Student Name:________________________________

uOttawa ver AA

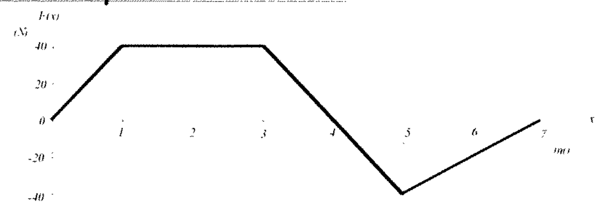
Student Number:________________________________

Closed Book examination: Duration: 100min

PART I (48%) <u>Using the scantron sheet answer all MC questions below.</u>

1 An object moves from $x = 0$ m to $x = 7$ m subject to the force shown in the diagram. How much work in J is done on the object by the force when the object moves from x=1m to x=5m

a) -40 b)-20 c) 0 d) 20 e) 80

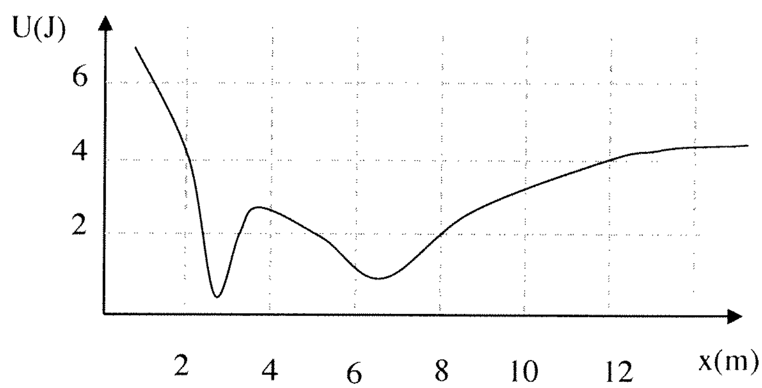


2. The object of mass m moves with velocity v along a circle of radius r in a clockwise direction. After travelling half of the circle work done by the centripetal force f is given by:

a) $F(\pi r)$ b) Ft c) $-\pi mv^2$ d) $-m v^2/r$. e) 0

3. Particle moves under influence of conservative force whose potential energy is shown in the diagram. At t=0 particle has K=2J at x= 8m. What is the position of **<u>the right turning point</u>** for this particle?

a) x= 10m b) x=12m c) x=∞
d) x=4m e) x= 2m



4. Bullet hits the rigid wall, and embeds in it, to certain known depth. Which of the following correct:

a) Linear momentum is conserved and kinetic energy is conserved,
b) Linear momentum is not conserved and total energy is conserved.
c) Kinetic energy is conserved but using its conservation is not effective to solve this problem.
d) Linear momentum is conserved but is is not effective way to use it to solve this problem.
e) None of the above is true.

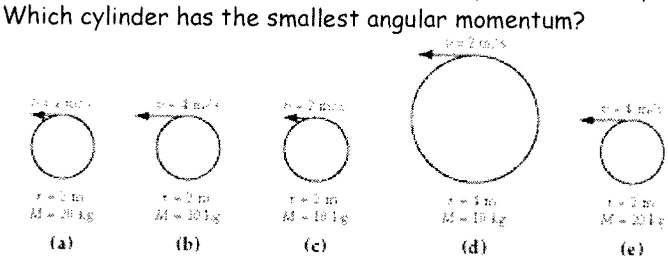
5. The 100 granade explodes into three pieces inside the thick, steel, horizontal pipe. The 60g piece emerges from the left end of the pipe with the speed of 1m/s, 10g piece emerges from the right side of the pipe with the speed of 6m/s. What will be the speed and the direction of the third piece of the granade?

a) 0 b) 0.5m/s to the right c) 0.5m/s to the left d) 1m/s to the right e) none of the above

6. A wheel rotates about a fixed axis with an initial angular velocity of 20 rad/s. During a 5.0-s interval the angular velocity decreases to 10 rad/s. Assume that the angular acceleration is constant during the 5.0-s interval. How many radians does the wheel turn through during the 5.0-s interval?

a) 95 rad **b)** 85 rad **c)**65 rad **d)** 75 rad **e)** 125 rad

7.The diagram below shows five cylinders, each cylinder rotating with constant angular velocity about its central axis. The magnitude of the tangential velocity of one point of each cylinder is shown, along with each cylinder's radius and mass. Which cylinder has the smallest angular momentum?

