SINGAPORE POLYTECHNIC

2016/17 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. 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 (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. An object of mass 0.0200 kg is moving in a plane. The x and y coordinates (measured in metres) of the object are given by $x(t) = t^3 - t^2$ and $y(t) = 4t^3 + t$ where t is in seconds.

a) At $t = 2.00$ s, find the x- and y- components of the object's acceleration.
b) At $t = 2.00$ s, find the magnitude and direction of the net force acting on the object.
c) What is the total work done on the object between $t = 0$ and $t = 2.00$ s?

(14 marks)

A2. A particle with charge -2.00×10^{-9} C is moving in a uniform magnetic field $\mathbf{B} = (-1.50\text{ T})\,\mathbf{k}$. The magnetic force acting on the particle is found to be $\mathbf{F} = -(4.50 \times 10^{-7}\text{ N})\,\mathbf{i} + (6.00 \times 10^{-7}\text{ N})\,\mathbf{j}$.

a) Calculate the x- and y- components of the particle's velocity.
b) Explain why the z- component of the particle's velocity cannot be determined.
c) If the x-y plane motion is circular, what is the radius of the circle? The mass of the particle is 1.00×10^{-12} kg.

(14 marks)

A3. A circular loop of radius r and resistance R is placed perpendicular to a variable magnetic field. The induced emf in the loop is $\varepsilon = \pi r^2 \alpha B_0 e^{-\alpha t}$ where α is a positive constant, t is the time and B_0 is the magnetic field at $t = 0$.

a) Determine the dimension of α and state its SI unit.
b) What is the induced current in the loop?
c) Obtain an expression for the magnetic field.

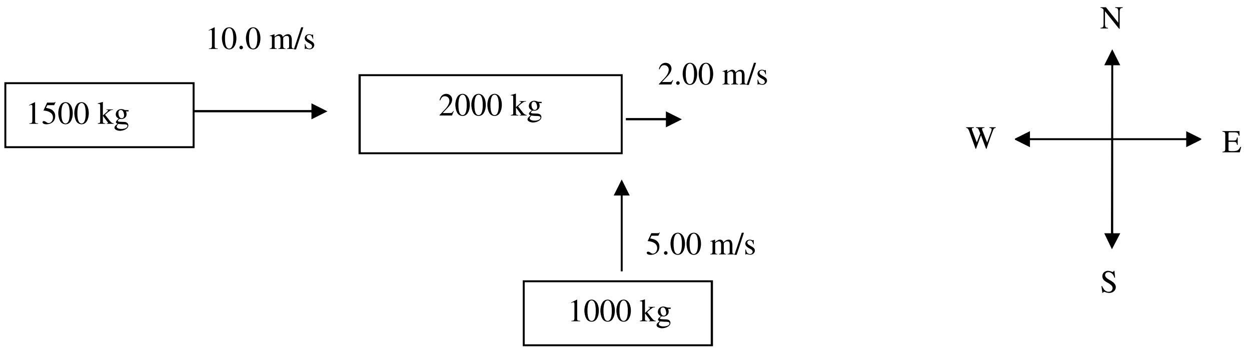
(14 marks)

A4. An object of mass 1.00 kg undergoes simple harmonic motion with period 1.50 s and amplitude 0.400 m. At $t = 0$, the object is at $x = 0$ (equilibrium position) and moving in the positive x-direction.

a) What is the angular frequency of this motion?
b) Express the displacement of the object as a function of time.
c) What is the kinetic energy of the object at $x = 0$?

(14 marks)

A5. A 2000 kg truck is traveling east at 2.00 m/s when it is hit simultaneously at the side by a car of mass 1000 kg traveling north at 5.00 m/s and at the rear by a bus of mass 1500 kg that is travelling east at 10.0 m/s (as shown in the figure). After the collision, the three vehicles become entangled and move as one body.



a) What are the x- and y- components of the velocity of the body just after the collision?
b) What is the magnitude and direction of the velocity of the body just after the collision?
c) Is the collision elastic or inelastic? Justify your answer with suitable calculations.

(14 marks)

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

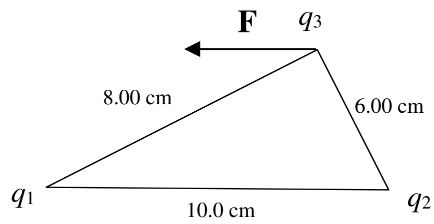
Answer all THREE questions in this section.

B1. A massless unstretched nor compressed spring with spring constant 500 N/m is hung from the ceiling. An object of mass 2.00 kg is then attached to the lower end of the spring and released. Ignore air resistance.

a) What is the speed of the object after it has descended 0.0200 m from its initial position?
b) What is the maximum speed of the object as it descends?

(20 marks)

B2. The below figure shows three charges placed on the vertices of a right triangle. The charge q_3 is positive and has a magnitude 3.00×10^{-6} C. Charge q_2 is unknown while the magnitude of charge q_1 is known to be 1.00×10^{-6} C. The sign of q_1 is not known. It is known that the net force **F** on q_3 due to the other two charges is along the negative x-direction. You can take q_1 and q_2 to lie on the x-axis.



a) If $\mathbf{F}_1$ and $\mathbf{F}_2$ are the forces exerted by q_1 and q_2 respectively on q_3, draw a possible diagram depicting $\mathbf{F}_1$ and $\mathbf{F}_2$ such that the net force is **F**.
b) Deduce the signs of q_1 and q_2 based on the scenario obtained in (a). Explain your answer.
c) Calculate the magnitude of q_2.
d) Calculate the magnitude of the net force **F**.

(20 marks)

B3. A bus travels up a hill at a constant speed of 20 km/h and returns down the hill at a constant speed of 30 km/h. Calculate the average speed of the bus for the whole trip.

(10 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

$\vec{F} = m\frac{d\vec{v}}{dt} = m\vec{a},\ F = \mu N$

$a = \frac{dv}{dt},\ a = \frac{v^2}{r}, F = m\frac{v^2}{r}$

$\vec{J} = \int \vec{F}dt = \Delta\vec{p}$

$W = \int \vec{F}.\,d\vec{r},\ W_{net} = K_f - K_i$

$KE = \frac{1}{2}mv^2,\ PE = mgh$

$PE = \frac{1}{2}kx^2, P = \frac{W}{t},\ \ P = \frac{dW}{dt}$

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

$\Delta U = Q - W$

$W = \int pdV$

$Q_V = nC_V\Delta T$ const vol

$Q_p = nC_p\Delta T$ const pressure

$Q = mC\Delta T$

$Q = mL$

Ideal Gas

$pV = nRT$

$pV^\gamma = c$ (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

$\omega = \frac{d\theta}{dt}, \quad \alpha = \frac{d\omega}{dt}$

$\omega = \omega_0 + \alpha t,\ v = \omega r$

$\omega^2 = \omega_0{}^2 + 2\alpha(\theta - \theta_0)$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$I = \sum_i^n m_i r_i^2,\ I = \int r^2dm,\ K = \frac{1}{2}I\omega^2$

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

$R = R_1 + R_2 + R_3 + \ldots$ series

$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$ parallel

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$ series

$C = C_1 + C_2 + C_3 + \ldots$ 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}