Kuwait University **Physics Department**

Physics 101

Fall Semester

Final Exam

Monday, December 25, 2017

05:00 pm – 07:00 pm

Student's Name: ………………..…………………….…………….. Serial Number: ….…………

Student's Number: ….…………………………………….. Section: ………………….

Choose your Instructor's Name:

Dr. Ahmed Al-Jassar	Dr. Abdul Mohsen
Dr. Hala Al-Jassar	Dr. Tareq Al Refai
Dr. Fatema Al Dosari	Dr. Abdul Khaleq
Dr. Nasser Demir	Dr. Belal Salameh

For Instructors use only

Grades:

#	Q1	Q2	Q3	Q4	SP1	SP2	SP3	SP4	SP5	SP6	SP7	LP1	LP2	LP3	Total
Pts	1	1	1	1	3	3	3	3	3	3	3	5	5	5	40

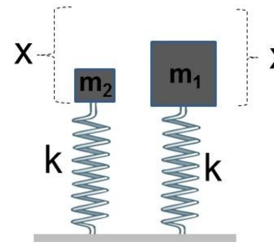
Important:

1. Answer all questions and problems.
2. Full mark = 40 points as arranged in the above table.
   i) 4 **Q**uestions.
   ii) 7 **S**hort Problems.
   iii) 3 **L**ong Problems.
3. No solution = No points.
4. Use **SI units**.
5. Check the correct answer for each question.
6. Assume $g = 10\ m/s^2$.
7. Mobiles are **strictly prohibited** during the exam.
8. Programmable calculators, which can store equations, are not allowed.
9. **Cheating incidents will be processed according to the university rules.**

GOOD LUCK

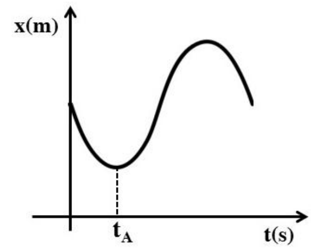
Part I: Questions (Choose the correct answer, one point each)

Q1. Two blocks ($\mathbf{m_1 > m_2}$) are placed on two identical vertical springs which are compressed by the same distance x. When the blocks are released they are projected vertically upward. **At their maximum height, both blocks will have:**



* the same maximum height.
* the same gravitational potential energy.
* different kinetic energies.
* different total mechanical energies.

Q2. The position-time graph of an object moving along the x axis is shown in the figure. **The velocity and acceleration of the object at the instant t_A are:**



* $V = 0, a < 0.$
* $V = 0, a = 0.$
* $V = 0, a > 0.$
* $V > 0, a = 0.$

Q3. m_1 and m_2 are two equal masses. m_1 moves with speed **v** toward a stationary mass m_2 on a frictionless horizontal surface. **The maximum energy transferred to m_2 occurs if the collision is a:**

* one dimensional elastic collision.
* one dimensional inelastic collision.
* completely inelastic collision.
* two-dimensional inelastic collision.

Q4. For a force $\vec{F}$ to be conservative when applied to a particle

* $\vec{F}$ must have the same value at all points of the particle path.
* $\vec{F}$ must have the same direction at all points of the particle path.
* $\vec{F}$ must be always parallel to the displacement of the particle.
* The work done by $\vec{F}$ for motion in closed paths must be zero.

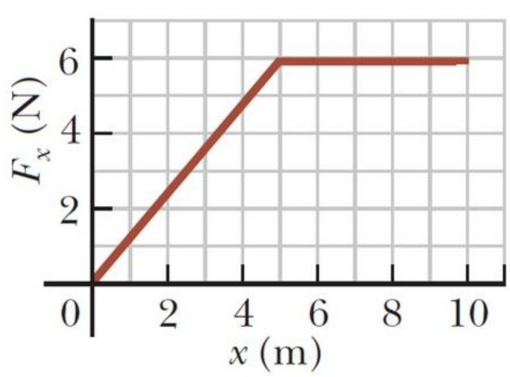
SP1. A 2 kg block is subject to a single force F_x that varies with position as shown in the figure. If the speed of the block at x=10 m is 9 m/s **find its speed (in m/s) at x=0 m.**