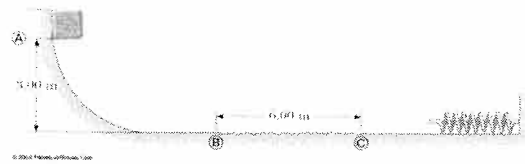


PART II (52%)

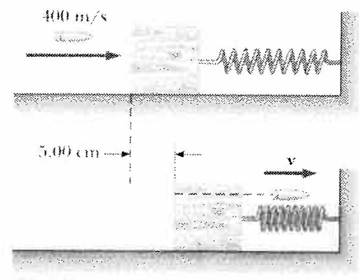
Answer 4 out of following 5 questions in the examination booklet. Each question is worth 13%

ON THE FRONT PAGE OF THE EXAM BOOKLET INDICATE WHICH QUESTIONS ARE BE MARKED.

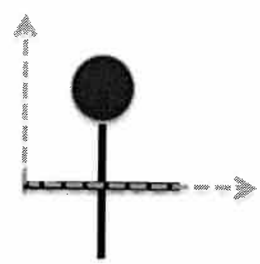
1 A 10.0-kg block is released from point *A* in Figure below. The track is frictionless except for the portion between points B and *C* , which has a length of 6.00 m. The block travels down the track, hits a spring of force constant 2 250 N/m, and compresses the spring 0.300 m from its equilibrium position before coming to rest momentarily. Determine the coefficient of kinetic friction between the block and the rough surface between B and *C*.



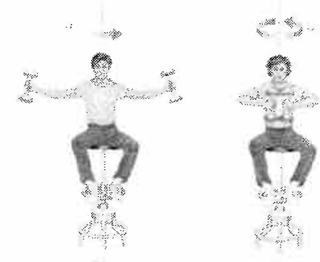
2 A 5.00-g bullet moving with an initial speed of 400 m/s is fired into and passes through a 1.00-kg block, as in Figure on the right. The block, initially at rest on a frictionless, horizontal surface, is connected to a spring of force constant 900 N/m. The block moves by 5.00 cm to the right after impact.
Find
(a) the speed at which the bullet emerges from the block and (8)
(b) the mechanical energy converted into internal energy in the collision. (5)



3 Two identical rods(M=2kg, L=4m) and a flat disk(M=1kg, R=1m) are welded together as shown. (rods form a cross of equal arms)
i) Find the coordinated of Centre of Mass (CM) of the whole object.(6)
ii) Find the moment of inertia of this object when it rotates about the vertical axis.(7)



4 A student sits on a freely rotating stool holding two weights, each of mass 4.00 kg. When his arms are extended horizontally, the weights are 1.00 m from the axis of rotation and he rotates with an angular speed of 0.750 rad/s. The moment of inertia of the student plus stool is 3.00 $kg{\cdot}m^2$ and is assumed to be constant. The student pulls the weights inward horizontally to a position 0.200 m from the rotation axis.
(a) Find the new angular speed of the student. (7)
(b) Find the kinetic energy of the rotating system before and after he pulls the weights inward. (6)



5 A 15.0-m uniform ladder weighing 500 N rests against a frictionless wall. (The ground is not frictionless.) The ladder makes a 60.0° angle with the horizontal. The ladder is just on the verge of slipping when the firefighter (weighting 600N) is 9.00 m up.
(a) Draw large, neat, and clear FBD representing all the forces acting on the ladder (3p)
(b) Using proper forces components write down the specific equations that correctly describe this situation (3p)
(c) Find the coefficient of static friction between ladder and ground (7P)

