Kuwait University **Department of Physics**

General Physics I for Biological Sciences (Phy 121)

Second Midterm Examination
Fall Semester, 2022-2023

December 10, 2022

Time: 2:00 PM to 3:30 PM

Instructors: Drs. Ali, Al-Otaibi, Al-Smadi, Hadipour, Kokkalis and Razee

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Solution

Instructions to the Students:

- Answer all the questions. Show all your working in this booklet.
- All communication devices must be switched off and placed in your bag or deposited with the invigilator in charge. Anyone found using a communication device will be disqualified.
- Programmable calculators, which can store equations, are not allowed. You may use a non-programmable calculator.
- **Take $g = 9.8$ m/s^2.**
- **Use SI units**.

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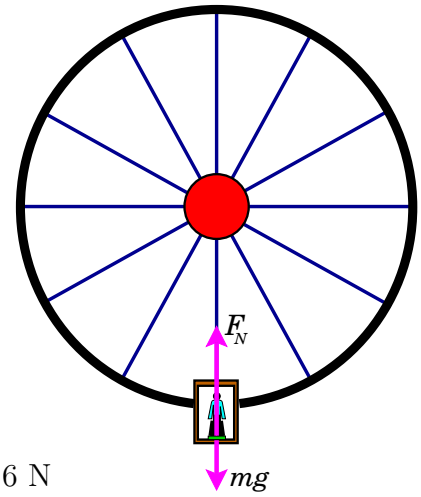
1. A Ferris wheel of radius $R = 25$ m rotates in a vertical plane at a constant frequency of 6 revolutions per minute (rpm). An 80-kg passenger is standing on a scale. Find the reading in the scale (in kg) when he is at the lowest position. **4 points**



Solution:
The frequency of rotation and the speed of the passenger are

$$f = \frac{6}{60} = 0.1 \text{ s}^{-1} \qquad v = 2\pi R f = 15.71 \text{ m/s}$$

The reading in the scale is $\dfrac{F_N}{g}$ in kg.

We have $F_N - mg = m\dfrac{v^2}{R} \implies F_N = mg + m\dfrac{v^2}{R} = 1573.6$ N

$$\implies \text{Reading} = 160.6 \text{ kg}$$

2. A wheel of radius 1.2 m accelerates uniformly about its centre from 11 rad/s to 37 rad/s in 10 s.
   (a) Find the angular acceleration of the wheel. **1 point**
   (b) Find the tangential acceleration of a point on the rim of the wheel. **1 point**
   (c) Find the radial (centripetal) acceleration of this point 5 s after the wheel started accelerating. **2 points**

Solution:
The initial and the final angular speeds are

$$\omega_0 = 11 \text{ rad/s} \qquad \omega = 37 \text{ rad/s}$$

The angular acceleration: $\alpha = \dfrac{\omega - \omega_0}{t} = 2.6 \text{ rad/s}^2$

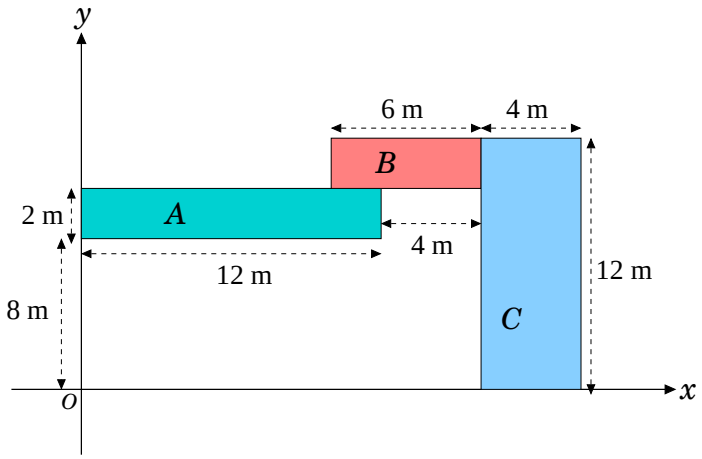
The tangential acceleration: $a_{tan} = \alpha R = 3.1 \text{ m/s}^2$