$W_{total} = \Delta K$

$\frac{1}{2}(5)(6) + (5)(6) = \frac{1}{2}mV_f^2 - \frac{1}{2}mV_i^2$

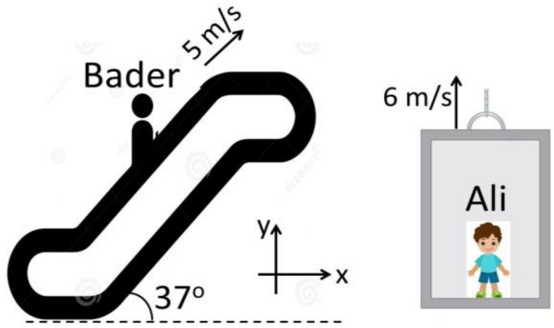
$45 = (9)^2 - V_i^2$

V_i=6 m/s



Answer: V_i=6 m/s

SP2. Bader rides an escalator which moves at a speed of 5 m/s and Ali rides an elevator which moves up at a speed of 6 m/s as shown in the figure. **Find the velocity (in m/s) of Bader with respect to Ali in unit vector notation.**



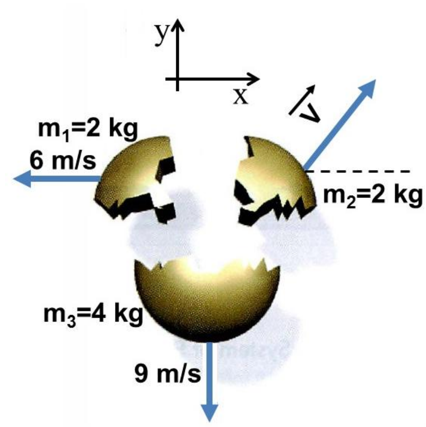
$\vec{V}_{A/G} = +6\,\hat{j}\ \mathrm{m/s}$

$\vec{V}_{B/G} = [5\cos(37^o)\,\hat{\imath} + 5\sin(37^o)\hat{j}]\mathrm{m/s} = (4\hat{\imath} + 3\hat{j})\mathrm{m/s}$

$$\vec{V}_{B/A} = \vec{V}_{B/G} - \vec{V}_{A/G} = (4\hat{\imath} - 3\hat{j})\mathrm{m/s}$$

Answer: $\vec{V}_{B/A} = (4\hat{\imath} - 3\hat{j})\mathrm{m/s}$

SP3. <u>**A stationary**</u> object in free space explodes into three pieces as shown in the figure. **What is the velocity (in m/s) of the top right piece (m_2) after the explosion? Express your answer in unit vector notation.**



$$\sum \vec{p}_i \qquad = \qquad \sum \vec{p}_f$$

$0 = m_1\vec{V}_{1f} + m_2\vec{V}_{2f} + m_3\vec{V}_{3f}$

$0 = 2(-6\hat{\imath}) + 2\vec{V} + 4(-9\hat{j})$

$\vec{V} = (6\hat{\imath} + 18\hat{j})$ m/s

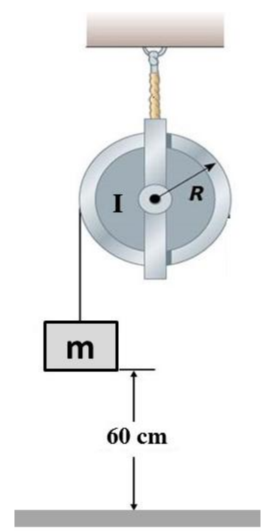
Answer: $\vec{V} = (6\hat{\imath} + 18\hat{j})$ m/s

SP4. A 3 kg block is suspended from the free end of a light rope which is wrapped around a frictionless pulley (R = 0.2 m) as shown in the figure. If the block is released from rest when it is 60 cm above the floor **and its speed just before it touches the floor is 3 m/s, calculate the moment of inertia of the pulley (in kg m^2).**

$$E_i \quad = \quad E_f$$

$$\mathrm{mgh} = \frac{1}{2}m\,V_f^2 + \frac{1}{2}\,I\,\omega_f^2 = \frac{1}{2}m\,V_f^2 + \frac{1}{2}\,I\,(\frac{V_f}{R})^2$$