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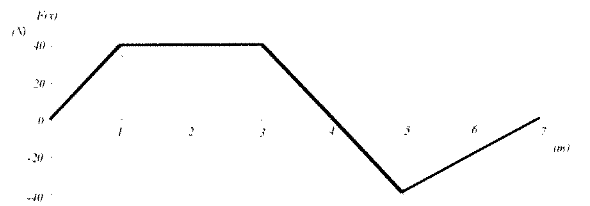


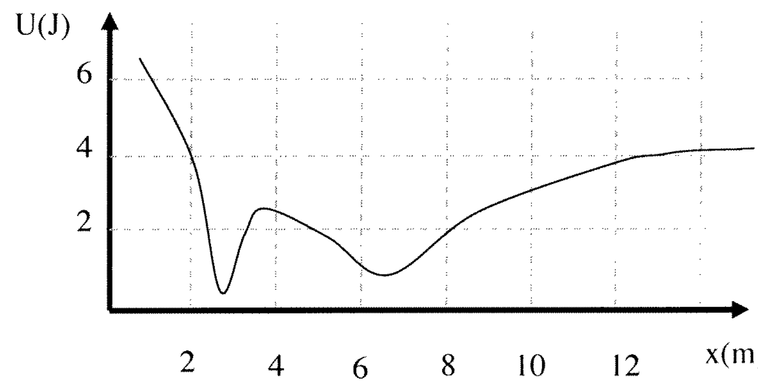
2. The object of mass m moves with velocity v along a circle of radius r in a clockwise direction. After travelling one quarter of the circle, the work done by the centripetal force f is given by:

a) 0 b) *Ft* c) $-\pi mv^2$ d) $-m\,v^2/r$. e) $F(\pi r)$

3. Particle moves under influence of conservative force whose potential energy is shown in the diagram. At t=0 particle has K=2J at x= 8m. What is the position of **the left turning point** for this particle?

a) x= 10m b) x=12m c) x=∞

d) x=4m e) x= 2m



4. Bullet hits the rigid wall, and embeds in it, to certain known depth. Which of the following correct:

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c) Linear momentum is conserved but is is not effective way to use it to solve this problem.

d) Kinetic energy is conserved but using its conservation is not effective to solve this problem.

e) None of the above is true.

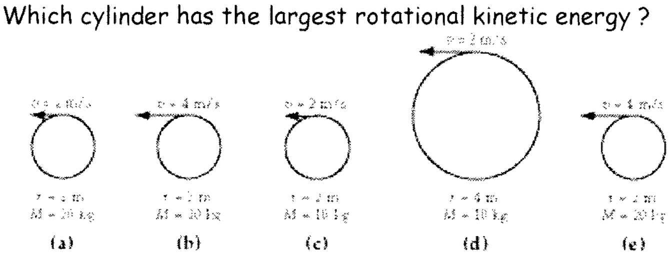
5. The 100 granade explodes into three pieces inside the thick, steel, horizontal pipe. The 60g piece emerges from the left end of the pipe with the speed of 1m/s, 10g piece emerges from the right side of the pipe with the speed of 3m/s. What will be the speed and the direction of the third piece of the granade?

a) 0 b) 0.5m/s to the right c) 0.5m/s to the left d) 1m/s to the right e) none of the above

6. A wheel rotates about a fixed axis with an initial angular velocity of 20 rad/s. During a 4.0-s interval the angular velocity decreases to 10 rad/s. Assume that the angular acceleration is constant during the 4.0-s interval. How many radians does the wheel turn through during the 4.0-s interval?

a) 95 rad **b)** 85 rad **c)**60 rad **d)** 75 rad **e)** none of theses aswers

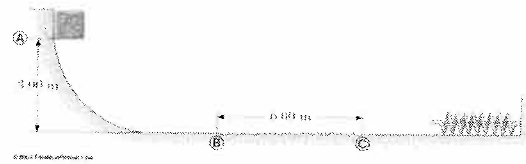
7.The diagram below shows five cylinders, each cylinder rotating with constant angular velocity about its central axis. The magnitude of the tangential velocity of one point of each cylinder is shown, along with each cylinder's radius and mass. Which cylinder has the largest rotational kinetic energy ?



