Stu. No.: ____________________

PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. A satellite orbiting the Earth in a stable circular orbit of radius r_1 has an orbital speed of v_1. Another, identical, satellite is in a stable circular orbit twice as far from the centre of the Earth. The orbital speed of the second satellite is

D

(A) $v_2 = 2v_1$ (B) $v_2 = \frac{1}{v_1}$ (C) $v_2 = 4v_1$ (D) $v_2 = \frac{v_1}{\sqrt{2}}$ (E) $v_2 = \sqrt{2} \times v_1$

$F_{grav} = ma_c$

$\frac{GM_E m}{r_1^2} = \frac{mv_1^2}{r_1}$

$v_1 = \sqrt{\frac{GM_E}{r_1}}$; $v_2 = \sqrt{\frac{GM_E}{r_2}} = \sqrt{\frac{GM_E}{2r_1}}$

$v_2 = \frac{v_1}{\sqrt{2}}$

A2. Which one of the following forces is conservative?

C

(A) The normal force.
(B) Air resistance.
(C) The gravitational force.
(D) The static frictional force.
(E) Tension.

A3. Which one of the following statements concerning an object in uniform circular motion is ***NOT*** correct?

v, r constant

E

(A) The centripetal force acts inward toward the centre of rotation.
(B) The magnitude of the centripetal acceleration is constant.
(C) The magnitude of the velocity is constant.
(D) The centripetal force is due to the other forces acting on the object.
(E) The object is in equilibrium. $\Rightarrow \Sigma\vec{F} = 0$, but $\Sigma F = ma_c$ for circular motion.

A4. Suppose you are standing on the edge of a platform and jump straight down to the ground. Which one of the following statements best explains why you should bend your knees as your feet hit the ground?

D

(A) Bending your knees decreases the impulse that the ground exerts on you as you come to rest.
(B) Bending your knees decreases the change in momentum that you undergo as you come to rest.
(C) Bending your knees decreases the time over which the force of the ground brings you to rest.
(D) Bending your knees decreases the average force that the ground exerts on you as you come to rest.
(E) Bending your knees decreases your mass.

Impulse - Momentum Theorem
$\vec{F}\Delta t = \Delta\vec{p}$ $\therefore$ increasing Δt decreases $\vec{F}$.

A5. Two identical hockey pucks collide on a frictionless ice surface. The collision is elastic. Which one of the following statements is ***NOT*** correct?

D

(A) The total kinetic energy is conserved.
(B) The total momentum in the x direction is conserved.
(C) The total momentum in the y direction is conserved.
(D) The kinetic energy of each puck must be equal after the collision.
(E) The net external force acting on the two pucks is zero.

KE is conserved
$\vec{p}$ (p_x and p_y) is conserved.

continued on page 3 ...

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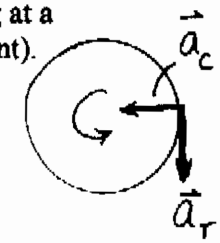
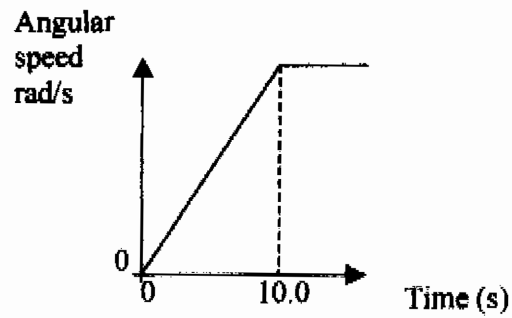
A6. You are standing on the edge of a rotating horizontal platform. The platform is rotating at a steadily decreasing angular velocity (the motor has been turned off and friction is present). Which one of the following statements is correct concerning your total acceleration?



E

(A) Your total acceleration is directed opposite to your tangential velocity.
(B) Your total acceleration is directed in the same direction as your tangential velocity.
(C) Your total acceleration is directed radially toward the centre of the platform.
(D) Your total acceleration is directed radially away from the centre of the platform.
(E) Your total acceleration has a component directed radially toward the centre of the platform and a component directed opposite to your tangential velocity.