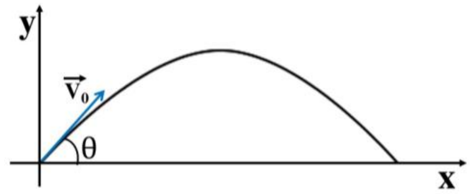
$$I = \frac{2\mathrm{mgh}R^2}{V_f^2} - m\,R^2 = \frac{2(3)(10)(0.6)(0.2)^2}{3^2} - 3(0.2)^2 = 0.04\ \mathrm{kg\ m^2}$$



Answer: I=0.04 kg m^2

SP5. A stone is projected from the ground level at an angle θ above the horizontal. **If the initial speed (V_o) of the stone is five times greater than its speed at the maximum height, find the angle θ.**

$$V_0 = 5V_0\cos(\theta)$$

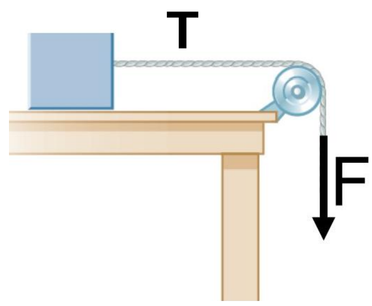


$$\cos(\theta) = \frac{1}{5}$$

$$\theta = \cos^{-1}\left(\frac{1}{5}\right) = 78.5^{o}$$

Answer: $\theta = 78.5^{o}$

SP6. A box resting on **a smooth horizontal surface** is attached to a light rope that passes over a frictionless pulley (R=0.1 m, $I = 0.01$ kg m^2). The rope is pulled from its lower end by a constant force (F= 7 N) and the block **accelerates to the right at 3 m/s²** as shown in the figure. **Find the tension force (T) (in N) exerted on the block by the rope.**



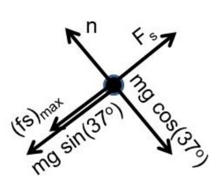
$$\alpha = \frac{a}{R} = \frac{3}{0.1} = 30\ \text{rad/s}^2$$

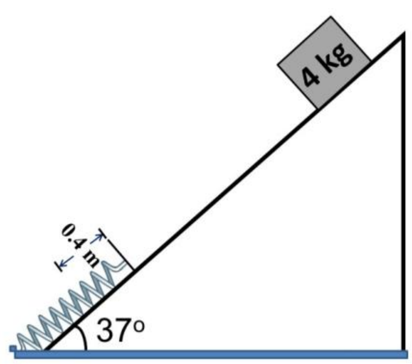
$$\sum \tau = I\,\alpha = (F - T)R$$

$$T = F - \frac{I\alpha}{R} = 7 - \frac{0.01(30)}{0.1} = 4\ \text{N}$$

Answer: $T = 4$ N

SP7. A 4 kg block slides down a rough incline plane then compresses a spring of force constant k= 500 N/m a distance of 0.4 m before stopping. If μ_s=0.8 and μ_k=0.4, **will the block move back up the incline? Justify your answer. (<u>No points without drawing the free body diagram</u>)**





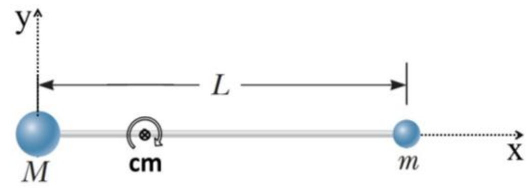
$$F_{\text{spring}} = kx = 500(0.4) = 200\ \text{N}$$

$$mg\sin(\theta) + (f_s)_{max} = mg\big(\sin(\theta) + \mu_s\cos(\theta)\big) = 49.6\text{N}$$

Since $F_{\text{spring}} > (mg\sin(\theta) + (f_s)_{max})$, then the block will move back up the incline.

Part III: Long Problems (5 points each)

LP1. Two small balls with masses M=0.4 kg and m=0.2 kg are connected by **a very light** rigid rod of length L=1.2 m as shown in the figure.



a) Find the position (in m) of the center of mass of the system of the two balls with respect to the origin.

$$x_{cm} = \frac{Mx_1 + mx_2}{M + m} = \frac{(0.4)(0) + (0.2)(1.2)}{0.4 + 0.2} = 0.4 \text{ m}$$

Answer: $X_{cm} = 0.4$ m

b) Find the moment of inertia (in kg m^2) of the system about the center of mass.

$$I_{cm} = Mx_1^2 + mx_2^2 = (0.4)(0.4)^2 + (0.2)(0.8)^2 = 0.192 \; kg\, m^2$$

Answer: $I_{cm} = 0.192 \; kg\, m^2$

c) The system starts to rotate from rest with a constant acceleration of 2 rad/s^2 about an axis which passes through its center of mass. Find the rotational kinetic energy (in J) of the system at t=3 s.