PART II (52%)

Answer 4 out of following 5 questions in the examination booklet. Each question is worth 13%
ON THE FRONT PAGE OF THE EXAM BOOKLET INDICATE WHICH QUESTIONS ARE BE MARKED.

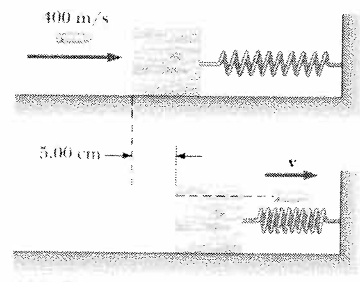
1 A 20.0-kg block is released from point A in Figure below. The track is frictionless except for the portion between points B and C , which has a length of 6.00 m. The block travels down the track, hits a spring of force constant 1 250 N/m, and compresses the spring 0.400 m from its equilibrium position before coming to rest momentarily. Determine the coefficient of kinetic friction between the block and the rough surface between B and C.



2 A 10.00-g bullet moving with an initial speed of 400 m/s is fired into and passes through a 1.00-kg block, as in Figure. The block, initially at rest on a frictionless, horizontal surface, is connected to a spring of force constant 1200 N/m. Right after impact, the block moves to the right compressing the spiring to a maximum value of 5cm. Find:

(a) the speed at which the bullet emerges from the block (8)

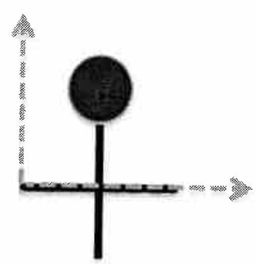
(b) the mechanical energy converted into internal energy in the collision.(5)



3 Two identical rods(M=3kg, L=2m) and a flat disk(M=2kg, R=0.5m) are welded together as shown. (Rods form a cross of equal arms).

i) Find the coordinates of Centre of Mass (CM) of the whole object. (6)

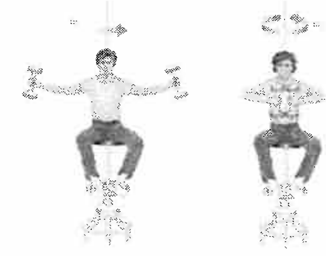
ii) Find the moment of inertia of this object when it rotates about the y -axis.(7)



4 A student sits on a freely rotating stool holding two weights, each of mass 4.00 kg . When his arms are extended horizontally, the weights are 1.20 m from the axis of rotation and he rotates with an angular speed of 0.650 rad/s. The moment of inertia of the student plus stool is 4.00 kg·m^2 and is assumed to be constant. The student pulls the weights inward horizontally to a position 0.400 m from the rotation axis.

(a) Find the new angular speed of the student. (7)

(b) Find the kinetic energy of the rotating system before and after he pulls the weights inward.(6)



5 A 12.0-m uniform ladder weighing 600 N rests against a frictionless wall. (The ground is not frictionless.) The ladder makes a 60.0° angle with the horizontal. The ladder is just on the verge of slipping when the firefighter weighting 600N is 7.00 m up.

