PART A

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

A1. Consider a satellite in a stable circular orbit around the Earth. The radius of the orbit is equal to twice the radius of the Earth. It is observed that the contents of the satellite appear to be weightless. Which one of the following statements best describes the reason for the apparent weightlessness?

(D)

- (A) The gravitational force of the Earth on the satellite's contents is so small as to be negligible.
- (B) The Satellite's contents experience a 'heavenly body' force that is equal and opposite to the gravitational force of the Earth.
- (C) The speed of the satellite is so great that the gravitational force of the Earth on the satellite's contents is negligible.
- (D) The gravitational force of the Earth acts on the satellite and its contents to provide the necessary centripetal acceleration. Thus both the satellite and its contents are in 'free fall'.
- (E) The necessary centripetal acceleration is provided by the satellite's rockets engines, thus the gravitational force no longer influences the satellite's contents.

A2. Which one of the following statements is **FALSE** for a satellite in a stable circular orbit around the Earth?

(C)

- (A) The speed of the satellite depends on the Universal Gravitational Constant.
- (B) The speed of the satellite depends on the mass of the Earth.
- (C) The speed of the satellite depends on the mass of the satellite.
- (D) The speed of the satellite depends on the radius of the orbit.
- (E) The speed of the satellite depends on the height of the satellite above the Earth's surface.

$F_g = ma_c$

$\therefore \frac{GM_E m}{r^2} = m\frac{v^2}{r}$

$\therefore v = \sqrt{\frac{GM_E}{r}}$

A3. A stone is tied to the end of a string and whirled in a vertical circle so that the stone always has a constant speed. Which one of the following statements is **FALSE**?

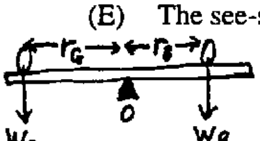
(C)

- (A) The period of the stone's circular motion is constant.
- (B) The tension in the string varies throughout the circle.
- (C) The string is most likely to break when the stone is at the top of the circle.
- (D) The magnitude of the centripetal acceleration of the stone is constant throughout the circle.
- (E) The velocity of the stone changes throughout the circle.

A4. A heavy boy and a light girl are sitting on a massive see-saw (teeter-totter) at distances from the pivot point such that the see-saw is balanced. (Assume the see-saw is balanced when no riders are on it.) If both the girl and the boy move forward so that they are each now one-half their original distances from the pivot point, what will happen to the see-saw?

(E)

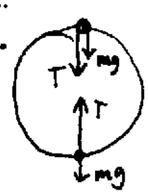
- (A) The side the boy is sitting on will tilt downward.
- (B) The side the girl is sitting on will tilt downward.
- (C) The side with the shortest distance between the pivot point and the child will tilt downward.
- (D) The side with the longest distance between the pivot point and the child will tilt downward.
- (E) The see-saw will remain balanced.



before moving: $\Sigma\tau_O = W_G r_G - W_B r_B = 0$

After moving: $\Sigma\tau_O = W_G \frac{r_G}{2} - W_B \frac{r_B}{2} = 0$

A3.



At top: $T + mg = m\frac{v^2}{r}$

At bottom: $T - mg = m\frac{v^2}{r}$

$v =$ constant $\therefore a_c = \frac{v^2}{r} =$ constant.

$\therefore$ T varies

T maximum at bottom $\therefore$ String most likely to break at bottom.

continued on Page 3...

A5. Complete the following statement: A force that acts on an object is said to be conservative if

(D)

(A) it obeys Newton's Laws of Motion.
(B) it results in a change in the object's kinetic energy.
(C) it always acts in the direction of motion of the object.
(D) the work it does on the object is independent of the path of the motion.
(E) the work it does on the object is equal to the increase in the object's kinetic energy.

A6. A stationary bomb explodes in gravity-free space breaking into a number of small fragments. Which one of the following statements concerning this event is true?

(D)

(A) Kinetic energy is conserved in the process.
(B) The fragments must have equal kinetic energies.
(C) The sum of the kinetic energies of the fragments must be zero.
(D) The vector sum of the linear momenta of the fragments must be zero.
(E) The velocity of any one fragment must be equal to the velocity of any other fragment.

A7. Which one of the following statements is correct concerning the impulse experienced by an object?

(C)

(A) Impulse equals the rate of change of the object's momentum.
(B) Impulse equals the product of the net force acting on the object and the object's displacement.
(C) Impulse equals the change in the object's momentum.
(D) Impulse equals the rate of change of the object's kinetic energy.
(E) Impulse equals the product of the net force acting on the object and the object's velocity.

A8. A boy and a girl are riding on a merry-go-round that is turning at a constant rate. The boy is near the outer rim and the girl is closer to the centre. Which one of the following statements is correct?

