 marks)

A3. A standing wave is set-up on a string due to two traveling waves. The wave function of the standing wave is $y(x, t) = (4.44\text{ mm}) \sin[(32.5\text{ rad/m})\,x] \sin[(754\text{ rad/s})t]$.

a) Find the wave functions of the two traveling waves.
b) Find the wavelength, frequency, wave speed and amplitude of the traveling waves.
c) What is the maximum transverse speed of a particle on the traveling waves?

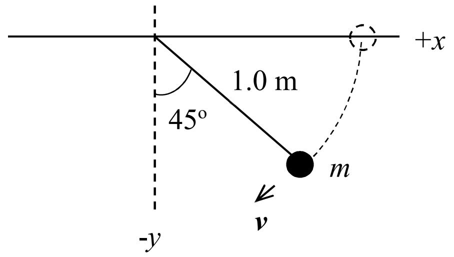
(14 marks)

A4. An object of mass 0.45 kg is connected to a spring which has a force constant 26.0 N/m. Both object and spring are on a frictionless surface. The object is set into oscillations when released from rest at a distance of 0.0325 m from the equilibrium position.

a) What is the period of oscillation?
b) Calculate the speed of the object when it is half way to the equilibrium position.
c) What is the maximum speed of the object?
d) What is the magnitude of the maximum acceleration of the object?

(14 marks)

A5. A 1.0 kg mass m is attached to the ceiling by a 1.0 m non-elastic string. The mass is held horizontally initially before it falls in a vertical circular path as shown below.



a) Assuming no air resistance, when the string is at 45° to the $-y$ axis, determine

i) the decrease in the height of the mass.
ii) the speed, kinetic energy and linear momentum of the mass.
iii) the velocity $\boldsymbol{v}$ of the mass in terms of unit vectors $\mathbf{i}$ and $\mathbf{j}$.
iv) the magnitude of the centripetal acceleration $\boldsymbol{a}_r$ of the mass.

b) i) Write the acceleration due to gravity $\boldsymbol{g}$ in terms of unit vector $\mathbf{j}$.
ii) What is the total acceleration $\boldsymbol{a}$ when the string is at 45°? Given that $\boldsymbol{a} = \boldsymbol{a}_r + \boldsymbol{g}$.

(14 marks)

Section B (50 marks)

Answer all THREE questions in this section.

B1. A 2.0 kg mass is resting on a smooth horizontal surface. A force of $0.5t$ N acts on it for 5.0 s. Determine

a) the impulse of the force.
b) the linear momentum of the mass at 5.0 s.
c) the speed of the mass at 5.0 s.
d) the kinetic energy of the mass at 5.0 s.
e) If at t = 10 s, the 2.0 kg mass collides head-on with a 1.0 kg mass and both move off together as one object, what is the velocity and kinetic energy of the combined object?

(20 marks)

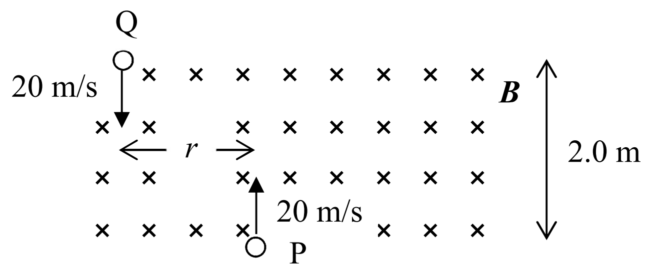
B2. A stone was projected from a height of 10 m so that it landed with velocity $\boldsymbol{v} = 3.0\,\mathbf{i} - 4.0\,\mathbf{j}$ m/s. Assume there is no air resistance.

a) If the stone's journey took 1.5 s, show that it was not projected horizontally.
b) Determine the angle at which the stone was projected.
c) What is the stone's horizontal range?

(15 marks)

B3. P and Q are particles of mass 10^{-2} kg on the x-y plane. P has +0.20 C of charge and Q is electrically neutral. $\boldsymbol{B}$ is a 1.0 T uniform magnetic field directed perpendicularly into the page as shown in the figure below. At the same time, P and Q are projected into the magnetic field at 20 m/s.

a) What is the radius r of the circular path traversed by P?
b) How long does P take to travel one quarter of a circle?
c) What is the distance travelled by Q in the same time?
d) Will P and Q collide? Explain with calculation.



(15 marks)

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

Formula sheet

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

Kinematics

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

Dynamics

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

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

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

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

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

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

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

Constants

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