**Kuwait University** **Physics Department**

# Physics 101

Fall Semester

Final Exam

Monday, December 16, 2019

2:00 pm – 4:00 pm

Model Answer

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

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

Choose your Instructor's Name:

| | |
|---|---|
| Prof. Yacoub Makdisi | Dr. Abdul Mohsen |
| Dr. Ahmed Al-Jassar | Dr. Tareq Al Refai |
| Dr. Hala Al-Jassar | Dr. Abdel Khaleq |
| Dr. Nasser Demir | Dr. Belal Salameh |
| Dr. Fatema Douseri | |

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**:

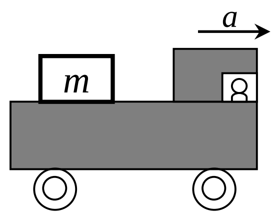
1. Answer all questions and problems.
2. Full mark = 40 points as arranged in the above table.
   i) 4 **Q**uestions
   ii) 7 **S**hort **P**roblems
   iii) 3 **L**ong **P**roblems.
3. No solution = no points.
4. Check the correct answer for each question.
5. Assume g = 10 m/s$^2$.
6. Mobiles are **strictly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

GOOD LUCK

**<u>Part I: Questions</u> (one point each)**

**Q1.** A box of mass ***m*** sits on the back of a truck that is moving to the right with **constant acceleration *a***. If **the box <u>does not slide with respect to the truck</u>**, then the force of friction acting on the box

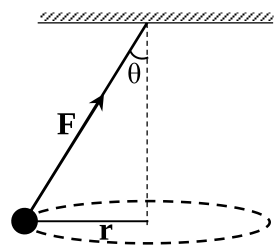
(*) is static and to the right.
* is static and to the left.
* is kinetic and to the right.
* is zero because the box does not slide.




**Q2.** The ball of a conical pendulum is rotating in a horizontal plane **with constant speed** as shown**. The work done on the ball by the tension $\vec{F}$ during one complete revolution equals**

* $F(2\pi r\ sin\theta)$
* $F(2\pi r\ cos\theta)$
* $F(2\pi r\ tan\theta)$

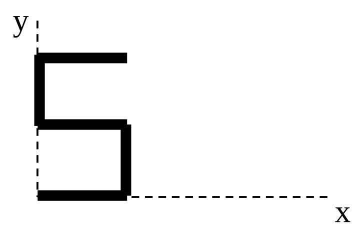
(*) zero




**Q3.** Five uniform bars, **<u>each of length L</u>** are connected to form the number 5 as shown. **The position of the center of mass of the object is**

* (½ L, ½ L)   * (L, ½ L)

(*) (½ L, L)   * (L, L)

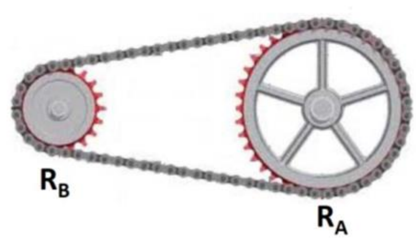



**Q4.** A and B are two wheels connected by a belt that does not slip and **runs with constant <u>linear</u> acceleration *a***. If **$R_A$ = 2 $R_B$**, **then the relation between their angular accelerations $\alpha_A$ and $\alpha_B$ is:**

* $\alpha_A = \alpha_B$
* $\alpha_A = 2\ \alpha_B$

(*) $\alpha_A = \frac{1}{2}\alpha_B$

* $\alpha_A = \frac{1}{4}\alpha_B$

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**<u>Part II: Short Problems (3 points each)</u>**

**SP1.** The position of a car moving along a straight road is given by $x = -3t^2 + 2t^3$, where *x* is in meters and *t* is in seconds. **Calculate the car's acceleration (in m/s²) at $t = 4\ s$.**

$$v(t) = \frac{dx}{dt} = -6t + 6t^2$$

$$a(t) = \frac{dv}{dt} = -6 + 12t$$

$$a(4s) = -6 + 12(4) = 42\ m/s^2$$

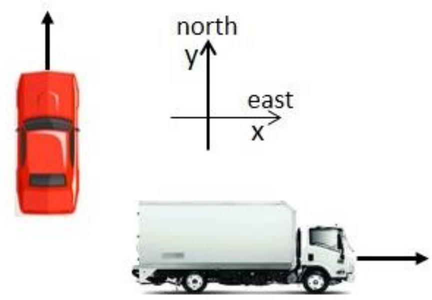
Answer: $a(4s) = 42\ m/s^2$

**SP2.** A truck is moving **east** with a constant velocity of 80 km/h, and a car is moving **north** with a constant velocity of 100 km/h. **Find the car's velocity relative to the truck ($\vec{V}_{C/T}$ )(in km/h) in unit vector notation.**

