CONFIDENTIAL

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2013/2014

COURSE NAME	:	MECHANICS PHYSICS
COURSE CODE	:	BWC 10103
PROGRAMME	:	1 BWC
EXAMINATION DATE	:	DECEMBER 2013/JANUARY 2014
DURATION	:	3 HOURS
INSTRUCTION	:	A) ANSWER **ALL** QUESTIONS IN SECTION A B) ANSWER **THREE (3)** QUESTIONS IN SECTION B

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

SECTION A

Q1 (a) What is the difference between Lagrangian and Hamiltonion mechanics

(4 marks)

(b) Consider a mass-spring system is moving in one dimension parameterised by the coordinate x. The particle is subject to a conservative force whose potential is $U(x)$ and $K(v)$.

(i) Write down the Lagrangian of the system, $L(x, v)$.

(2 marks)

(ii) Write down the Lagrange equations for the system described in Q1(b)(i), and use them to show that the particle acceleration, a is equal to $-\frac{k}{m}x$

(6 marks)

(c) Consider the motion of a particle of mass m with one degree of freedom parameterised by a coordinate x in a potential $V(x)$.

(i) Explain how the Hamiltonian $H(p, x)$ is obtained from the Lagrangian, and write down its expression.

(4 marks)

(ii) Write down the Hamilton equations for the system described in Q1(c)(i).

(4 marks)

Q2 (a) A sphere is rotating with angular velocity, ω at coordinate point, $r = (5,5)$ in two dimensional xy-axis system. In this coordinates system, the sphere moving at a velocity, v and then accelerate with a magnitude of a. If the coordinates frame is rotated by 45° counter-clockwise, determine

(i) A new coordinates, $\boldsymbol{r}'$ for the sphere in the rotating coordinates System

(2 marks)

(i) Tangential velocity, $\boldsymbol{v}'$ in the rotating coordinates system

(2 marks)

(ii) Tangential acceleration, $\boldsymbol{a}'$ in the rotating coordinates system

(2 marks)

(b) Two asteroids X and Y of equal masses of $M = 3.5\times10^{18}$ kg are located 3.00 km apart as shown in Figure **Q2(b)**. The gravitational constant, G= 6.674 x 10^{-11} $N(m/kg)^2$. What is the net gravitational force of the spaceship with mass $m = 2.50\times10^{7}$ kg when it is located,

(i) At point A?

(4 marks)

(ii) At point B?

(4 marks)

(c) A satellite, S moves around a planet, P in an elliptical orbit as shown in Figure **Q2(c)**. What is the ratio of the speed of the satellite between point a and point b?

(6 marks)

SECTION B

Q3 (a) Three field quantities are given by

$$P = 2\mathbf{a}_x - \mathbf{a}_z$$
$$Q = 2\mathbf{a}_x - \mathbf{a}_y + 2\mathbf{a}_z$$
$$R = 2\mathbf{a}_x - 3\mathbf{a}_y + \mathbf{a}_z$$

Determine

(i) $(P+Q)\times(P-Q)$

(2 marks)

(ii) $Q \bullet R\times P$

(2 marks)

(iii) $\sin\theta_{QR}$

(2 marks)

(b) Write the rectangular coordinate location **A**(3, 4, 2) in the cylindrical coordinate system.

(4 marks)

(c) A function of ϕ is given by, $\phi = x^2y - xz^3$. Find the gradient of this function, $\nabla\phi$.

(4 marks)

(d) Find a unit vector normal to the surface, $x^2y + xz = 2$ at the point (1,-1,1)

(6 marks)

Q4 (a) A particle with a mass, m moves along a line so that at any time t, its position is given by $x(t) = 2\pi t + \sin(2\pi t)$

(i) Write an expression for the velocity $v\ (t)$ of the particle.

(2 marks)

(ii) Write an expression for the acceleration $a\ (t)$

(2 marks)

(b) Under a specific force field, ***F***, a particle of mass, $m = 3$ kg moves along a space curve with a position vector, r is given as a function of time, t by $r = (t^2 - 2t)\mathbf{i} + (t^3 + 3t^2)\mathbf{j} - 5t^2\mathbf{k}$

Find

(i) the vector unit of the momentum for the particle, ***P***

(4 marks)

(ii) the vector unit of the force field, ***F***

(4 marks)

(c) The force, ***F*** acting on a particle are $(6\mathbf{i} + 2\mathbf{j} + 3\mathbf{k}), (3\mathbf{i} - 2\mathbf{j} + 6\mathbf{k})$ and $(2\mathbf{i} - 3\mathbf{j} - 6\mathbf{k})$. The particle is displaced from $(5\mathbf{i} - \mathbf{j} - \mathbf{k})$ to $(2\mathbf{i} - \mathbf{j} - 3\mathbf{k})$.

