UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2014/2015

COURSE NAME	:	MECHANICS PHYSICS
COURSE CODE	:	BWC 10103
PROGRAMME	:	1 BWC
EXAMINATION DATE	:	DECEMBER 2014 / JANUARY 2015
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS IN SECTION A 2. ANSWER **THREE (3)** QUESTIONS ONLY IN SECTION B

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

SECTION A

Q1 (a) What is the different 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 subjected 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 Q(b)(i), and use them to show that the particle acceleration, a is equal to $-\frac{k}{m}x$

(8 marks)

(c) Consider the motion of a particle of mass m with one degree of freedom parameterised by a coordinate x in a potential $V(x)$. Explain how the Hamiltonian $H(p, x)$ is obtained from the Lagrangian, and write down its expression.

(6 marks)

Q2 (a) A sphere is rotating with angular velocity, ω at coordinate point, $\boldsymbol{r} = (5, 5)$ in two dimensional xy-axis system. In this coordinates system, the sphere moves at a velocity, v then accelerates 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)

(ii) tangential velocity, $\boldsymbol{v}'$ in the rotating coordinates system.

(2 marks)

(iii) 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, $G = 6.674\text{x}10^{11}\text{N(m/kg)}^2$. 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, $\phi = x^2 y - xz^3$. Find the gradient of this function, $\nabla\phi$

(4 marks)

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

(2 marks)

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

(2 marks)

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

(i) the resultant force, $\boldsymbol{F}$ applied to this particle.

(4 marks)

(ii) the displacement of this particle, $\boldsymbol{r}$.

(4 marks)

(iii) the work, W to move this particle.

(4 marks)

Q5 (a) A particle performs simple harmonic motion with a period of 16 s. At time $t = 2$ s, the particle passes through the origin, while at $t = 4$ s, 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 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 show 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 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) The rotational inertia of an object shown in Figure **Q6 (a)** depends not only on its mass distribution but also on the location of the axis of rotation.

(i) Show that the moment of inertia of a uniform hollow cylinder of inner radius R_1, outer radius R_2, and mass M, is $I = ½\ M(R_1^2 + R_2^2)$, if the rotation axis is through the center along the axis of symmetry.

(10 marks)

(ii) Obtain the moment of inertia for a solid cylinder.

(2 marks)

(b) A small child runs and jumps onto a merry-go-round which has a moment of inertia, I_0 about its axis of rotation is shown in Figure **Q6 (b)**. The child has mass, m and is initially moving with velocity, v, grabs onto a bar attached to the plate which is a distance, R from the center of the merry-go-round. The merry-go-round was initially not rotating. Assume that the child is running tangential to the merry-go-round before jumping on as shown. What fraction of the initial kinetic energy of the running child remains in the final system (i.e. what is KE_f/KE_i)? Give your answer in terms of I_0, m, v, R.

(8 marks)

Q7 (a) A system that is rotationally imbalanced will not have its angular momentum and angular velocity vectors in the same direction shown in Figure **Q7(a)**. A torque is required to keep an unbalanced system rotating. Determine the magnitude of the net torque, τ_{net} needed to keep the illustrated system turning.

(12 marks)

(b) A baseball of mass 0.15 kg is initially traveling horizontally at 50 m/s. It is struck by a bat, after which the baseball is still travelling horizontally but in exactly the opposite direction from its initial motion at a speed of 40 m/s. Consider the collision of the bat and the ball which is shown in Figure **Q7 (b)**. Assume that before the collision, the bat is moving in a horizontal circle at an angular velocity of ω rad/s. Assume that the player holding the bat exerts no torque. The bat has a moment of inertia of 0.30 kgm^2 about the pivot and the ball hits at a point that is 80 cm away from the pivot. After the collision, the bat is still swinging in the same direction around the same pivot but with a reduced angular velocity of 0.35 ω. Find the numerical value of ω.