$\vec{V}_{T/G} = +80\,\hat{\imath}\;km/h$

$\vec{V}_{C/G} = +100\,\hat{\jmath}\;km/h$

$\vec{V}_{C/T} = \vec{V}_{C/G} - \vec{V}_{T/G} = (-80\,\hat{\imath} + 100\,\hat{\jmath})\;km/h$



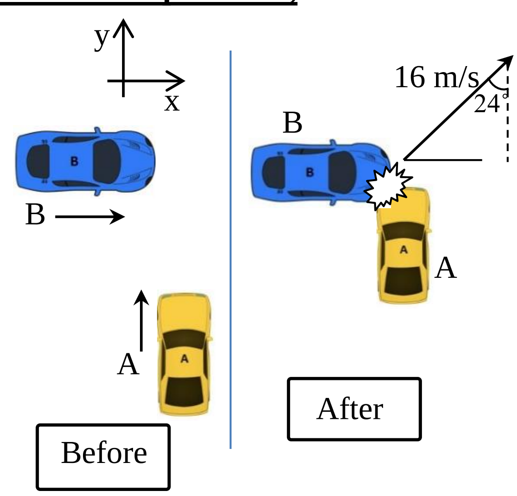

Answer: $\vec{V}_{C/T} = (-80\,\hat{\imath} + 100\,\hat{\jmath})\;km/h$

**SP3.** Car A is driving **north**, and car B is driving **east** collide and **stick together**. After the collision the wreckage moves with a velocity of 16 m/s as shown. **<u>If cars A and B are of equal mass,</u> find the speed (in m/s) of car B before the collision**.

$\Sigma P_{x_i} = \Sigma P_{x_f}$

$m_B\,V_{B_i} = 2m_B v_f \sin(24^\circ)$

$V_{B_i} = 2(16)\sin 24 = 13\;m/s$




Answer: $V_{B_i} = 13\;m/s$

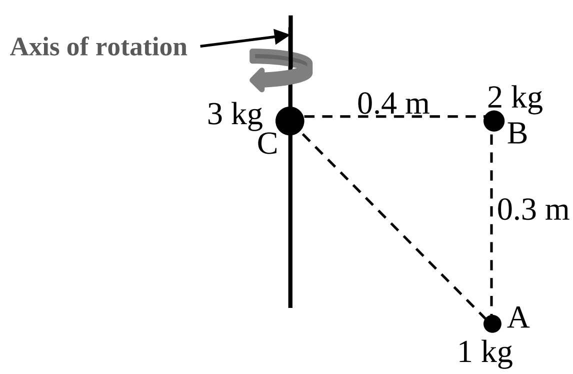
**SP4.** A system consists of three **small** disks as shown. Find the **<u>rotational kinetic energy for the system</u> (in J)** if it rotates about an axis that passes **through disk C and parallel to the line connecting B and A** with an angular speed of 3 rad/s.

$I = \Sigma m_i\, r_i^2$

$= m_A(0.4)^2 + m_B(0.4)^2 + m_C(0)^2$

$= 1(0.4)^2 + 2(0.4)^2 = 0.48\;kg.m^2$

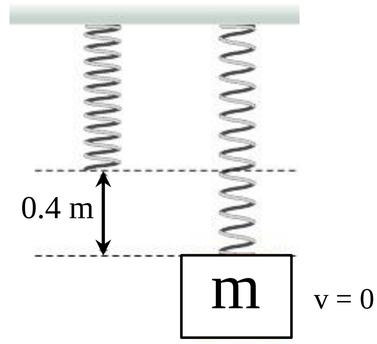
$K = \frac{1}{2} I\,\omega^2 = \frac{1}{2}(0.48)(3)^2 = 2.16\,J$




Answer: $K = 2.16\,J$

**SP5.** A block of mass 2 kg is attached to the end of a spring. The spring is stretched a distance of 0.4 m then **the mass stops momentarily before oscillating**. **Find the spring constant k in (N/m).**

