PART A

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

A1. Two satellites move in the same orbit around the Earth. Satellite A has twice the mass of satellite B. Which statement is true?

(A)

- (A) The speed of B is equal to that of A.
- (B) The speed of B is twice that of A.
- (C) The speed of B is half that of A.
- (D) The speed of B is four times that of A.
- (E) The speed of B is one-fourth that of A.

$F_A = \frac{G M_E m_A}{r^2} = m_A a_c = m_A \frac{v_A^2}{r}$

$\Rightarrow v_A = \sqrt{\frac{G M_E}{r}}$

and $v_B = \sqrt{\frac{G M_E}{r}}$ independent of m_A or m_B

A2. A car goes around a curve of radius *r* at speed *v* and experiences a centripetal acceleration *a*. If the car is to go around the same curve at a speed 2*v*, the required centripetal acceleration is

(C)

(A) a (B) $2a$ (C) $4a$ (D) $\frac{1}{4}a$ (E) $\frac{1}{2}a$

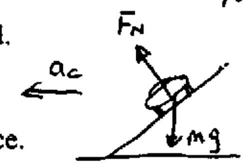
$a_c = \frac{v^2}{r} = a$

$\therefore a_2 = \frac{(2v)^2}{r} = 4\frac{v^2}{r} = 4a$

A3. Which one of the following forces causes the centripetal acceleration when a car negotiates a frictionless banked curve?

(B)

- (A) The vertical component of the normal force between the car and the road.
- (B) The horizontal component of the normal force between the car and the road.
- (C) The vertical component of the car's weight.
- (D) The horizontal component of the car's weight.
- (E) The component of the car's weight that is parallel to the banked road surface.



A4. A 4 kg mass is moving with speed 2 m/s, and a 2 kg mass is moving with speed 4 m/s, on a horizontal frictionless surface. Both objects encounter the same constant force, which directly opposes their motion, and are brought to rest by it. Which statement best describes the time it takes for each object to come to rest.

(E)

- (A) The 4 kg mass takes twice as long as the 2 kg mass.
- (B) The 4 kg mass takes half as long as the 2 kg mass.
- (C) The 4 kg mass takes four times as long as the 2 kg mass.
- (D) The 4 kg mass takes one quarter as long as the 2 kg mass.
- (E) The masses take the same time to come to rest.

$F\Delta t_{4kg} = P_f - P_o = 0 - (4\,kg)(2\,m/s) = -8\,kg\,m/s$

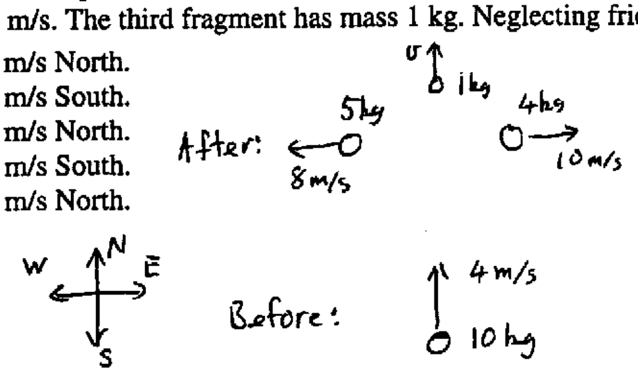
$F\Delta t_{2kg} = 0 - (2\,kg)(4\,m/s) = -8\,kg\,m/s$

$\Rightarrow \Delta t_{4kg} = \Delta t_{2kg}$

A5. A small bomb of mass 10 kg is moving toward the North with a speed of 4 m/s. It explodes into three fragments. Shortly after the explosion it is observed that a 5 kg fragment is moving toward the West with speed 8 m/s, and a second fragment with mass 4 kg is moving toward the East with speed 10 m/s. The third fragment has mass 1 kg. Neglecting friction, what is its velocity?

(A)

- (A) 40 m/s North.
- (B) 40 m/s South.
- (C) 60 m/s North.
- (D) 60 m/s South.
- (E) 80 m/s North.



