SINGAPORE POLYTECHNIC

2015/16 SEMESTER TWO 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 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. The velocity of an object of constant mass is directly proportional to $t^{1/2}$ where t is time. Hence the force on the object is directly proportional to

a) t^2
b) t
c) $t^{1/2}$
d) $t^{-1/2}$

A2. Vectors **a**, **b** and **c** are related as follows: $\mathbf{a} = 4\mathbf{b}$ and $\mathbf{c} = -9\mathbf{b}$. The angle between **a** and **c** is _________ while the angle between **a** and **b** is _________.

a) 90º, 0º
b) 0º, 180º
c) 0º, 90º
d) 180º, 0º

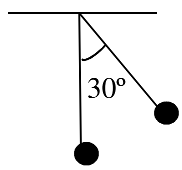
A3. A particle is projected at 60º to the horizontal from the ground such that its kinetic energy is K. Neglect air resistance. At the maximum height, the kinetic energy of the particle is

a) $K/8$
b) $K/4$
c) $K/2$
d) $3K/4$

A4. The velocity of a particle moving along the x-axis is $v = C + At + Bt^2$ where C, A and B are constants and t is the time in seconds. At $t = 0$, the particle is at $x = 0$. The displacement of the particle at $t = 1$ s is

a) $C + A/2 + B/3$
b) $C + 2A + 3B$
c) $C + 2A + B$
d) $A + 2B$

A5. In the figure, an object of mass m is held stationary at 30º with respect to the vertical. What is the magnitude of the horizontal force required to keep it in that position?



a) $3^{-1/2}\, mg$
b) $2mg$
c) $3^{1/2}\, mg/2$
d) $mg/2$

Section B (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 particle of mass 2.0 g is undergoing simple harmonic motion with an amplitude of 2.5 mm. Its maximum acceleration is 1.0×10^8 m/s^2.

a) Calculate the angular frequency and the frequency.
b) Calculate the velocity of the particle when it is 1.2 mm from the equilibrium.
c) Write an equation expressing the force acting on the particle as a function of the particle's position.

(10 marks)

B2. A plane circular conducting coil with 20 turns and radius 0.20 m is placed in a uniform magnetic field. The direction of the magnetic field makes an angle f 60° with respect to the normal direction to the coil. The magnetic field-strength is increased at a constant rate from 0.1 T to 0.5 T in a time interval of 40 s.

a) What is the rate of change of magnetic field?
b) What is the magnitude of the emf generated in the coil?
c) If the electrical resistance of the loop is 50 Ω what current flows around the coil as the magnetic field is increased?

(10 marks)

B3. A wave on a string is described by $y(x,t) = (0.50)\cos\left(6.8x + 17t\right)$ where all the quantities are in SI units.

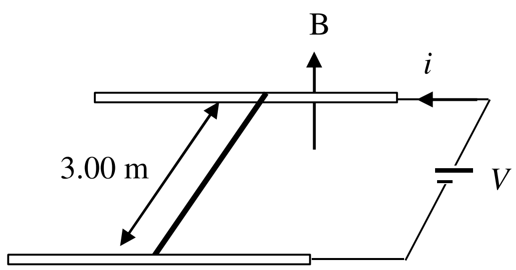
a) Determine the amplitude, wavelength and frequency of the wave.
b) What is the magnitude and direction of the velocity of the wave?
c) What are the maximum and minimum speeds of the particles of the string?

(10 marks)

B4. A metal wire of mass 0.0241 kg and length 3.00 m can slide on two frictionless rails as shown. A magnetic field *B* of magnitude 60.0 mT is applied perpendicular to the wire. The wire accelerates at 1.00 m/s^2.The total resistance in the circuit is 5.00 Ω.

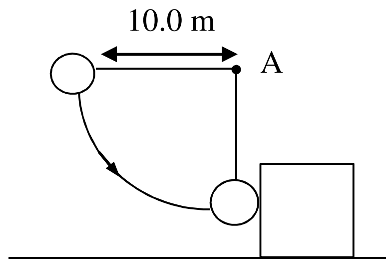
a) What is the magnitude of the force acting on the wire?
b) What is the current *i* in the circuit?
c) What is the voltage *V* required to produce an acceleration of 1.00 m/s^2 in the wire?

(10 marks)



B5. A ball of mass 1.00 kg is fastened to a cord that is 10.0 m long and fixed at point A as shown in the figure. The ball is them released when the cord is horizontal so that it moves in a circular path. At the bottom of its path, the ball strikes a 5.00 kg block initially at rest on a frictionless surface. The collision is elastic.

a) Find the speed of the ball just before the collision.
b) Find the velocity of the ball just after the collision.
c) Find the velocity of the block just after the collision.
d) Draw a diagram showing the direction of the ball and the block just after the collision.