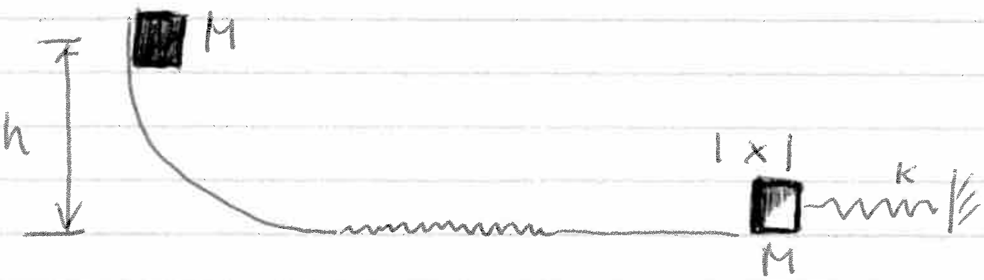
(a) Draw large, neat and clear FBD representing all the forces acting on the ladder (3p)

(b) Using proper forces components write down the specific equations that correctly describe this situation (3p)

(c) Find the coefficient of static friction between ladder and ground (7P)

Solutions

Q1



Initially all of the energy is in the form of gravitational potential energy

$$E_i = E_g = Mgh$$

After sustaining some losses due to friction all of the system energy is in the form of potential elastic energy

$$E_f = \frac{1}{2} k x^2$$

$$E_i - E_f = \text{losses}$$

$$Mgh - \frac{1}{2} k x^2 = \text{losses}$$

$$(10\text{kg})(9.8 \tfrac{m}{s^2})(6m) - \frac{1}{2} \cdot (2250 \tfrac{N}{m})(0.3)^2 m^2$$

$$588 J - 101.25 J = 486.75 J$$

$$|W| = |\vec{f} \cdot \vec{d}| = |\mu m g d \cos 180| = 486.75 J$$

$$\mu = 0.83$$

Solutions

Q2:

During the collision only linear momentum is conserved:

$$p_i = p_f$$

$$m_b v_b = M v + m_b v_b'$$

m_b - mass of the bulle[t]
M - mass of the bl[ock]
v_b - bullet initial vel
v - block velocity
v_b' - bullet final vel

In the above equation we don't know v of the block as well as v_b' final velocity of the bullet.

We can however find the v using the fact that after the collision block's kinetic energy will completely convert to the potential energy of the compressed spring

$$\frac{M v^2}{2} = \frac{1}{2} k x^2$$

$$v = \sqrt{\frac{k x^2}{M}} = \sqrt{\frac{900 \cdot (0.05)^2}{1}} \ m/s = 1.5 \ m/s$$

$$0.005 \cdot 400 = 1.5 + 0.005 v_b'$$

$$0.05 = 0.005 v_b'$$

Ans a) $v_b' = 100$

Q2:

Ans b) $K_i - K_f = \Delta E_i$

Change in the kinetic energy right after the collision is the increase in the internal energy:

$$\frac{1}{2} m v_b^2 - \left(\frac{1}{2} M v^2 + \frac{1}{2} m v_b'^2\right) = \Delta E_i$$

$$0.5 \cdot 0.005 (400)^2 - \left[0.5 (1.5)^2 + 0.5 \cdot 0.005 (100)^2\right] = \Delta E_i$$

$$400 - (1.125 + 25) = \Delta E_i$$

$$373.875 = \Delta E_i$$

Q3

disk CM (2, 3)
disk mass 1 kg

cross CM (2, 0)
cross mass 2 kg

System CM

$$x_{CM} = \frac{2\cdot 1 + 2\cdot 2}{3} = \frac{6}{3} = 2$$

$$y_{CM} = \frac{3\cdot 1 + 0\cdot 4}{5} = \frac{3}{5}$$

(a) CM (system) has coordinates of $\left(2, \frac{3}{5}\right)$

b) Moment of inertia $I_{SYSTEM} = I_{CM} + M D^2_{SYST}$

$$I_{CM} = I_{CM}(\text{cross}) + I_{CM}(\text{disk})$$

$$I_{CM}^{cross} = I_{CM\,Rod1} + I_{CM\,Rod2} = 0 + \frac{1}{12} M_1 L^2$$

$$I_{CM}^{CROSS} = \frac{1}{12} M L^2$$

$$I_{CM}^{disk} = \frac{1}{4} M R^2$$

$$I_{CM}(\text{SYSTEM}) = \frac{1}{12} M L^2 + \frac{1}{4} M R^2 =$$

$$= \frac{1}{12} 2 \cdot 4^2 + \frac{1}{4} 1 \cdot 1^2 = \frac{32}{12} + \frac{3}{12} = \frac{35}{12}$$