$\vec{P_o} = \vec{P_f}$

$\therefore P_{oN} = P_{fN}$

$\Rightarrow (10\,kg)(4\,m/s) = (1\,kg)\,v$

$\Rightarrow v = 40\,m/s$ North

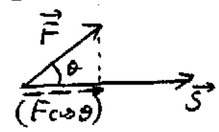
continued on page 3 ...

A6. A force will do work on an object only if

(D)

(A) the object remains stationary while the force is acting on it.
(B) there is no friction force present.
(C) the object does not accelerate while the force is acting on it.
(D) the force has a component that acts along the object's direction of motion.
(E) no other forces are present.

$W = F s \cos\theta$



A7. An elevator travels down an elevator shaft at a constant speed. The elevator is supported by a single cable. The only forces acting on the elevator are the tension in the cable and gravity. Which one of the following statements is true?

(E)

(A) The work done by the tension force is zero.
(B) The work done by gravity is zero.
(C) The magnitude of the work done by gravity is less than the magnitude of the work by the tension force.
(D) The magnitude of the work done by gravity is greater than the magnitude of the work by the tension force.
(E) The net work done on the elevator by the two forces is zero.

$W_{net} = KE_f - KE_o$
$= 0 \quad (v = \text{constant})$

A8. A hollow sphere and solid sphere with the same mass, but possibly different radii, are spinning with the same angular velocity. How do their angular momenta compare?

(E)

(A) The solid sphere has the greater angular momentum.
(B) The hollow sphere has the greater angular momentum.
(C) The spheres must have the same angular momentum.
(D) The spheres have the same angular momentum only if they have the same radii.
(E) It is impossible to tell which has the greater angular momentum without knowing the radii.

$L = I\omega$
Hollow sphere: $L_{sphere} = \frac{2}{3}MR_H^2\omega$
Solid sphere: $L_{solid} = \frac{2}{5}MR_S^2\omega$

A9. A diver tucks her body in mid flight, decreasing her moment of inertia by a factor of 2. Ignore any effects due to friction. Which one of the following statements is correct?

(C)

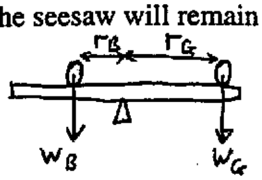
(A) Both her angular momentum and her angular velocity double.
(B) Both her angular momentum and her angular velocity decrease by a factor of 2.
(C) Her angular momentum remains constant but her angular velocity doubles.
(D) Her angular momentum remains constant but her angular velocity decreases by a factor of 2.
(E) Neither her angular momentum nor her angular velocity change.

$L_f = L_o$
$\frac{I_o}{2}\omega_f = I_o\omega_o$
$\omega_f = 2\omega_o$

A10. A seesaw consists of a uniform plank mounted so that it pivots about its centre. A heavy boy and a lightweight girl are sitting on the seesaw so that it is balanced. If they both move forward so that they are one-half their original distances from the pivot point, what will happen to the seesaw?

(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 seesaw will tilt but we cannot know which way without knowing the masses of the children.
(D) The seesaw will tilt but we cannot know which way without knowing the distances the boy and girl are from the pivot point.
(E) The seesaw will remain balanced.



$\Sigma\tau_o = W_B r_B - W_G r_G = 0$ since balanced.

After moving:

$\Sigma\tau_f = W_B\frac{r_B}{2} - W_G\frac{r_G}{2} = \frac{\Sigma\tau_o}{2} = 0$ ∴ still balanced.

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. The tip of the seconds hand of a clock is 0.125 m from the axis of rotation. What is the speed of the hand's tip?