The angular speed at 5 s: $\omega = \omega_0 + \alpha \times 5 = 24 \text{ rad/s}$

The radial acceleration: $a_R = \omega^2 R = 691 \text{ m/s}^2$

3. An object consists of three rectangular plates, A, B and C with masses $M_A = 2$ kg, $M_B = 1$ kg, $M_C = 5$ kg as shown. Find the $x-$coordinate and the $y-$coordinate of the centre of mass of the object.

3 points



Solution: We have

$$\begin{aligned} M_A &= 2 \text{ kg}, \quad x_A = 6 \text{ m}, \quad y_A = 9 \text{ m} \\ M_B &= 1 \text{ kg}, \quad x_B = 13 \text{ m}, \quad y_B = 11 \text{ m} \\ M_C &= 5 \text{ kg}, \quad x_C = 18 \text{ m}, \quad y_C = 6 \text{ m} \end{aligned}$$

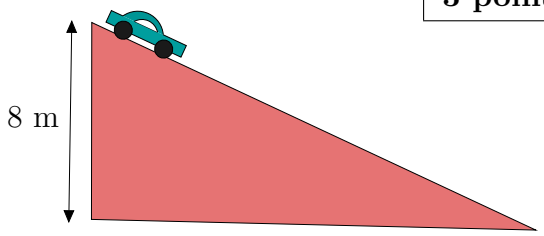
Then

$$x_{\text{CM}} = \frac{M_A x_A + M_B x_B + M_C x_C}{M_A + M_B + M_C} = 14.4 \text{ m}$$

$$y_{\text{CM}} = \frac{M_A y_A + M_B y_B + M_C y_C}{M_A + M_B + M_C} = 7.4 \text{ m}$$

4. A 1200-kg car starts at a speed of 12 m/s at the top of a 8.0-m high incline and reaches the ground level with speed 20 m/s in 9 s. Assume that the effects of friction is negligible. What was the average power of the engine during these 9 s?

3 points



Solution: We have

$$W_{net} = \text{KE}_f - \text{KE}_i$$

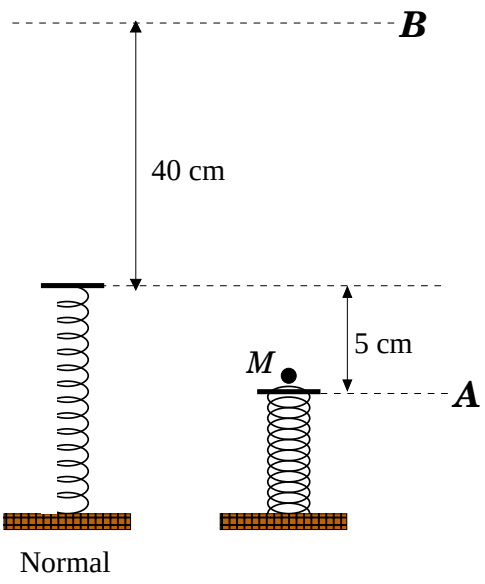
$$\implies W_{engine} + W_{gravity} = \frac{1}{2}M(20)^2 - \frac{1}{2}M(12)^2$$

$$\implies W_{engine} + Mgh = 1.536 \times 10^5 \implies W_{engine} = 5.952 \times 10^4 \text{ J}$$

$$\implies P_{engine} = \frac{W_{engine}}{t} = 6.6 \text{ kW}$$

5. A spring with stiffness constant $k = 100$ N/m stands vertical on the ground. A small 0.02-kg ball is used to compress the spring by 5 cm and the ball is released from that height (point A). Find the speed of the ball when it is 40 cm above the equilibrium position of the spring (height of point B). Ignore air resistance.

