Kuwait University — Department of Physics

General Physics I for Biological Sciences (Phy 121)

Second Midterm Examination

Fall Semester 2023-2024

December 9, 2023
Time: 2:00 PM to 3:30 PM

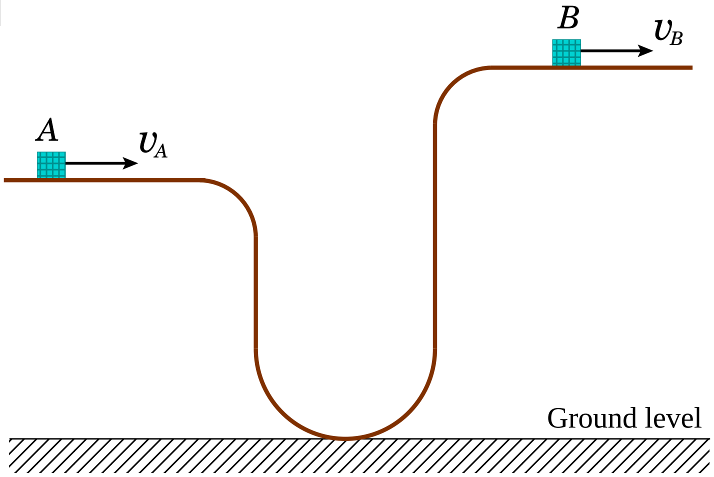
Instructors: **Dr. Abdullah, Dr. Afrousheh, Dr. Al-Otaibi, Dr. Hadipour, Dr. Kokkalis, Dr. Razee and Dr. Zaman**

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 $g = 9.8$ m/s^2**.

1. A frictionless track is in a vertical plane as shown. A small box of mass $M = 0.7$ kg leaves point A with speed $v_A = 5$ m/s and arrives at point B with speed $v_B = 3$ m/s.
   (a) Find the net work done by all the forces acting on the box when it moved from A to B. **2 points**
   (b) Find the work done by the force of gravity when the box moved from A to B. **1 point**



Solution: The net work done is:

$$W_{net} = \text{KE}_B - \text{KE}_A$$

$$\Longrightarrow W_{net} = \frac{1}{2}Mv_B^2 - \frac{1}{2}Mv_A^2 = -5.6 \text{ J}$$

Since the force of gravity is the only force (apart from the normal force, which does not do any work), we have

$$W_G = W_{net} = -5.6 \text{ J}$$

2. The average force of friction on a 1200-kg car moving on a horizontal road is $F_{fr} = 600$ N. It takes the car 15 s to uniformly accelerate from rest to a speed of 24 m/s on this road, during which it travels a distance of 180 m. Find the average engine power. **4 points**

Solution: The work-energy principle is

$$W_{engine} + W_{fr} = \frac{1}{2}Mv^2 \quad \Longrightarrow \quad W_{engine} - F_{fr}d = \frac{1}{2}Mv^2$$

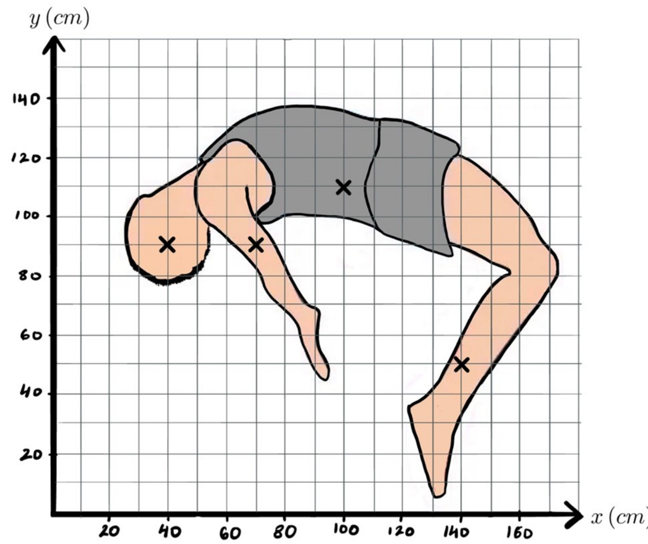
$$\Longrightarrow \quad W_{engine} = F_{fr}d + \frac{1}{2}Mv^2 = 453600 \text{ J}$$