For seconds hand, period, $T = 60\ s$

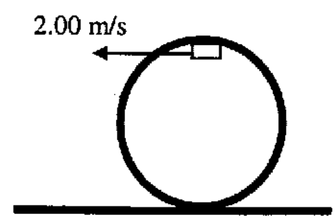
Speed of tip $= v_T = r\omega$ and $\omega = \frac{2\pi}{T}$

$$= \frac{2\pi r}{T}$$

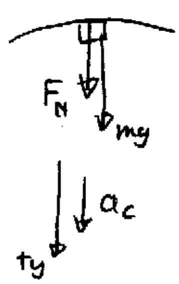
$$= \frac{2\pi\,(0.125\ m)}{60.0\ s}$$

$$= 1.31 \times 10^{-2}\ m/s$$

B2. A small block, of mass 0.0500 kg, has a speed of 2.00 m/s at the top of a frictionless, vertical, circular loop-the-loop of radius 0.100 m. Calculate the magnitude of the normal force of the loop on the block.



FBD of force on block at top.



$$\Sigma F_y = F_N + mg = ma_c$$

$$\Rightarrow \quad F_N + mg = m\frac{v^2}{r}$$

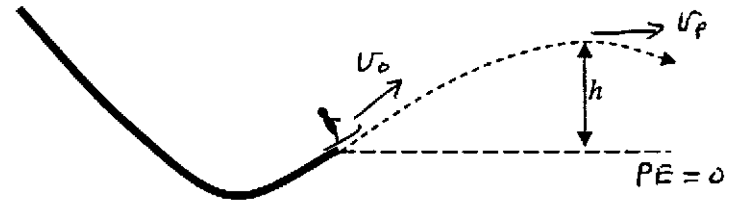
$$\Rightarrow \quad F_N = \frac{mv^2}{r} - mg = m\left(\frac{v^2}{r} - g\right)$$

$$= 0.0500\ kg\left(\frac{(2.00\ m/s)^2}{0.100\ m} - 9.80\ m/s^2\right)$$

$$= 1.51\ N$$

continued on page 5 ...

B3. A ski jumper travels down the slope and up a jump ramp. Just as the skier leaves the ramp he is travelling at a speed of 14.0 m/s. At the highest point of the jump his speed is 13.0 m/s. Ignoring friction with the air, what is his height *h* above the end of the ramp at the highest point of the jump?



Ignoring Friction.

$$E_f = E_o$$

$$KE_f + PE_f = KE_o + PE_o$$

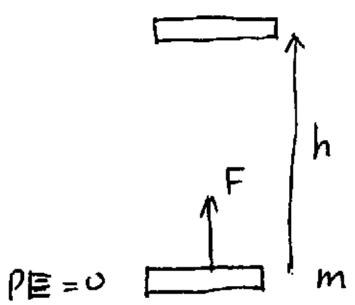
$$\frac{1}{2}mv_f^2 + mgh = \frac{1}{2}mv_o^2 + 0$$

$$\Rightarrow gh = \frac{1}{2}v_o^2 - \frac{1}{2}v_f^2$$

$$\Rightarrow h = \frac{v_o^2 - v_f^2}{2g}$$

$$= \frac{(14.0\ m/s)^2 - (13.0\ m/s)^2}{2(9.80\ m/s^2)} = 1.38\ m$$

B4. A 3.00×10^2 kg steel beam is being lifted straight up at a constant speed to a work site that is 10.0 m above the ground. The crane being used produces a constant power of 4.00×10^2 W. How long does it take to get the beam from the ground to the work site? (Ignore any frictional effects.)



Work done lifting beam

$$W_F = E_f - E_o$$

$$= KE_f + PE_f - KE_o + PE_o$$

$KE_f = KE_o$ since speed is constant

$$W_F = mgh$$

$$= Pt \quad \text{since } P = \text{constant}$$

$$\Rightarrow t = \frac{mgh}{P}$$

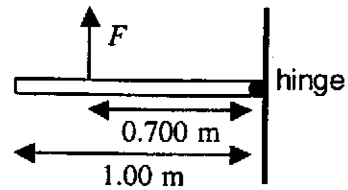
$$= \frac{(3.00 \times 10^2\ kg)(9.80\ m/s^2)(10.0\ m)}{(4.00 \times 10^2\ W)}$$

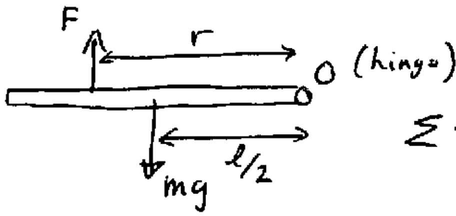
$$= 73.5\ s$$

continued on page 6 ...

