Kuwait University Department of Physics

General Physics I for Biological Sciences (Phy 121)

Second Midterm Examination

Fall Semester 2024-2025

November 30, 2024

Time: 2:00 PM to 3:30 PM

Instructors: **Dr. Abdulmohsen, Dr. Al-Failakawi, Dr. Al-Otaibi, Dr. Al-Refai, Dr. Burahmah, Dr. Hadipour, Dr. Kokkalis and Dr. Razee**

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.
- Cheating incidents will be processed according to the University rules.
- **Use SI units**.
- **Take $g = 9.8\ \mathrm{m/s^2}$**.

1. A 1200-kg car traveling on a horizontal road encounters a net frictional force of magnitude $F_{fr} = 500$ N. If the car has to **accelerate from 15 m/s to 25 m/s** in a distance of 160 m on this road, what average power of the enginw is required? **4 points**

Solution: The work-energy principle is

$$W_{engine} + W_{fr} = \frac{1}{2}Mv_f^2 - \frac{1}{2}Mv_i^2$$
$$\implies W_{engine} - F_{fr}d = 240000 \implies W_{engine} = 320000 \text{ J}$$

To accelerate from 15 m/s to 25 m/s in a distance of 160 m, the time taken is

$$t = \frac{d}{\overline{v}} = \frac{d}{\frac{1}{2}(v_f + v_i)} = 8 \text{ s}$$

The power delivered by the engine is

$$P_{engine} = \frac{W_{engine}}{t} = 40000 \text{ W}$$

OR

To accelerate from 15 m/s to 25 m/s in a distance of 160 m, the **net** acceleration needed is

$$a = \frac{25^2 - 15^2}{2 \times 160} = 1.25 \text{ m/s}^2$$

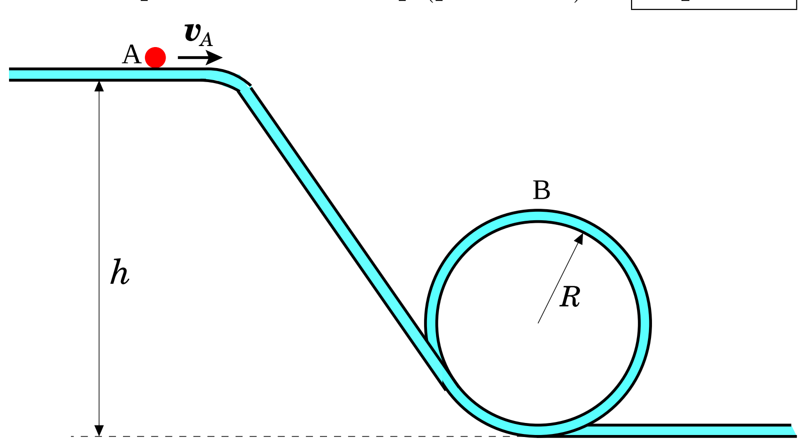
The net force applied by the engine is

$$F_{engine} = Ma + F_{fr} = 2000 \text{ N}$$

The power delivered by the engine is

$$P_{engine} = F_{engine}\overline{v} = 2000 \times \frac{1}{2}(15 + 25) = 40000 \text{ W}$$

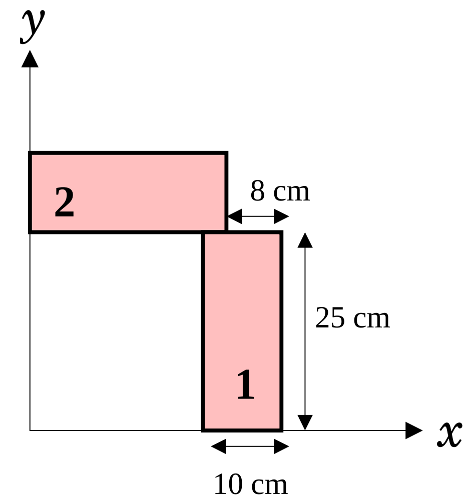
2. A frictionless track consists of a ramp of height $h = 30$ cm and a vertical circular loop of radius $R = 10$ cm as shown. A small ball starts at the position A with speed $v_A = 0.9$ m/s. Find its speed at the top of the circular loop (position B). **4 points**



Solution: The work-energy principle is

$$\text{KE}_A + \text{PE}_A = \text{KE}_B + \text{PE}_B$$
$$\implies \frac{1}{2}Mv_A^2 + Mgh = \frac{1}{2}Mv_B^2 + Mg \times 2R$$
$$\implies v_B^2 = v_A^2 + 2gh - 4gR = 2.77$$
$$\implies v_B = 1.66 \text{ m/s}$$

3. Two identical bricks of mass 2 kg each are arranged in the $xy-$plane as shown. Find the coordinates of the centre of mass of this system of two bricks. **4 points**



Solution:

Brick 1	$x_1 = 25.0$ cm+8.0 cm-5.0 cm $= 28.0$ cm	$y_1 = 25.0$ cm/2 $= 12.5$ cm
Brick 2	$x_2 = 25.0$ cm/2 $= 12.5$ cm	$y_2 = 25.0$ cm+5.0cm $= 30.0$ cm

$$x_{CM} = \frac{Mx_1 + Mx_2}{2M} = 20.3 \text{ cm}$$

$$y_{CM} = \frac{My_1 + My_2}{2M} = 21.3 \text{ cm}$$

4. A grinder running at full speed is switched off at $t = 0$. The blades come to rest after completing 200 rotations in 25 s. The blades are 3 cm long.