(E)

(A) The girl has greater angular acceleration than the boy.
(B) The girl has greater angular velocity than the boy.
(C) The girl has greater centripetal acceleration than the boy.
(D) The girl has greater tangential speed than the boy.
(E) The girl and boy have equal angular velocities.

A9. When analyzing the condition for rotational equilibrium of a body, one takes the sum of the torques about an axis of rotation. This axis of rotation

(E)

(A) must pass through the body's centre of gravity.
(B) must pass through the line of action of the forces acting on the body.
(C) must pass through the centre of the body.
(D) must pass through the point about which the body is rotating.
(E) may be chosen anywhere.

A10. Two uniform solid spheres, A and B, have the same mass. The radius of sphere B is twice that of sphere A. The axis of rotation passes through the centre of each sphere. Which one of the following statements concerning the moments of inertia of these spheres is true?

(A)

(A) The moment of inertia of sphere A is one-fourth that of sphere B. $I \propto r^2$
(B) The moment of inertia of sphere A is one-half that of sphere B.
(C) The moment of inertia of sphere A is 5/4 times that of sphere B.
(D) The moment of inertia of sphere A is 5/8 times that of sphere B.
(E) The two spheres have equal moments of inertia.

continued on page 4 ...

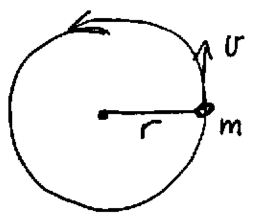
Student No.: ____________________

PART B

FOR EACH OF THE FOLLOWING PROBLEMS, B1 TO B5, ON PAGES 4 TO 6, WORK OUT THE SOLUTION IN THE SPACE PROVIDED AND ENTER YOUR ANSWERS ON PAGE 6.

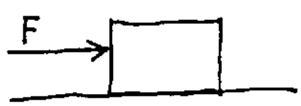
ONLY THE ANSWERS WILL BE MARKED. THE SOLUTIONS WILL NOT BE MARKED.

B1. A child of mass 25.0 kg is sitting on a horizontal merry-go-round at a distance of 1.10 m from its centre. The merry-go-round rotates at a constant rate and the child has a speed of 1.35 m/s. Calculate the magnitude of the net force exerted on the child.



$$F_{net} = m a_c = m \frac{v^2}{r} = \frac{(25.0\text{ kg})(1.35\text{ m/s})^2}{(1.10\text{ m})} = \underline{41.4\text{ N}}$$

B2. A man pushes a 100-kg box across a level floor at a constant speed of 2.00 m/s by applying a horizontal force on the box. The average power supplied by the man onto the box is 392 W. Calculate the magnitude of the average force that the man exerts on the box.



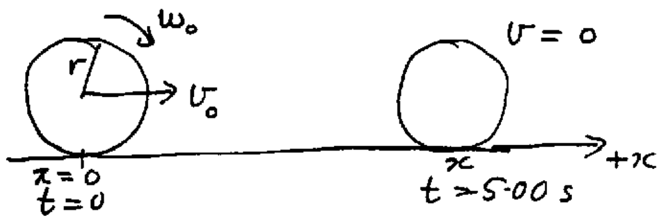
$\overline{P} = \overline{F} v$ $\quad v$ = constant.

$\overline{P}$ = average power supplied by average force $\overline{F}$

$$\overline{F} = \frac{\overline{P}}{v} = \frac{392\text{ W}}{2.00\text{ m/s}} = \underline{196\text{ N}}$$

continued on page 5 ...

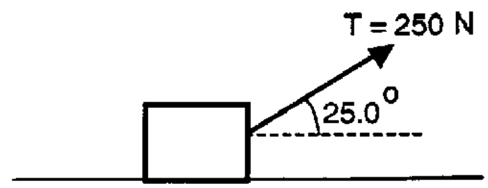
B3. A bicycle wheel of radius 0.700 m is rolling without slipping on a horizontal surface with an angular speed of 12.6 rad/s. The cyclist then applies the brakes uniformly and the bicycle comes to a stop in 5.00 s. How far did the bicycle travel during the 5.00 s of braking?