Student No.: ____________________

B5. A uniform rod, of mass 1.60 kg and length 1.00 m, is supported horizontally by a hinge at one end, and a vertical rope attached 0.700 m from the hinge. The system is in equilibrium and the tension in the rope is F. Calculate the magnitude of the force F.





$$\sum \tau_O = mg\left(\frac{l}{2}\right) - Fr = 0 \quad \text{since equilibrium}$$

$$\Rightarrow F = \frac{mgl}{2r}$$

$$= \frac{(1.60\,\text{kg})(9.80\,\text{m/s}^2)(1.00\,\text{m})}{2(0.700\,\text{m})}$$

$$= 11.2\ \text{N}$$

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	1.31×10^{-2} m/s
B2	1.51 N
B3	1.38 m
B4	73.5 s
B5	11.2 N

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.

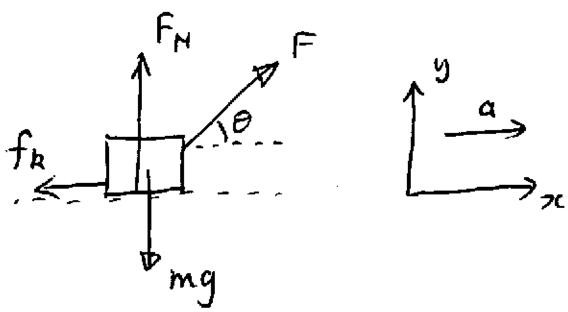
THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

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. A rope is used to drag a 50.0 kg box across a horizontal floor. The tension in the rope is 150 N and the rope makes an angle of 30.0° with the horizontal. The coefficient of kinetic friction between the box and the floor is 0.250.

(a) Draw a free-body diagram of the box, clearly showing the forces acting on it and your choice of coordinate system.



(b) Calculate the magnitude of the acceleration of the box.

Answer: $0.523\ m/s^2$

$$\Sigma F_x = F\cos\theta - f_k = ma \quad (1)$$

$$\Sigma F_y = F_N + F\sin\theta - mg = 0 \quad (2)$$

and $f_k = \mu_k F_N$

$$(2) \Rightarrow F_N = mg - F\sin\theta$$

$$(1) \Rightarrow F\cos\theta - \mu_k(mg - F\sin\theta) = ma$$

$$\Rightarrow a = \frac{F\cos\theta - \mu_k(mg - F\sin\theta)}{m}$$

$$= \frac{(150\ N)\cos 30° - 0.250(50.0\ kg \times 9.80\ m/s^2 - 150\ N\sin 30°)}{50.0\ kg}$$

$$= 0.523\ m/s^2$$

continued on page 8 ...

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C2. A train shunting system allows a rail car to roll down an incline to join up with another rail car. Car 1, which has a total mass of 15,000 kg, starts from rest and rolls down a height *h* before colliding with car 2, which has a total mass of 35,000 kg. Car 2 is initially at rest. When the cars collide their couplings lock so that from then on they roll together.

(a) It is observed that just after the two cars lock together they are moving with speed 0.813 m/s. If we ignore friction, calculate the height *h* from which car 1 started from rest.