   (a) Find the angular speed of the blades at $t = 0$ s. **3 points**

   (b) Find the tangential acceleration (a_{tan}) of a point on the tip of a blade. **2 points**

Solution:

(a)

$$\theta - \theta_0 = 200 \times 2\pi = 1256.6 \text{ rad}$$

$$\overline{\omega} = \frac{\theta - \theta_0}{25} = 50.26 \text{ rad/s}$$

$$\overline{\omega} = \frac{1}{2}(\omega_0 + \omega) = \frac{\omega_0}{2} \implies \omega_0 = 2 \times \overline{\omega} = 100.5 \text{ rad/s}$$

(b)

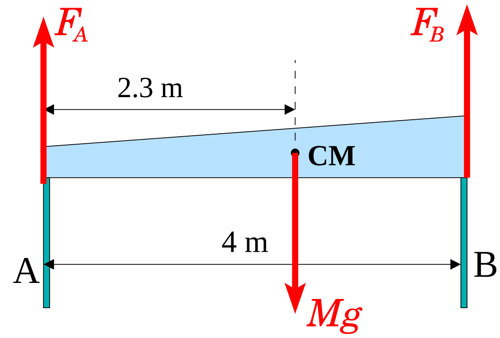
$$\alpha = \frac{0 - \omega_0}{25} = -4.02 \text{ rad/s}^2$$

$$a_{tan} = \alpha R = -0.12 \text{ m/s}^2$$

5. A 4-m long bar rests horizontally on two supporting vertical legs A and B as shown. The centre of mass of the bar is 2.3 m from leg A and the normal force exerted by the leg A on the bar is 125 N.

   (a) Find the mass of the bar. **2 points**

   (b) Find the normal force exerted by leg B on the bar. **2 point**



Solution: The free-body diagram is shown. We choose the **pivot at the right-end** of the bar. The net torque on the bar about this pivot is

$$-F_A \times 4 + Mg \times (4 - 2.3) = 0$$

$$\Longrightarrow \quad M = \frac{F_A \times 4}{g \times 1.7} = 30 \text{ kg}$$

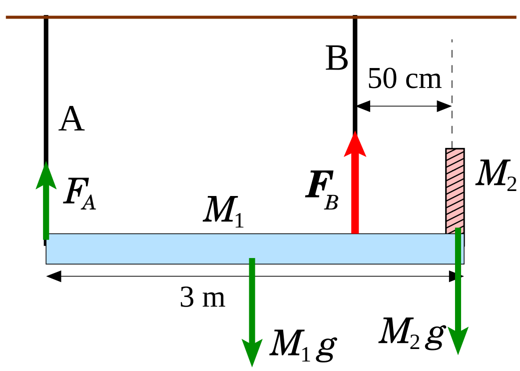
The net force is zero,

$$F_A + F_B = Mg \implies F_B = 169 \text{ N}$$

6. A 3-m long 30-kg (M_1) uniform bar hangs horizontally by two supporting vertical ropes A and B attached to the ceiling as shown. A box of mass M_2 is placed at the right-end of the bar. The tension in the rope B is $F_B = 650$ N. The structure is in equilibrium.

   (a) Find M_2. **2 points**

   (b) Find the tension F_A in rope A. **2 points**



Solution: The free-body diagram is shown. We choose the **pivot at the point where the rope A is attached to the bar**. Then the net torque on the bar is,

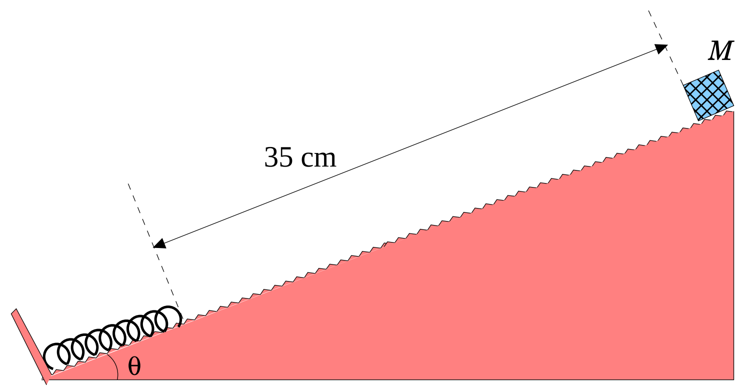
$$+F_B \times 2.5 - M_1 g \times 1.5 - M_2 g \times 3 = 0$$

$$\Longrightarrow \quad M_2 = \frac{F_B \times 2.5 - M_1 g \times 1.5}{g \times 3.0} = 40 \text{ kg}$$

The net force is zero,

$$F_A + F_B - M_1 g - M_2 g = 0 \implies F_A = 36 \text{ N}$$

7. A small box of mass $M = 1.8$ kg is released from rest on a rough incline ($\theta = 18^o$). It slides down 35 cm and hits a spring, compressing the spring by 7 cm when it momentarily comes to rest. If the spring constant is $k = 380$ N/m, find the coefficient of kinetic friction (μ_k) between the box and the incline. **5 points**



Solution: The distance travelled by the box is

$$d = 0.35 + 0.07 = 0.42 \text{ m}$$

The height discended by the box is

$$h = d \ \sin 18^o = 0.13 \text{ m}$$

The normal force on the box is

$$F_N = Mg \ \cos\theta = 16.8 \text{ N}$$

The work-energy principle is

$$\text{KE}_i + \text{PE}_i + W_{NC} = \text{KE}_f + \text{PE}_f$$

$$\implies 0 + 0 + Mgh - (\mu_k F_N)d = 0 + \frac{1}{2}k(0.07)^2 + 0$$

$$\implies 2.29 - \mu_k F_N \ d = 0.93$$

$$\implies \mu_k = 0.19$$