**(Note: the block is NOT in equilibrium)**

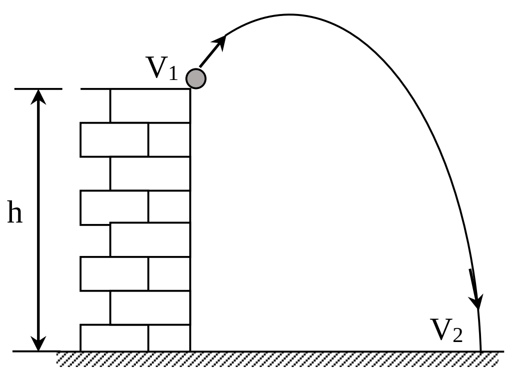



$$mgx = \frac{1}{2}kx^2$$

$$k = \frac{2\,mg}{x} = \frac{2(2)(10)}{0.4} = 100\;N/m$$

Answer: $k = 100\;N/m$

**SP6.** A ball of mass 0.5 kg is fired from the top of a building with a speed of 5 m/s. The ball strikes the ground with a speed of 15 m/s. If the height of the building is h=12 m, **find the work (in J) done by air resistance**.



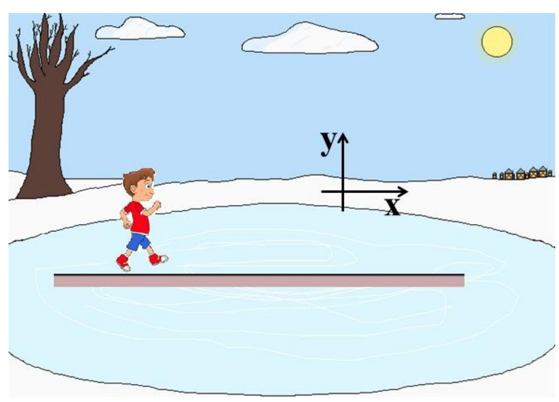

$$E_f - E_i = W_{f_k}$$

$$\frac{1}{2}mv_f^2 - \left(\frac{1}{2}\,mv_i^2 + mgh\right) = W_{f_k}$$

$$W_{f_k} = \frac{1}{2}\,(0.5)(15)^2 - \left(\frac{1}{2}(0.5)(5)^2 + 0.5(10)(12)\right) = -10\,J$$

Answer: $W_{f_k} = -10\,J$

**SP7.** A boy of mass **M** is standing on a slab of mass $\mathbf{m_c = 5\,M}$ that is resting on a frozen lake. Assume there is no friction between the slab and the ice. If the boy starts **walking forward at 2 m/s**, **with what velocity (in m/s) does the slab move?**




$$\vec{V}_{cm_i} = \vec{V}_{cm_f}$$

$$0 = \frac{m_1\vec{V}_{1_f} + m_2\vec{V}_{2_f}}{m_1 + m_2}$$

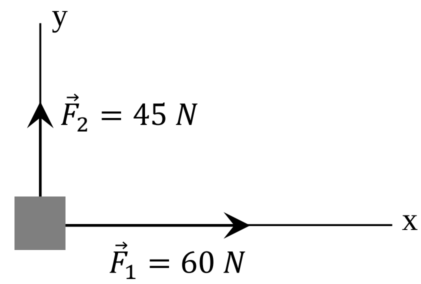
$$\frac{M(2\hat{\imath}) + 5M(\vec{V}_{2_f})}{6M} = 0$$

$$\Rightarrow \vec{V}_{2_f} = \frac{-2}{5}\hat{\imath} = -0.4\,\hat{\imath}\;m/s$$

Answer: $\vec{V}_{2_f} = -0.4\,\hat{\imath}\;m/s$

## Part III: Long Problems (5 Points each)

**LP1.** $\vec{F}_1$ and $\vec{F}_2$ are the only forces acting on a box of mass 15 kg, as shown.




**a) Find the box's acceleration $\vec{a}$ (in m/s²) in unit vector notation.**

$\Sigma\vec{F} = m\vec{a}$

$60\,\hat{\imath} + 45\,\hat{\jmath} = 15\,\vec{a}$

$\Rightarrow \vec{a} = (4\,\hat{\imath} + 3\,\hat{\jmath})\ m/s^2$

Answer: $\vec{a} = (4\,\hat{\imath} + 3\,\hat{\jmath})\ m/s^2$

**b) If the box starts from rest, calculate the distance (in m) covered by the box within 6 s.**

$|\vec{a}| = \sqrt{(4)^2 + (3)^2} = 5\ m/s^2$

$d = V_i t + \frac{1}{2}at^2$

$= 0 + \frac{1}{2}(5)(6)^2 = 90\ m$

Answer: $d = 90\ m$

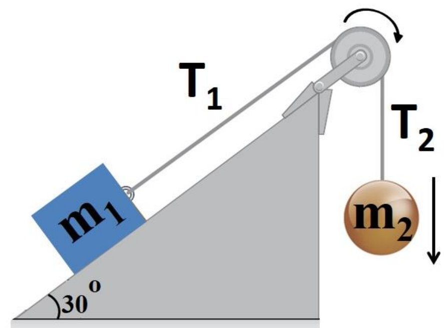
**c) If $\vec{F}_3$ is applied to keep the box moving <u>with constant velocity</u>, what is the magnitude of $\vec{F}_3$?**