A7. The graph shows angular speed versus time for rotating blades on a lawnmower. Which one of the following statements is ***NOT*** correct?



D

(A) The blades start from rest at $t = 0$.
(B) The angular speed is constant from $t = 10$ s onward.
(C) The magnitude of the angular acceleration is constant from $t = 0$ to 10 s.
(D) The magnitude of the angular displacement is directly proportional to the time from $t = 0$ to 10 s.
(E) The magnitude of the angular displacement is directly proportional to the time from $t = 10$ s onward.

A8. Is it possible for a 1 N force and a 2 N force to exert the same torque?

$\tau = F\ell$

C

(A) No.
(B) Yes, if the 1 N force has a lever arm that is half that of the 2 N force.
(C) Yes, if the 1 N force has a lever arm that is twice that of the 2 N force.
(D) Yes, if the 1 N force has a lever arm that is one-quarter that of the 2 N force.
(E) Yes, if the 1 N force has a lever arm that is four times that of the 2 N force.

A9. Consider each of the following four objects: a hoop, a solid disk, a solid sphere, and a hollow sphere. Each object has a mass M and a radius R. The axis of rotation passes through the centre of each object, and is perpendicular to the plane of the hoop and the plane of the solid disk. Which object requires the largest torque to give it the same angular acceleration?

A

$\sum \tau = I\alpha$

(A) the hoop (B) the solid disk (C) the solid sphere
(D) the hollow sphere (E) each requires the same torque

$I_{hoop} = MR^2$ is largest

A10. It is observed that a figure skater spinning on one skate, with both arms and one leg outstretched, can increase her angular velocity by pulling in her arms and leg toward the axis of rotation. This increase in angular velocity occurs because

C

$I_1\omega_1 = I_2\omega_2$

(A) both her angular momentum and her moment of inertia increase.
(B) her angular momentum is conserved and her moment of inertia increases.
(C) her angular momentum is conserved and her moment of inertia decreases.
(D) her angular momentum increases and her moment of inertia decreases.
(E) both her angular momentum and her moment of inertia decrease.

continued on page 4 ...

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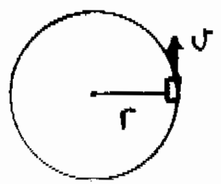
PART B

FOR EACH OF THE FOLLOWING PROBLEMS, WORK OUT THE SOLUTION IN THE SPACE PROVIDED AND ENTER YOUR ANSWERS ON PAGE 6.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1. Calculate the time for a race car travelling at a constant speed of 90.0 m/s to travel once around a circular track of radius 1850 m.

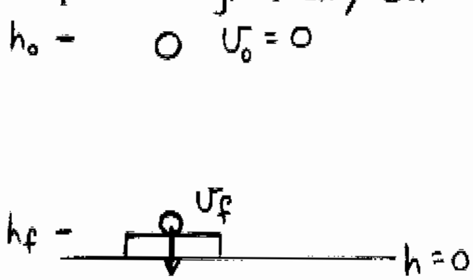


T = Period,

$$v = \frac{2\pi r}{T} \Rightarrow T = \frac{2\pi r}{v} = \frac{2\pi\,(1850\text{m})}{90.0\text{m/s}}$$

$$T = 129\text{s}$$

B2. A ball of mass 0.230 kg is dropped from rest from a height of 1.83 m above the floor and lands on a platform 0.109 m above the floor. Calculate the speed of the ball just before it hits the platform. Ignore any effects due to air resistance.



Cons. of Mechanical Energy

$$E_f = E_o$$

$$KE_f + PE_f = KE_o + PE_o$$

$$KE_f = KE_o + PE_o - PE_f$$

$$\frac{1}{2}mv_f^2 = 0 + mgh_o - mgh_f$$

$$v_f = \sqrt{2g(h_o - h_f)}$$

$$v_f = \left[2\,(9.80\text{m/s}^2)(1.83\text{m} - 0.109\text{m})\right]^{1/2} = 5.81\text{m/s}$$

continued on page 5 ...