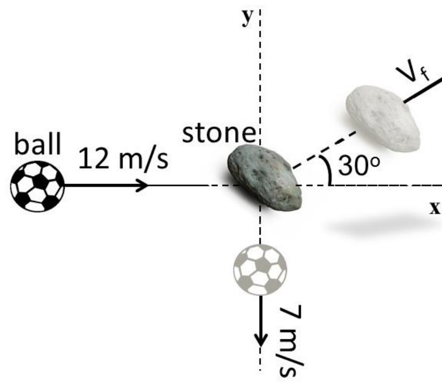
$$\omega_f = \omega_i + \alpha t$$

=0 + 2(3) = 6 rad/s

$$K_{rot} = \frac{1}{2} I\omega^2 = \frac{1}{2}(0.192)(6)^2 = 3.5 \text{ J}$$

Answer: $K_{rot} = 3.5$ J

LP2. A 2 kg stone **rests on** a frictionless horizontal surface. A ball of mass 0.5 kg **traveling horizontally at 12 m/s** strikes the stone and deflects **at right angle relative to its original direction** as shown in the figure. The stone moves after the collision in the shown direction.



a) Find the velocity <u>of the center of mass</u> of the system after the collision in unit vector notation.

$$\vec{V}_{cm_i} = \vec{V}_{cm_f} = \frac{m_1\vec{V}_{1i} + m_2\vec{V}_{2i}}{m_1 + m_2} = \frac{0.5(12\hat{\imath}) + 0}{0.5 + 2}$$

$$= +2.4\hat{\imath}\ m/s$$

Answer: $\vec{V}_{cm_f} = +2.4\hat{\imath}\ m/s$

b) Find the speed (V_f) (in m/s) of the stone after the collision.

$$\sum p_{yi} = \sum p_{yf}$$

$$0 + 0 = 2V_f \sin 30^o - 0.5(7)$$

$$V_f = 3.5\ m/s$$

Answer: $V_f = 3.5\ m/s$

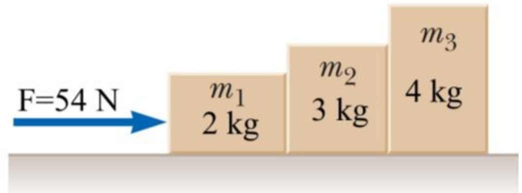
c) Calculate the change in the kinetic energy (in J) of the system due to the collision.

$$\Delta K = \sum K_f - \sum K_i$$

$$\left[\frac{1}{2}(0.5)(7)^2 + \frac{1}{2}(2)(3.5)^2\right] - \left[\frac{1}{2}(0.5)(12)^2\right] = -11.5\,J$$

Answer: $\Delta K = -11.5\,J$

LP3. Three blocks are in contact with one another on **a rough horizontal surface** (μ_k=0.4), a constant horizontal force F is applied to the first block as shown in the figure.



a) Find the magnitude of the acceleration of the blocks.

$$F - \mu_k Mg = Ma$$

$$a = \frac{F - \mu_k Mg}{M} = \frac{54 - 0.4(9)(10)}{9} = 2\ m/s^2$$

Answer: $a = 2\ m/s^2$

b) Find the magnitude of the contact force between m1 and m2.

<u>For m1:</u> $F - \mu_k m_1 g - F_{21} = m_1 a$

$$F_{21} = F - \mu_k m_1 g - m_1 a = 54 - 0.4(2)(10) - 2(2) = 42\ N$$

Answer: $F_{21} = 42\ N$

c) Find the total work done on the three blocks as they move 6 m to the right.

$$W_{total} = W_F + W_{f_k}$$

$$F(r) + f_k(r) = (F - \mu_k Mg)(r)$$

$$= (54 - 0.4(9)(10))(6) = 108\ J$$

Answer: $W_{total} = 108\ J$