Find

(i) the resultant force, ***F*** applied to this particle

(3 marks)

(ii) the displacement of this particle, ***r***.

(3 marks)

(iii) the work, W to move this particle

(2 marks)

Q5 (a) A particle performs simple harmonic motion with a period of 16 secs. At time $t = 2$ secs, the particle passes through the origin, while at $t = 4$ secs, its velocity, v is 4 ms^{-1}. Show that the amplitude of the motion is $\frac{32\sqrt{2}}{\pi}$

(6 marks)

(b) The block, having a mass of 7.5 kg, is immersed in a liquid as shown in Figure **Q5(b)**. The damping force acting on the block has a magnitude of $F = (12v)$ N, where v is the velocity of the block in ms^{-1}. If the block is pulled down 0.24 m and released from rest, determine the position of the block, x as a function of time, t. The spring constant, k of the spring is 600 Nm^{-1}. Consider positive displacement to be downward.

(6 marks)

(c) A mass-spring system is oscillated vertically under damped simple harmonic motion with natural angular frequency, ω as shown in Figure **Q5(c)**. As a maximum external force, F_{max} is applied to the system, its driving angular frequency, ω_d is reduced twice as of its natural angular frequency, ω.

(i) Determine a driving force, F_d of the system.

(4 marks)

(ii) Write the applied force, F as a function of time, t

(4 marks)

Q6 (a) A wheel has a constant angular acceleration, α of 4.0 radians per sec^2. The wheel turns through an angle of 150 radians in 3.0 sec time interval. If the wheel starts from rest, find its angular speed, ω as it rotates at 3.0 sec interval.

(4 marks)

(b) The angular speed of an engine is increased uniformly from 900 rpm to 2700 rpm in 15 sec.

(i) What is its angular velocity, ω?

(4 marks)

(ii) How many revolutions does the engine make in 15 sec?

(4 marks)

(c) A solid sphere of mass m is fastened to another sphere of mass $2m$ by a thin rod with a length of $3x$ as shown in Figure **Q6(c)**. The spheres have negligible size and the rod has negligible mass. What is the moment of inertia of the system of spheres as the rod is rotated about the point located at position x, as shown?

(8 marks)

Q7 (a) Center of mass of three bodies 10 g, 20 g and 25 g is at (1, -2, 1). Where should another 30 g body be placed, so that the center of mass is at (1, 1, 1)

(6 marks)

(b) A bowling ball is rotating at *z*-axis in the direction shown in Figure **Q7(b)**. The ball has mass, *m* of 6 kg and radius, *r* of 12 cm. If it is spinning at 10 rev/sec, find

(i) Moment inertia of the sphere, *I*

(2 marks)

(ii) The magnitude and the direction of its angular momentum, *L*

(2 marks)

(iii) The direction of angular momentum, *L* as it rotates in reverse order.

(2 marks)

(c) A uniform rod of length, L = 1m and mass, M = 1kg is pivoted freely at one end as shown in Figure **Q7(c)**. As it is released from its initial vertical position, it swings counter-clockwise at $\theta = 30^\circ$ with respect to the original position.

(i) What is the angular acceleration, α of the rod at $\theta = 30^\circ$

(4 marks)

(ii) What is the tangential linear acceleration, *a* of the free end when the rod is horizontal?

(4 marks)

-END OF QUESTION-

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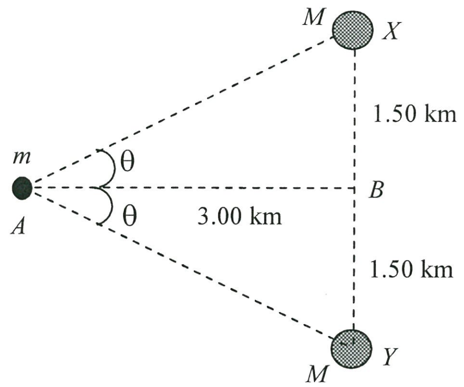

FIGURE Q2(b)

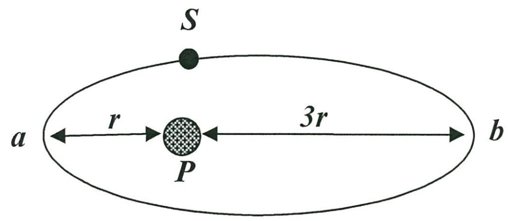

FIGURE Q2 (c)

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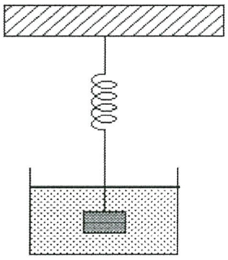

FIGURE Q5(b)