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B3. A soccer player kicks a stationary ball of mass 0.402 kg. The duration of the kick is 0.0925 s and the ball has a final velocity after the kick of +17.5 m/s. Calculate the magnitude of the average force exerted on the ball. by the player.

$\vec{F} \longrightarrow \bigcirc \longrightarrow \vec{v}_f$

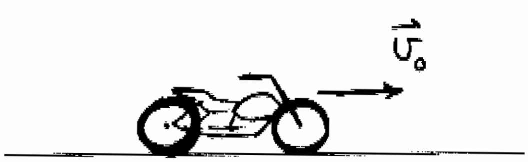
Impulse- Momentum Theorem:

$$\vec{F}\Delta t = \Delta\vec{p}$$

$$|\vec{F}| = \frac{|\Delta\vec{p}|}{\Delta t} = \frac{p_f - p_0}{\Delta t} = \frac{mv_f - mv_0}{\Delta t} = \frac{mv_f}{\Delta t} \quad (v_0 = 0)$$

$$|\vec{F}| = \frac{(0.402\,kg)(17.5\,m/s)}{0.0925\,s} = 76.1\,N$$

B4. As a motorcycle approaches an intersection, the rider applies the brakes and the motorcycle wheels have a constant angular acceleration of magnitude 8.71 rad/s^2 as the motorcycle comes to rest in a time of 8.60 s. Given that the radius of the motorcycle tires is 0.284 m, calculate the **linear** speed of the motorcycle before the brakes were applied.



$v_0 = r\omega_0$

and

$\omega = \omega_0 + \alpha t$

$\therefore \; \omega - \alpha t = \omega_0$

$r = 0.284\,m$

$\alpha = 8.71\,rad/s^2$

$t = 8.60\,s$

$\omega = 0$

$$v_0 = r\omega_0 = r(\omega - \alpha t) = -r\alpha t \quad (\omega_0 \text{ is -ve since CW})$$

$$v_0 = |-(0.284\,m)(8.71\,rad/s^2)(8.60\,s)|$$

$$v_0 = 21.3\,m/s$$

continued on page 6 ...

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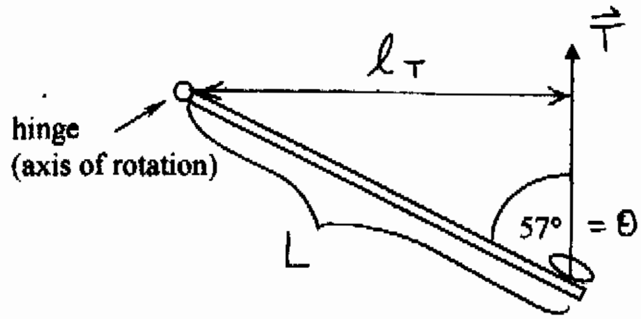
B5. A string is tied to a doorknob at a distance of 0.790 m from the hinge as shown. At the instant shown, the tension in the string is 5.20 N. Calculate the torque on the door due to the tension in the string.



$\tau = T\ell_T$

where $\ell_T = L\sin\theta$

$\tau = TL\sin\theta = (5.20\,N)(0.790\,m)(\sin 57.0°)$

$\tau = 3.45\ N\cdot m$

ANSWERS FOR PART B

ENTER THE ANSWERS FOR THE PART B PROBLEMS IN THE BOXES BELOW.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1	129 s
B2	5.81 m/s
B3	76.1 N
B4	21.3 m/s
B5	3.45 N·m

continued on page 7 ...