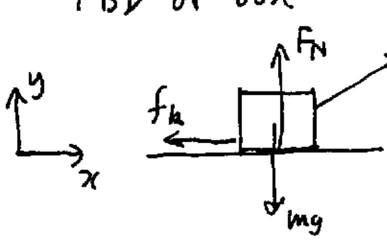
$v_0 = r\omega_0$
$v = 0$
$x = ?$
$t = 5.00$ s
$a = ?$

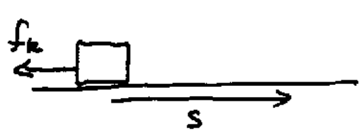
$$x = \frac{1}{2}(v_0 + v)t$$
$$= \frac{1}{2}(r\omega_0 + 0)t$$
$$= \frac{r\omega_0 t}{2}$$
$$= \frac{(0.700 \text{ s})(12.6 \text{ rad/s})(5.00 \text{ s})}{2}$$
$$= \underline{22.1 \text{ m}}$$

B4. A box is dragged at a constant velocity along a horizontal floor by means of a rope which is attached to the box and held at an angle of 25.0° above the horizontal as shown. The tension in the rope is 250 N. Calculate the work done by the friction force on the box when the box moves a horizontal distance of 1.25 m.



FBD of box





$W_f = f_k s \cos 180°$
$= -f_k s$

Constant velocity ∴ $a = 0$ equilibrium

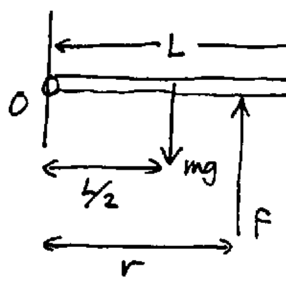
$$\Sigma F_x = T\cos 25° - f_k = 0$$
$$\Rightarrow f_k = T\cos 25°$$

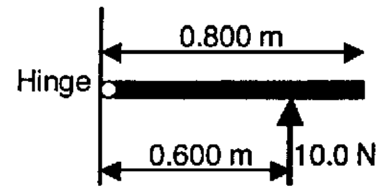
∴ Work done by friction force

$$W_f = -f_k s$$
$$= -T(\cos 25°)s$$
$$= -(250 \text{ N})\cos 25° (1.25 \text{ m})$$
$$= \underline{-283 \text{ J}}$$

continued on page 6 ...

B5. A uniform bar, of length 0.800 m, is attached by a frictionless hinge to a wall so that it is free to rotate in a vertical plane. The bar is held horizontal by a vertical force of 10.0 N applied at a point that is 0.600 m from the hinge. Calculate the mass of the bar.





Equilibrium: $\Sigma\tau = 0$

$$\Sigma\tau_{hinge} = Fr - mg\frac{L}{2} = 0$$

$$\Rightarrow \quad mg\frac{L}{2} = Fr$$

$$\Rightarrow \quad m = \frac{2Fr}{gL}$$

$$= \frac{2(10.0\,\mathrm{N})(0.600\,\mathrm{m})}{(9.80\,\mathrm{m/s^2})(0.800\,\mathrm{m})}$$

$$= \underline{1.53\ \mathrm{kg}}$$

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	41.4 N
B2	196 N
B3	22.1 m
B4	−283 J
B5	1.53 kg

continued on page 7 ...

Student No.: ____________________

PART C

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

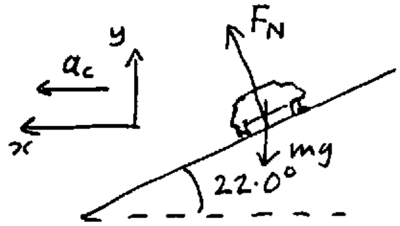
THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

SHOW YOUR WORK – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY. EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

C1. An expressway off-ramp curve of radius 50.0 m is banked at an angle of 22.0°. Calculate the speed at which a car can negotiate the curve when there is no friction between the car's tires and the road surface. Include a free body diagram of the forces on the car in your solution.

$\boxed{14.1 \text{ m/s}}$



Friction forces = 0

$$\Sigma F_x = F_N \sin 22° = m a_c = m\frac{v^2}{r} \quad (1)$$

$$\Sigma F_y = F_N \cos 22° - mg = 0 \quad (2)$$

From (2) $F_N = \dfrac{mg}{\cos 22°}$

$\therefore$ (1) $\Rightarrow \dfrac{\cancel{m}g}{\cos 22°}\sin 22° = \cancel{m}\dfrac{v^2}{r}$