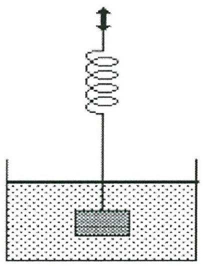

FIGURE Q5(c)

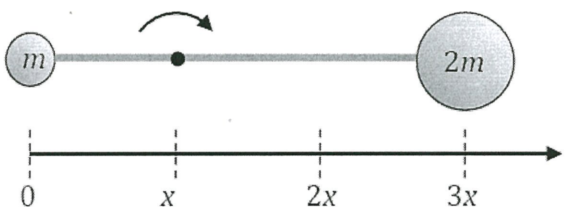

FIGURE Q6(c)

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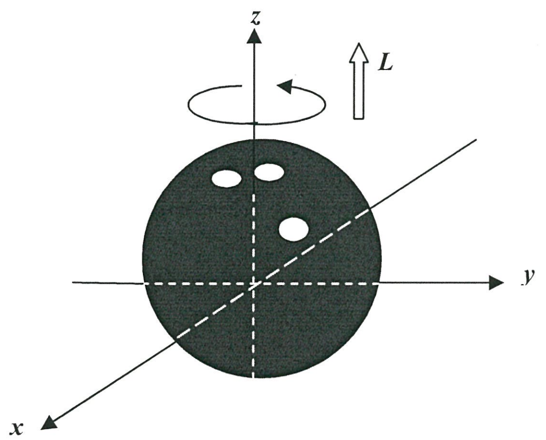

FIGURE Q7(b)

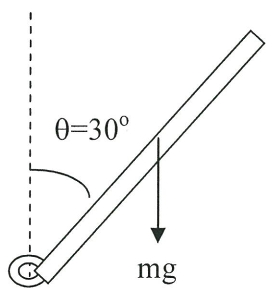

FIGURE Q7(c)

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LIST OF FORMULA

$L = K - U$ $\quad \frac{d}{dt}\left(\frac{\partial L}{\partial v}\right) - \frac{\partial L}{\partial x} = 0$	$\frac{dx}{dt} = \frac{\partial H}{\partial p}$ $\frac{dp}{dt} = -\frac{\partial H}{\partial x}$
$v = v' + \omega r'$ $a = a' + 2\omega v' + (d\omega / dt)r' + \omega^2 r')$	$F = -G\frac{m_1 m_2}{R^2}$
$A \cdot B = AB\cos\theta_{AB}$	$A \times B = AB\sin\theta_{AB}$
$x = \rho \cdot \sin(\varphi) \cdot \cos(\theta)$ $\quad y = \rho \cdot \sin(\varphi) \cdot \sin(\theta)$ $z = \rho \cdot \cos(\varphi)$ $\rho^2 = x^2 + y^2 + z^2$ $\quad \tan\left(\theta = \frac{y}{x}\right)$ $\cos(\varphi) = \frac{z}{\sqrt{x^2 + y^2 + z^2}} = \frac{z}{\rho}$	$\nabla f(x, y) = \frac{\partial f}{\partial x} i + \frac{\partial f}{\partial y} j + \frac{\partial f}{\partial z} k$ $\hat{n} = \frac{A}{\lvert A \rvert}$
$\frac{d}{dx}(\sin x) = \cos(x)$	$\frac{d}{dx}(\cos x) = -\sin(x)$
$F = ma$	$F = -kx$
$x(t) = A\cos(\omega t + \phi)$	$\omega = \sqrt{\frac{k}{m}}$
$F = -kx - bv = ma$	$x(t) = x_o \cos\left(\sqrt{\frac{k}{m}} t\right)$
$x(t) = Ae^{-(b/2m)t}\cos(\omega' t + \phi)$ $\quad F(t) = F_{\max}\cos(\omega_d t)$	$y = y_o + y_{o_y} t + \frac{1}{2} a_y t^2$
$x = x_o + v_{o_x} t + \frac{1}{2} a_x t^2$ $X_{cm} = \frac{\sum m_i X_i}{\sum m_i}$, $Y_{cm} = \frac{\sum m_i Y_i}{\sum m_i}$, $Z_{cm} = \frac{\sum m_i Z_i}{\sum m_i}$	$I_{sphere} = \frac{2}{5} MR^2$ $I_{rod} = \frac{1}{3} ML^2$ $L = I\omega$, $\quad \tau = F \times r$
$\mathrm{r} = x\mathbf{i} + y\mathbf{j} + z\mathbf{k}$ $v = \frac{dr}{dt} i + \frac{dr}{dt} j + \frac{dr}{dt} k$ $a = \frac{dv}{dt} i + \frac{dv}{dt} j + \frac{dv}{dt} k$	$v = \omega r$ $\quad a = \omega^2 r$ $T = \frac{2\pi}{\omega}$