PART C

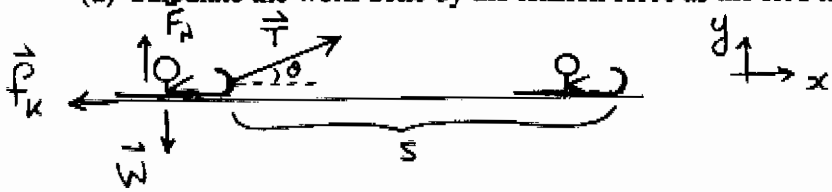
IN EACH OF THE FOLLOWING QUESTIONS, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

<u>SHOW YOUR WORK</u>. NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY. EQUATIONS NOT PROVIDED ON THE FORMULA SHEET MUST BE DERIVED.

C1. A boy is pulling a sled, with his younger sister on it, across a horizontal 10.0-m-long patch of grass by pulling on a rope attached to the sled. The total weight of the girl and sled is 392 N (total mass of 40.0 kg). The tension in the rope is 130 N and the rope makes an angle of ~~30.0°~~ 29.6° with the horizontal. The coefficient of kinetic friction between the sled and the grass is ~~0.350~~. 0.348

(a) Calculate the work done by the tension force as the sled is pulled across the grass.



$$\boxed{1.13 \times 10^3\ J}$$

$$W = (F\cos\theta)s$$

$$W_T = (130N \cos 29.6°)(10.0m) = 1.13 \times 10^3\ J$$

ALTERNATE SOL'N FOR (b):

$$W_{f_k} = (f_k \cos 180°)(s) \quad \text{and} \quad f_k = \mu_k F_N$$

since $\Sigma F_y = 0$, $F_N + T\sin\theta - W = 0$

$$F_N = W - T\sin\theta$$

$$\therefore W_{f_k} = \mu_k (W - T\sin\theta)(\cos 180°)s$$

$$W_{f_k} = -1.14 \times 10^3\ J$$

(b) Given that the speed of the sled before it reached the patch of grass was 0.800 m/s and the speed at the other side of the patch of grass is 0.324 m/s, calculate the work done by the kinetic frictional force as the sled is pulled across the patch of grass.

$$\boxed{-1.14 \times 10^3\ J}$$

Recall Work-Energy Theorem:

$$W_{net} = \Delta KE$$

Since $\vec{W}$ and $\vec{F}_N$ are $\perp$ to $\vec{s}$, they do no work

$$\therefore W_{net} = W_{f_k} + W_T$$

so $W_{f_k} + W_T = KE_f - KE_0$

$$W_{f_k} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_0^2 - W_T = \tfrac{1}{2}(40.0kg)\left[(0.324 m/s)^2 - (0.800 m/s)^2\right] - 1.13 \times 10^3\ J$$

$$W_{f_k} = -1.14 \times 10^3\ J$$

continued on page 8

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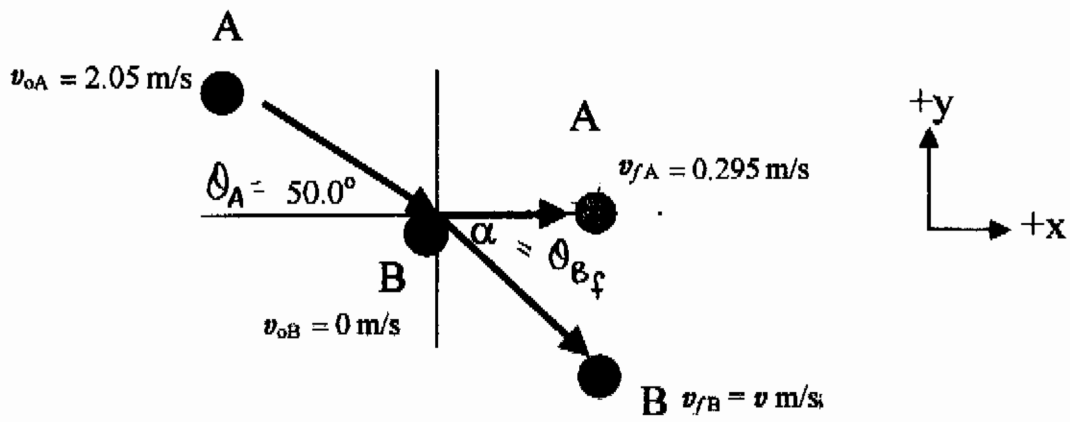
C2. Two billiard balls of identical mass collide on a frictionless table. Initially ball B is at rest. Ball A has a speed of 2.05 m/s and strikes ball B at an angle of 50.0° with respect to the negative x axis (see diagram). After the collision, ball A has a speed of 0.295 m/s directed along the positive x axis and ball B has a speed v m/s directed at an angle α to the positive x axis.