Q3 cont

$$I_{\substack{SYSTEM \\ CM}} = I_{CM} + M_{SYST} \cdot D^2$$

$$I_{SYSTEM} = \frac{35}{12} + 5 \cdot 2^2 = \frac{35}{12} + 20$$

$$I_{SYSTEM} = 22.92$$

Q4

$m = 4 kg$
$\omega_i = 0.75 \frac{r}{s}$
$I_o = 3 kg m$
$r_i = 1 m$
$r' = 0.2 m$

This system conserves angular momentum

$$L_i = L_f$$

$$I_i \omega_i = I_f \omega_f$$

$$\omega_i \left(I_o + 2mr^2\right) = \omega_f \left(I_o + 2mr'^2\right)$$

$$\omega_f = \omega_i \left(\frac{I_o + 2mr^2}{I_o + 2mr'^2}\right)$$

$$\omega_f = 0.75 \frac{rad}{s} \left(\frac{3 + 2 \cdot 4 \cdot 1^2}{3 + 2 \cdot 4 \cdot 0.2^2}\right)$$

$$\omega_f = 0.75 \frac{rad}{s} \left(\frac{11}{3.32}\right)$$

$$\underline{\omega_f = 2.49 \frac{rad}{s}}$$

b) . KINETIC ENERGY IS NOT CONSERVED

$$E = \frac{1}{2} I \omega^2 = \frac{1}{2}(I\omega)\omega = \frac{1}{2} L \omega$$

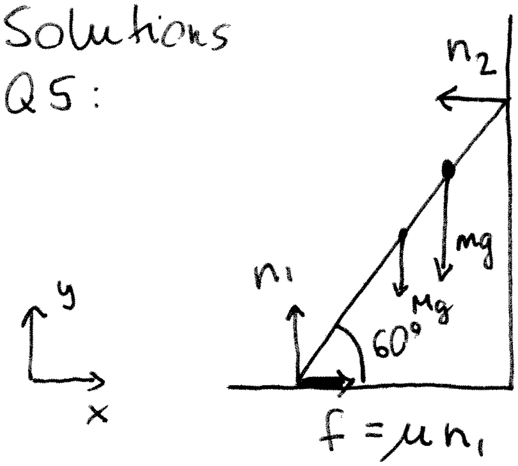
$E_i = \frac{1}{2} L_i \omega_i$ | $E_f = \frac{1}{2} L \omega_f$

$E_i = \frac{1}{2}(8.25)(0.75)$ | $E_f = \frac{1}{2}(8.25)(2.49)$

$E_i = 3.09 J$ | $E_f = 10.89 J$

Solutions

Q5:



Equilibrium

⇓

$\sum F_x = 0$; $\sum F_y = 0$; $\sum \tau = 0$

$f - n_2 = 0$; $n_1 - Mg - mg = 0$

$\sum \tau = 0$

$$n_2(L \sin 60) - mg(9 \cos 60) - Mg\left(\frac{L}{2} \cos 60\right) = 0$$

$$n_2(15 \sin 60) - 600(9 \cos 60) - 500(7.5 \cos 60) = 0$$

$$13 \quad n_2 = 2700 + 1875 = 4575$$

$$n_2 = 351.92$$

$$n_1 = Mg + mg = 4575$$

$$f - n_2 = 0 \quad \Rightarrow \quad f = n_2 = \mu n_1$$

$$\mu = \frac{n_2}{n_1} = \frac{351.92}{4575} = 0.077$$