(8 marks)

-END OF THE QUESTION-

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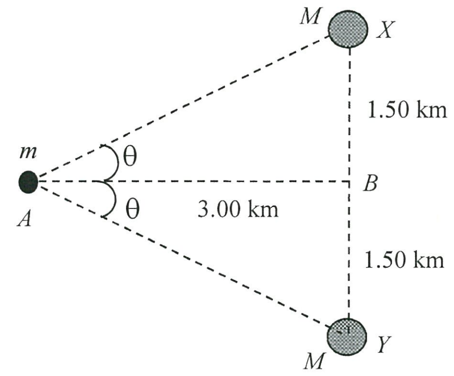

FIGURE Q2(b)

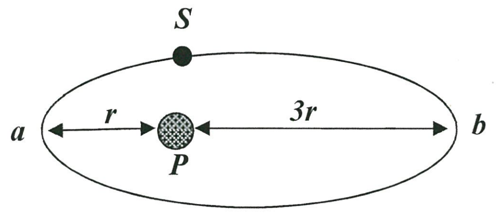

FIGURE Q2(c)

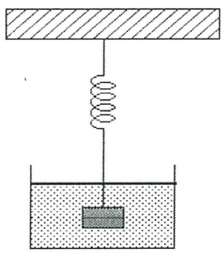

FIGURE Q5(b)

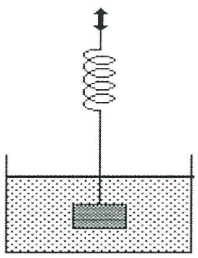

FIGURE Q5(c)

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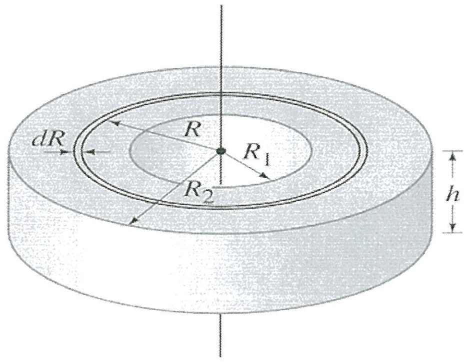

FIGURE Q6(a)

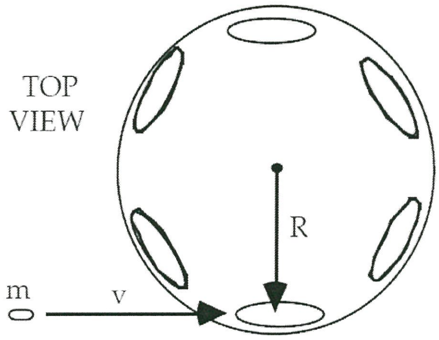

FIGURE Q6(b)

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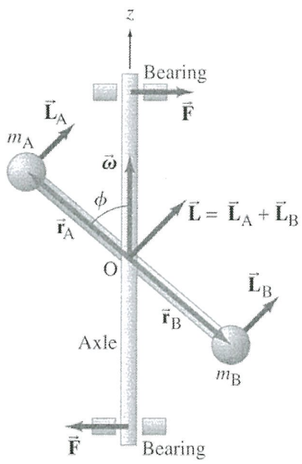

FIGURE Q7(a)

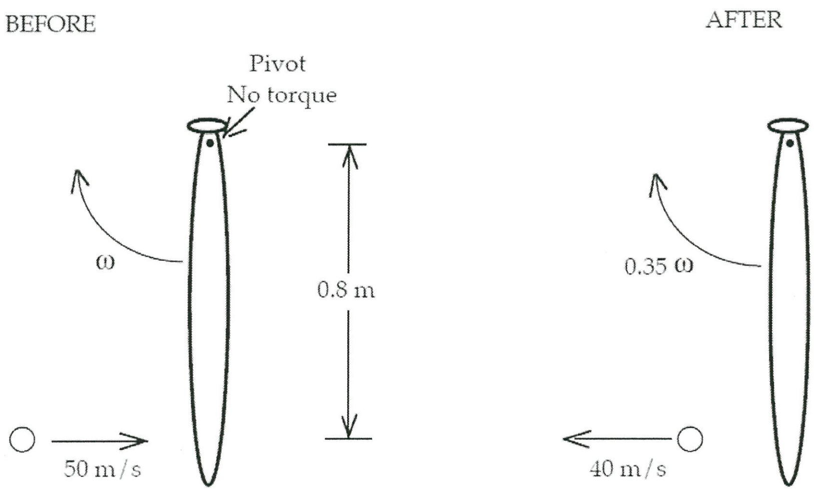

FIGURE Q7(b)

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LIST OF FORMULA

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