Answer: 0.375 m

v_1 = speed of car 1 just before colliding with car 2

Perfectly inelastic collision:

before: $[m_1] \rightarrow v_1 \quad [m_2]$

After: $[m_1 + m_2] \rightarrow V$

Conservation of momentum: $\vec{p}_o = \vec{p}_f$

$\Rightarrow m_1 v_1 + 0 = (m_1 + m_2) V$

$\Rightarrow v_1 = \frac{m_1 + m_2}{m_1} V = \frac{15{,}000\text{ kg} + 35000\text{ kg}}{15{,}000\text{ kg}} 0.813\text{ m/s} = 2.71\text{ m/s}$

Rolling car 1: no friction $\Rightarrow E_o = E_f$

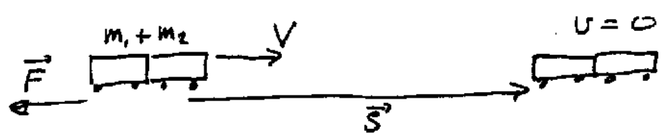
$\Rightarrow KE_o + PE_o = KE_f + PE_f$

$\Rightarrow 0 + m_1 g h = \frac{1}{2} m_1 v_1^2$

$\Rightarrow h = \frac{v_1^2}{2g} = \frac{(2.71\text{ m/s})^2}{2(9.80\text{ m/s}^2)} = 0.375\text{ m}$

(b) Just after the two cars lock together, when they are moving with speed 0.813 m/s, brakes are applied which bring the cars to rest. The cars come to rest at a distance of 25.0 m from the point where the brakes were applied. Using the work-energy theorem, calculate the magnitude of the net braking force on the cars.

Answer: 661 N



$W_F = E_f - E_o$

$-Fs = 0 - \frac{1}{2}(m_1 + m_2) V^2$

$\Rightarrow F = \frac{(m_1 + m_2) V^2}{2s}$

$= \frac{(15{,}000\text{ kg} + 35{,}000\text{ kg})(0.813\text{ m/s})^2}{2(25.0\text{ m})}$

$= 661\text{ N}$

continued on page 9 ...

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C3. A wheel is a solid disk of mass 2.70 kg and radius 0.150 m. It is attached to a motor that can supply a torque. The motor brings the wheel from rest to a rotation rate of 35.0 revolutions per second in a time of 2.00 s.

(a) Calculate the angular acceleration of the wheel.

110 rad/s²

$$\omega = \omega_0 + \alpha_1 t \quad , \omega_0 = 0$$

$$\alpha_1 = \frac{\omega}{t} = \frac{(35\ \text{rev/s})\left(\frac{2\pi\ \text{rad}}{1\ \text{rev}}\right)}{(2.00\ \text{s})}$$

$$= 110\ \text{rad/s}^2$$

(b) Calculate the torque supplied by the motor.

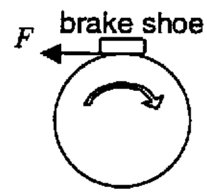
3.34 N.m

$$\tau_1 = I\alpha_1 = \tfrac{1}{2}MR^2\alpha_1$$

$$= \tfrac{1}{2}(2.70\ \text{kg})(0.150\ \text{m})^2(110\ \text{rad/s}^2)$$

$$= 3.34\ \text{N.m}$$

(c) After the motor is shut off the wheel coasts without friction at 35.0 rev/s. It is then brought to rest by the application of a brake shoe, which supplies a constant magnitude force *F* at a tangent to the rim of the wheel. Find the magnitude of the required force, *F*, so that the wheel has a constant angular acceleration of magnitude 44.2 rad/s².



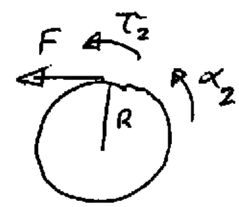
8.95 N

$$\tau_2 = FR = I\alpha_2 = \tfrac{1}{2}MR^2\alpha_2$$

$$\Rightarrow F = \frac{MR\alpha_2}{2}$$

$$= \frac{(2.70\ \text{kg})(0.150\ \text{m})(44.2\ \text{rad/s}^2)}{2}$$

$$= 8.95\ \text{N}$$



END OF EXAMINATION