(a) Calculate v and α.

Linear momentum is conserved.

$\boxed{v = 1.87\ m/s}$

$\alpha = 56.9°$

$P_{f_{x_{tot}}} = P_{o_{x_{tot}}}$ and $P_{f_{y_{tot}}} = P_{o_{y_{tot}}}$

x-dir'n: $\cancel{m} v_{f_{B_x}} + \cancel{m} v_{f_A} = \cancel{m} v_{o_A} \cos\theta_A$

$v_{f_{B_x}} = v_{o_A}\cos\theta_A - v_{f_A} = (2.05\,m/s)(\cos 50.0°) - 0.295\,m/s$

$v_{f_{B_x}} = 1.023\,m/s$

y-dir'n: $\cancel{m} v_{f_{B_y}} + 0 = -\cancel{m} v_{o_A} \sin\theta_A$

$v_{f_{B_y}} = -v_{o_A}\sin\theta_A = -(2.05\,m/s)(\sin 50.0°) = 1.57\,m/s$

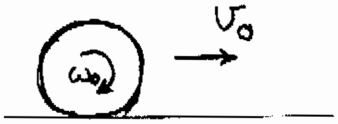
$\therefore\ v_{f_B} = v = \sqrt{v_{f_{B_x}}^2 + v_{f_{B_y}}^2} = 1.87\,m/s$ @

$\theta_{B_f} = \alpha = \text{invtan}\left(\frac{v_{f_{B_y}}}{v_{f_{B_x}}}\right) = \text{invtan}\left(\frac{1.57\,m/s}{1.023\,m/s}\right) = 56.9°$ below $+x$-axis

continued on page 9 ...

C3. A 2.45-kg solid cylinder of radius 0.508 m rolls without slipping along a flat horizontal surface, rotating at a rate of ~~41.5~~ 41.1 rad/s about its cylindrical axis.

(a) Calculate the magnitude of the tangential velocity of a point on the rim of the cylinder.



$\boxed{20.9\ \text{m/s}}$

$$v_T = r\omega_0$$

$$v_T = (0.508\,\text{m})(41.1\ \text{rad/s})$$

$$v_T = 20.9\ \text{m/s}$$

(b) Calculate the moment of inertia of the rolling cylinder.

$\boxed{0.316\ \text{kg}\cdot\text{m}^2}$

solid cylinder, $I = \frac{1}{2}mr^2$

$$I = \frac{1}{2}(2.45\,\text{kg})(0.508\,\text{m})^2 = 0.316\ \text{kg}\cdot\text{m}^2$$

(c) Calculate the average power required to bring the cylinder to rest in 10.0 s.

$\boxed{80.2\ \text{W}}$

$$\bar{P} = \frac{\Delta E}{t} = \frac{\Delta KE}{t} \quad \text{since} \quad \Delta PE = 0$$

$KE_f = 0$ (rest)

$$KE_0 = \frac{1}{2}mv_0^2 + \frac{1}{2}I\omega_0^2$$

$$KE_0 = \frac{1}{2}(2.45\,\text{kg})(20.9\,\text{m/s})^2 + \frac{1}{2}(0.316\,\text{kg}\cdot\text{m}^2)(41.1\,\text{rad/s})^2$$

$$KE_0 = 802\ \text{J}$$

$$\bar{P} = \frac{KE_0}{t} = \frac{802\ \text{J}}{10.0\,\text{s}} = 80.2\ \text{W}$$

END OF EXAMINATION