SINGAPORE POLYTECHNIC

2017/18 SEMESTER TWO 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 help sheet for reference. Please ensure that you do not have any other reference materials 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, $g = 9.80 \text{ m/s}^2$.

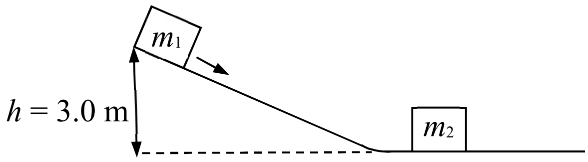
8. Except for sketches, graphs and diagrams, no solution is to be written in pencil. Failure to comply will result in loss of marks.

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 have answered will be added, but the maximum mark you may obtain from this section is 50 marks.

A1. a) State the law of conservation of linear momentum.

b) The diagram below shows a mass $m_1 = 1.0$ kg sliding down a smooth inclined surface from rest. At the bottom of the inclined surface, it collides with an identical mass m_2 that is initially at rest. After collision, the two masses move as one object along a horizontal surface with coefficient of kinetic friction 0.25.



Calculate

i) the speed of m_1 just before colliding with m_2.
ii) the common speed of the two masses on impact.
iii) the work done by friction to bring the two masses to a stop.
iv) the speed of the two masses one second after the collision.

(14 marks)

A2. a) Transverse waves on a string have wave speed 8.00 m/s, amplitude 0.0700 m, and wavelength 0.320 m. The waves travel in the negative x-direction, and at $t = 0$, the waves at $x = 0$ has its maximum upward displacement.

i) Find the frequency, period and wave number of these waves.
ii) Write a wave function describing these waves.

b) Find the transverse displacement of a particle at $x = 0.360$ m and $t = 0.150$ s.

c) How much time must elapse from the instant in part b) until the particle has maximum upward displacement?

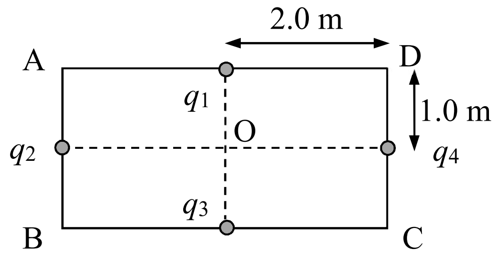
(14 marks)

A3. A stationary object A of mass $m_1 = 2.0$ kg is initially at the origin. A force, $F = 3.0x^2$, is applied on A where x is in metres. A second object B of mass $m_2 = 6.0$ kg moves with constant velocity 3.0 m/s along the positive x-axis.

i) Determine the acceleration of A as a function of x.
ii) What is the work done by the force on A when it is 1.0 m from the origin?
iii) What are the kinetic energies of A and B when A is 1.0 m from the origin?
iv) Determine the distance travelled by A before it has the same kinetic energy as B.

(14 marks)

A4. a) ABCD is a rectangle with sides 2.0 m by 4.0 m. A 0.001 C charge is located at the middle of each side of the rectangle as shown in the figure.



Determine

i) the electric field $\boldsymbol{E}$ at O.

ii) the electric potential V at O.

iii) the magnitude of the electric force on q_4.

b) If the charges are moved such that one charge is at every corner of the rectangle, what will be the electric field $\boldsymbol{E}$ and potential V at O?

(14 marks)

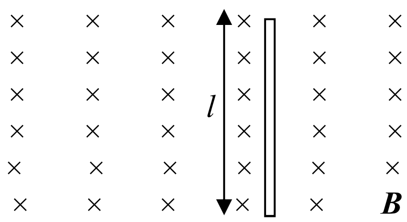
A5. a) A mass m is attached to a spring on a smooth horizontal surface. The spring constant is k. You may assume the spring is ideal and massless and there is no air resistance.

i) Show that the mass performs simple harmonic motion when it is displaced horizontally by Δx from its equilibrium position.

ii) Calculate the angular frequency of the oscillation if $m = 2.0$ kg and $k = 200$ N/m.

iii) Calculate the period of oscillation.

b) A brass rod of length l moves with simple harmonic motion perpendicular to a uniform magnetic field $\boldsymbol{B}$ as shown in the figure. The displacement x is given by $x = A\cos(\omega t)$ where A is the amplitude, ω is the angular frequency and t is the time. Determine the magnitude of the induced emf as a function of time.

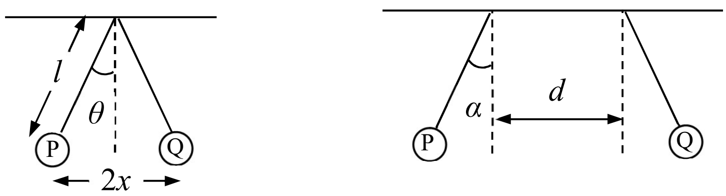


(14 marks)

Section B (50 marks)

Answer all THREE questions in this section.

B1. a) Fig. (a) shows two identical charged spheres, P and Q, of mass m and charge q and separated by an unknown distance $2x$. Both spheres are attached to the ceiling with light strings of length l. The acceleration due to gravity is g while the Coulomb's constant is k. The system is in equilibrium.



(a) (b)

i) Draw the free body diagram of the sphere P in Fig. (a).

ii) Assume θ to be small. Show that $\theta = \left(k\dfrac{q^2}{4mgl^2} \right)^{1/3}$.

(Note that for small angle approximation: $\sin\theta \approx \tan\theta \approx \theta$).

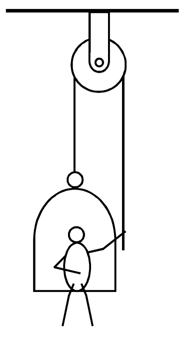
b) Fig. (b) shows spheres P and Q separated by a distance, d.

Show that $(\tan\alpha)(2l\sin\alpha + d)^2 = k\dfrac{q^2}{mg}$.

(15 marks)

B2. a) State Newton's second law of motion.

b) The diagram shows a man seated in a lift connected through a massless rope to a frictionless light pulley. When the man pulls on the rope, the normal reaction of the base of the lift on the man is 441.0 N. The lift's mass is 25 kg while that of the man's is 100 kg.



i) Draw the free body diagrams of the man and the lift.

ii) Determine the acceleration and the tension in the rope.

(20 marks)

B3. A positively charged particle C has a certain mass. Another positively charged particle D has twice the charge of C and four times the mass of C. Both particles are accelerated from rest by the same potential difference before they move into a region where there is a uniform magnetic field applied perpendicular to the motion of these particles. What is the mathematical relationship between the radii of the two particles? Show detailed calculations.

(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

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

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

$$F = k\frac{q_1 q_2}{r^2},\ k = \frac{1}{4\pi\varepsilon_o}$$
$$F = qE$$
$$V = k\frac{q}{r}, U = qV$$
$$\Phi_E = \oint \vec{E}.d\vec{A} = \frac{q}{\varepsilon_o}$$
$$V = Ed, W = qV, E = \frac{kq}{r^2}$$

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

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

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

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

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}