$\vec{F}_3 = -\Sigma\vec{F}$

$\Rightarrow |\vec{F}_3| = |\Sigma\vec{F}| = \sqrt{(45)^2 + (60)^2} = 75\ N$

Answer: $|\vec{F}_3| = 75\ N$

**LP2.** A block of mass $\mathbf{m_1 = 5\ kg}$ rests on **a frictionless** incline is attached to a ball of mass $\mathbf{m_2 = 8\ kg}$ by a light rope that passes over a pulley **of radius R = 0.2 m** as shown. **When the ball is released the pulley accelerates clockwise at 8 rad/s².**




**a) Find the tensions $T_1$ and $T_2$ (in N) in the rope.**

$$a = R\alpha = 0.2\ (8) = 1.6\ m/s^2$$

$$T_1 - m_1 g \sin\theta = m_1 a$$

$$T_1 = m_1(a + g\sin\theta)$$

$$= 5(1.6 + 10\sin(30))$$

$$= 33\ \ N$$

$$m_2\ g - \ T_2 = m_2\ a$$

$$T_2 = m_2(g - a) = 8\ (10 - 1.6) = 67.2\ N$$

Answer: $T_1 = 33\ \ N$

Answer: $T_2 = 67.2\ \ N$

**b) Find the net torque (in N.m) exerted on the pulley.**

$$\Sigma\tau = T_2 R - T_1 R = 67.2(0.2) - 33\ (0.2)$$

$$= 6.84\ \ N.m$$

Answer: $\Sigma\tau = 6.84\ \ N.m$

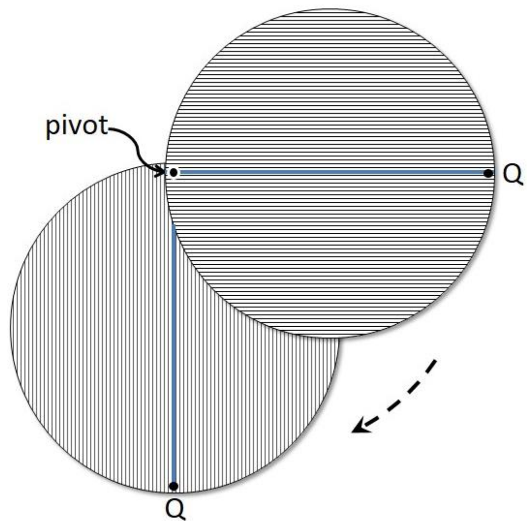
**c) Find the moment of inertia (in kg·m²) of the pulley.**

$$\Sigma\tau = I\ \alpha$$

$$\mathrm{I} = \frac{\Sigma\tau}{\alpha} = \frac{6.84}{8} = 0.855\ kg.m^2$$

Answer: $\mathrm{I} = 0.855\ kg.m^2$

**LP3.** A uniform solid disc (M = 4 kg, R = 0.2 m, and $I_{cm} = \frac{1}{2}MR^2$) **is pivoted at its rim** as shown. **The disc is released from rest at the horizontal position.**




**a) Find the moment of inertia (in kg·m²) of the disc about the pivot.**

$I_p = I_{cm} + MR^2$

$= \left(\frac{1}{2}MR^2 + MR^2\right) = \frac{3}{2}MR^2 = \frac{3}{2}(4)(0.2)^2 = 0.24\ kg.m^2$

Answer: $I_p = 0.24\ kg.m^2$

**b) Find the angular speed (in rad/s) of the disc when it reaches the vertical position.**

$MgR = \frac{1}{2} I_p \omega^2$

$4\,(10)(0.2) = \frac{1}{2}(0.24)\,\omega^2$

$\omega = 8.2\ rad/s$

Answer: $\omega = 8.2\ rad/s$

**a) Find the speed (in m/s) of point Q which is at the disc's rim when the disc reaches the vertical position.**

$v = \omega\,(2R) = 8.2\,(0.4) = 3.3\ m/s$

Answer: $v = 3.3\ m/s$