4 points



Solution: We choose the normal height of the spring as the zero-level of the potential energies. Then the principle of conservation of mechanical energy is

$$\text{KE}_A + \text{PE}_A = \text{KE}_B + \text{PE}_B$$

$$\Longrightarrow 0 + \frac{1}{2}k \times (0.05)^2 + Mg \times (-0.05)$$

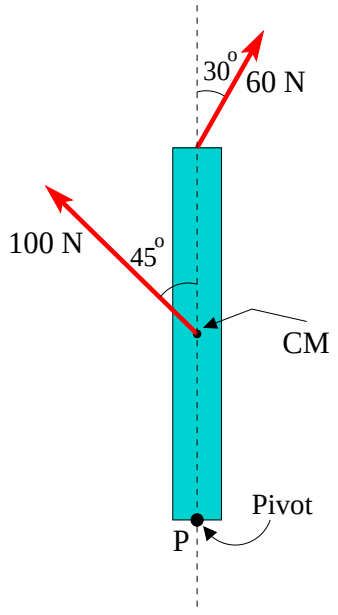
$$= \frac{1}{2}Mv^2 + 0 + Mg \times (0.40)$$

$$\Longrightarrow 0.1152 = \frac{1}{2}Mv^2 + 0.0784$$

$$\Longrightarrow 0.0368 = \frac{1}{2}Mv^2 \Longrightarrow v = 1.92 \text{ m/s}$$

6. Two forces of magnitudes 60 N and 100 N are acting on a massless beam of length 4 m. The beam is pivoted at point P. Find the net torque on the beam about the point P.

3 points



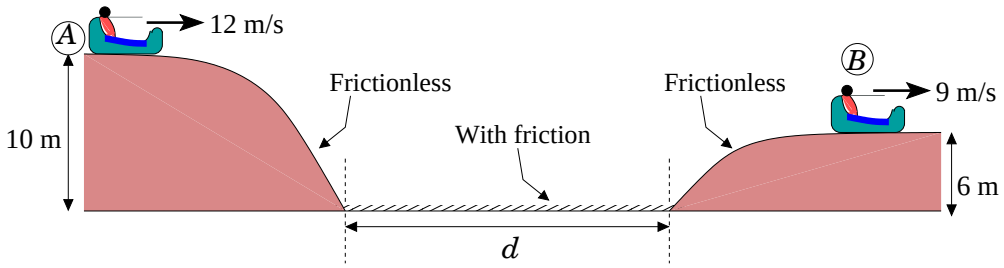
Solution:
The torque of the 60 N force is **negative** (rotates clockwise), and the torque of the 100 N force is **positive** (rotates counterclockwise). So the net torque is

$$\tau_{net} = -60 \times 4 \times \sin 30^o + 100 \times 2 \times \sin 45^o$$

$$= -120 + 141.4 = +21.4 \text{ m.N}$$

7. A part of a snow roller-coaster track is shown. Between two frictionless hills, the horizontal track of length d is rough with coefficient of kinetic friction $\mu_k = 0.08$. The sled has a speed of 12 m/s at the position A and when it reaches the position B, its speed becomes 9 m/s. Find the length d.

5 points



Solution: The Work energy principle is

$$W_{NC} = \mathrm{KE}_B - \mathrm{KE}_A + \mathrm{PE}_B - \mathrm{PE}_A$$

$$\implies -\mu_k M g \times d = \frac{1}{2} M \times (9)^2 - \frac{1}{2} M \times (12)^2 + Mg \times 6 - Mg \times 10$$

Cancelling out M and rearranging the terms, we get

$$\mu_k g d = \frac{1}{2}(12)^2 - \frac{1}{2}(9)^2 + g \times 10 - g \times 6 = 70.7$$

$$\implies d = \frac{70.7}{\mu_k g} = 90.2 \text{ m}$$