(10 marks)

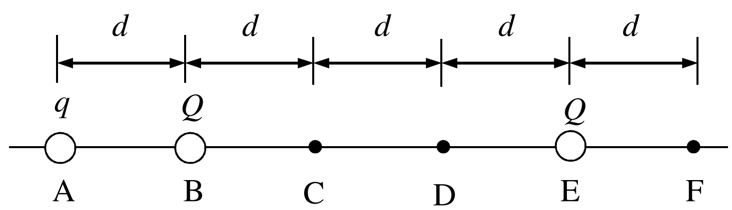
B6. An electron starting from rest at point C acquires 2.50×10^3 eV of kinetic energy to reach a point D. 1 eV = 1.6×10^{-19} J.

a) How much kinetic energy would a proton gain if it starts from rest at point D to reach point C? Explain your answer.
b) Determine the ratio of the final speed of the electron to that of the final speed of the proton at the end of their respective journeys.

(10 marks)

B7. The below figure shows a system of three positively charged particles along with their positions and distances between points. In terms of q, Q and d,

a) what is the total electric field at point C?
b) what is the total electric potential at point C?



(10 marks)

Section C (40 marks)

Answer all THREE questions in this section.

C1. a) What is the work done by a force $\vec{F} = (4\hat{i} + 3\hat{j})\,\mathrm{N}$ along $y = x^3$ from $x = 0$ to $x = 2$ m?

b) Energy is being transferred to an object of mass m. If the velocity and the acceleration of the object at any time t are $\frac{dx}{dt}$ and $\frac{d^2x}{dt^2}$ respectively, show that the rate of the energy transfer P is given by

$$P = m\left(\frac{d^2x}{dt^2}\right)\left(\frac{dx}{dt}\right)$$

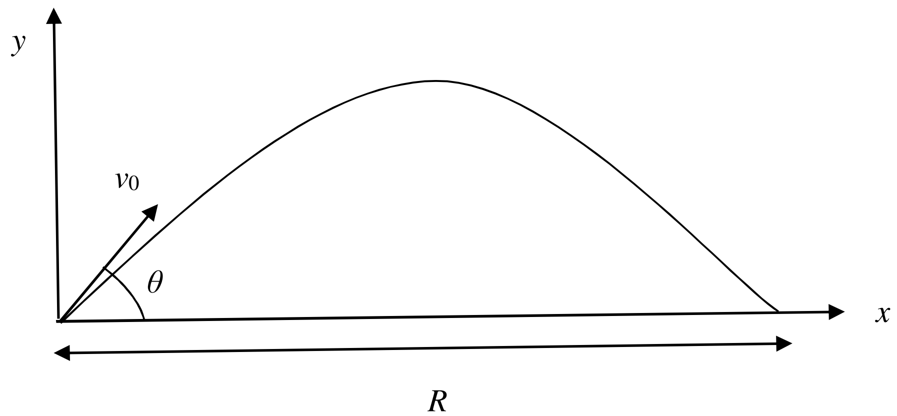
c) The position of an object of mass 2.00 kg is given (in metres) as $x(t) = 5t^2 - 3t$ where t is in seconds. Find the rate of energy transferred at $t = 3.00$ s.

(16 marks)

C2. An object is projected at an angle θ to the horizontal with a velocity v_0 as shown in the figure. Neglect air resistance.

a) What is the time taken by the object to reach the maximum height in terms of v_0, θ and g?

b) Show that the horizontal range R is $v_0^2\sin 2\theta/g$.



(17 marks)

C3. An object of mass 1 kg falls from a height of 10 m. While the object accelerates downwards, why don't we see the earth accelerate upwards? Explain using Newton's laws of motion. Neglect air resistance. The mass of the earth is around 6×10^{24} kg.

(7 marks)

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

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Formula sheet

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

Kinematics

$v_x = v_{0x} + a_x t$

$v_x{}^2 = v_{0x}{}^2 + 2a_x(x - x_0)$

$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$

$\vec{v} = \frac{d\vec{r}}{dt}, \quad \vec{a} = \frac{d\vec{v}}{dt}$

$y = (\tan\theta)x - (\frac{g}{2v^2\cos^2\theta})x^2$

Dynamics

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

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

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

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

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

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

Linear momentum

$\vec{p} = m\vec{v}$

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

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

$P = VI = I^2R = \frac{V^2}{R}$

$Q = It \quad V = IR$

Magnetism & electromagnetism

$\vec{F} = q\vec{v} \times \vec{B} \qquad \vec{F} = i\vec{L} \times \vec{B}$

$e.m.f. = -N\frac{d\Phi_B}{dt} = (\vec{v} \times \vec{B}) \cdot \vec{l}$

$\Phi_B = \vec{B}.\vec{A}$

Thermodynamics

$\Delta U = Q - W$

$W = \int p\,dV$

$Q_V = nC_V\Delta T$ 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

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

$\omega = \omega_0 + \alpha t$

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

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

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

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

$R = R_1 + R_2 + R_3 + \ldots$ 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
$e = -1.60 \times 10^{-19} / 1.60 \times 10^{-19}$ C

Coulomb's constant
$k = 8.988 \times 10^9$ N m^2 C^{-2}

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

Mass of proton
$m_p = 1.67 \times 10^{-27}$ kg

Mass of electron
$m_e = 9.11 \times 10^{-31}$ kg

Permeability of free space
$\mu_o = 4\pi \times 10^{-7}$ N A^{-2}

Permittivity of free space
$\varepsilon_o = 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2}

Speed of light in vacuum
$c = 3.00 \times 10^8$ m s^{-1}