$\Rightarrow g \tan 22° = \dfrac{v^2}{r}$

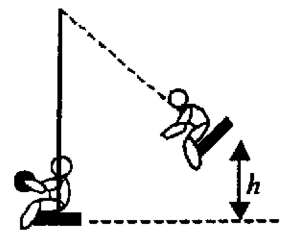
$\Rightarrow v = \sqrt{g r \tan 22°}$

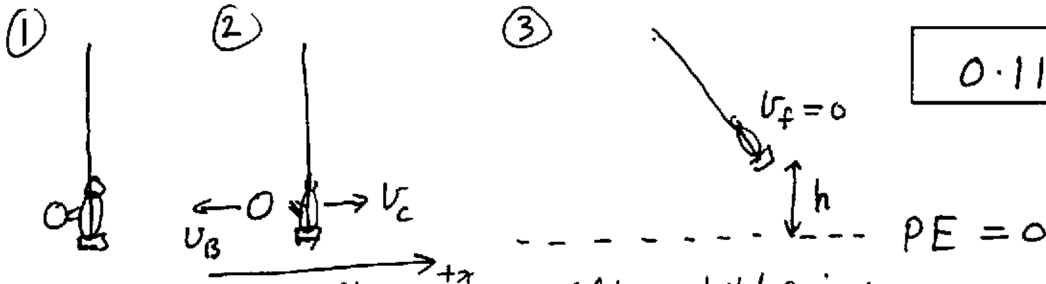
$= \sqrt{(9.80 \text{ m/s}^2)(50.0 \text{ m}) \tan 22.0°}$

$= \underline{14.1 \text{ m/s}}$

continued on page 8 ...

C2. A child of mass 20.0 kg is sitting at rest on a playground swing. The child is holding a ball of mass 2.50 kg. The child now throws the ball horizontally with a velocity of 12.0 m/s. Calculate the maximum height, *h*, to which the centre of gravity of the child on the swing rises above her original position. (Ignore any frictional effects and ignore the mass of the swing itself.)





Initially $v = 0$ | Just after ball thrown | After child swings to hieght h

$\boxed{0.115\ m}$

Situation ① to Situation ② use Conservation of Momentum

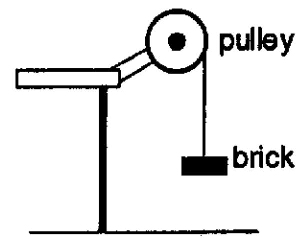
$$\vec{p}_o = \vec{p}_f$$
$$p_{ox} = p_{fx}$$
$$0 = m_c v_c - m_B v_B$$
$$\Rightarrow v_c = \frac{m_B v_B}{m_c} = \frac{(2.50\ kg)(12.0\ m/s)}{(20.0\ kg)}$$
$$= 1.50\ m/s$$

Situation ② to Situation ③ use Conservation of Mechanical Energy

$$E_o = E_f$$
$$KE_o + PE_o = KE_f + PE_f$$
$$\tfrac{1}{2} m_c v_c^2 + 0 = 0 + m_c g h$$
$$\Rightarrow h = \frac{v_c^2}{2g} = \frac{(1.50\ m/s)^2}{2\,(9.80\ m/s^2)}$$
$$= \underline{0.115\ m}$$

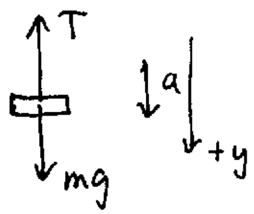
continued on page 9 ...

C3. A 4.60-kg brick is suspended by a light string that is wound around a pulley. The brick is released from rest and falls to the floor below. As it does so the pulley rotates and the string unwinds from the pulley. The pulley may be considered a solid disk of radius 1.50 m and mass 2.00 kg. (Assume the pulley has a frictionless axle and the string does not slip on the pulley.) Draw free body diagrams for the brick and the pulley and calculate the magnitude of the angular acceleration of the pulley as the brick is falling.



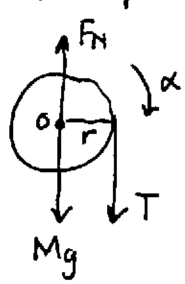
$$\boxed{5.37\ \text{rad/s}^2}$$

FBD for brick



$$\Sigma F_y = mg - T = ma \quad (1)$$

FBD for pulley



$$\Sigma \tau_0 = Tr = I\alpha \quad (2)$$

Now $I = I_{disk} = \frac{1}{2}Mr^2$

and $a = a_T = r\alpha$

From (1) $\Rightarrow T = mg - ma = mg - mr\alpha$

$\therefore$ (2) $\Rightarrow (mg - mr\alpha)r = \frac{1}{2}Mr^2\alpha$

$$\Rightarrow mg - mr\alpha = \frac{1}{2}Mr\alpha$$

$$\Rightarrow mg = \frac{1}{2}Mr\alpha + mr\alpha$$

$$\Rightarrow mg = \left(\frac{M}{2} + m\right)r\alpha$$

$$\Rightarrow \alpha = \frac{mg}{\left(\frac{M}{2}+m\right)r} = \frac{(4.60\text{ kg})(9.80\text{ m/s}^2)}{\left(\frac{2.00\text{ kg}}{2} + 4.60\text{ kg}\right)(1.50\text{ m})}$$

$$= \underline{5.37\ \text{rad/s}^2}$$

END OF EXAMINATION