The average power required by the engine is

$$\overline{P}_{engine} = \frac{W_{engine}}{t} = 3.02 \times 10^4 \text{ W}$$

3. The figure shows a jumper in action. The masses of different components of his body are given in the table. The centres of mass of the components are highlighted with crosses ($\times$) in the plot. Find the x and y coordinates of his centre of mass. **4 points**

Component	**Mass** (kg)
Head	4.5
Arms and Hands	8.1
Neck, Trunk and Upper Legs	42.9
Lower Legs and Foot	13.5



Solution:

$$x_{\text{CM}} = \frac{M_1x_1 + M_2x_2 + M_3x_3 + M_4x_4}{M_1 + M_2 + M_3 + M_4}$$
$$= \frac{4.5 \times 40 + 8.1 \times 70 + 42.9 \times 100 + 13.5 \times 140}{69} = 100.4 \text{ cm}$$

$$y_{\text{CM}} = \frac{M_1y_1 + M_2y_2 + M_3y_3 + M_4y_4}{M_1 + M_2 + M_3 + M_4}$$
$$= \frac{4.5 \times 90 + 8.1 \times 90 + 42.9 \times 110 + 13.5 \times 50}{69} = 94.6 \text{ cm}$$

4. The compact disk (radius $R = 6$ cm) accelerates uniformly from rest to 300 rpm in 10 s.

   (a) Find the angular acceleration of the disk. **2 points**

   (b) Find the radial acceleration of a point at the edge of the disk at $t = 10$ s. **1 point**

   (c) Find the tangential acceleration of a point at the edge of the disk. **1 point**

Solution:
The initial and the final angular speeds are

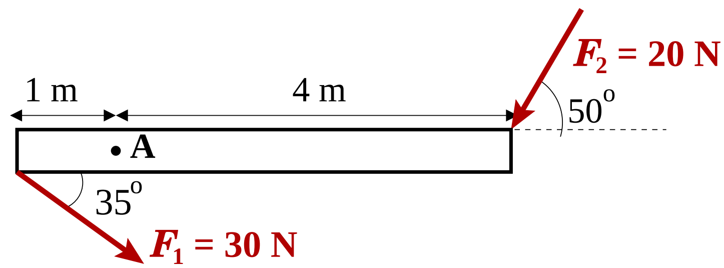
$$\omega_0 = 0 \text{ rad/s} \qquad \omega = \frac{300 \times 2\pi}{60} = 31.4 \text{ rad/s}$$

The angular acceleration: $$\alpha = \frac{\omega - \omega_0}{t} = 3.14 \text{ rad/s}^2$$

The radial acceleration: $$a_R = \omega^2 R = 59.2 \text{ m/s}^2$$

The tangential acceleration: $$a_{tan} = \alpha R = 0.19 \text{ m/s}^2$$

5. Two forces are acting on a 5-m long massless horizontal bar as shown. Find the net torque about the pivot point A. **3 points**



Solution:
The torque of $\vec{F}_1$ is **positive**

$$\tau_1 = +F_1 \times 1 \times \sin 35^o = +17.2 \text{ m} \cdot \text{N}$$

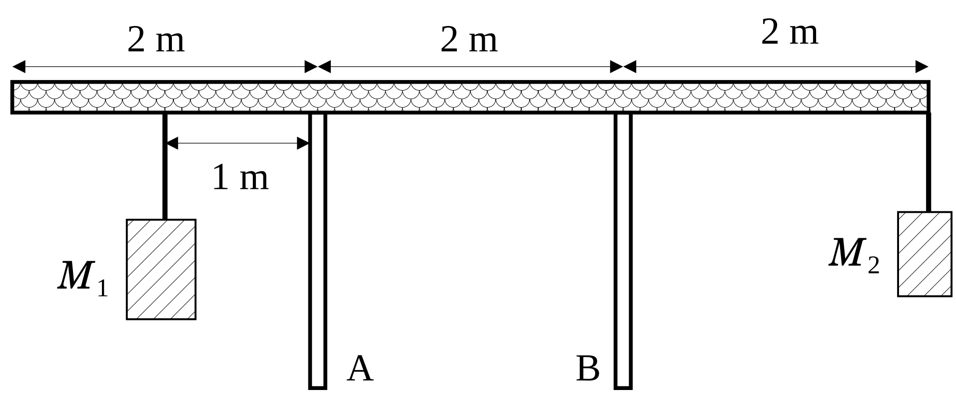
The torque of $\vec{F}_2$ is **negative**:

$$\tau_2 = -F_2 \times 4 \times \sin 50^o = -61.3 \text{ m} \cdot \text{N}$$

So, the net torque is

$$\tau = 17.2 - 61.3 = -44.1 \text{ m} \cdot \text{N}$$

6. A 10-kg horizontal beam is on two vertical support columns A and B. Two masses, $M_1 = 16$ kg and $M_2 = 12$ kg, are hanging from the beam as shown. Find the forces, F_A and F_B, on the beam due to the support columns. Assume the structure is in equilibrium. **4 points**



Solution: We choose the pivot at the point where the beam touches the column A. Then the second condition of equilibrium gives us

$$+M_1 g \times 1 - Mg \times 1 + F_B \times 2 - M_2 g \times 4 = 0$$

$$\implies F_B = \frac{-M_1 g + Mg + M_2 g \times 4}{2} = 206 \text{ N}$$

Force: $$F_A + F_B - M_1 g - Mg - M_2 g = 0 \implies F_A = 167 \text{ N}$$

7. A frictionless incline is at a distance of $d = 1.8$ m from an unstretched spring. The spring is compressed by $x = 20$ cm using a 0.3-kg box and then it is released [see Fig. 1]. The coefficient of kinetic friction between the horizontal surface and the box is $\mu_k = 0.2$. When the box reaches a height of $h = 80$ cm on the incline, its speed is $v = 3$ m/s [see Fig. 2].

   (a) Find the work done by the force of friction on the box. **2 points**

   (b) Find the spring constant k. **3 points**

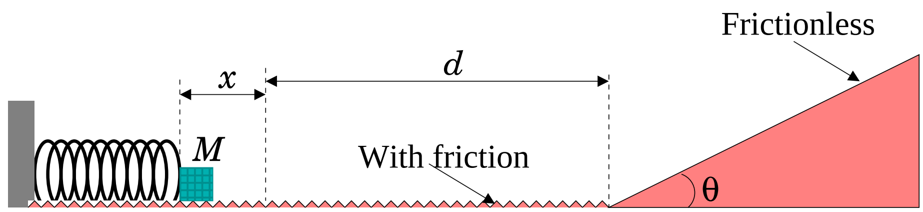


Fig. 1

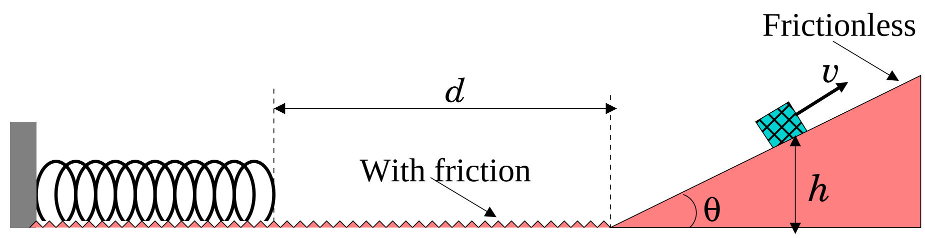


Fig. 2

Solution: (a) The box moves a distance $(d + x)$ on the rough surface. So the eork done by the force of friction is

$$W_{fr} = -(\mu_k M g)(d + x) = -1.18 \text{ J}$$

(b) The work-energy principle is

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

$$\Longrightarrow\ 0 + 0 + \frac{1}{2}kx^2 + W_{fr} = \frac{1}{2}Mv^2 + Mgh + 0$$

$$\Longrightarrow\ \frac{1}{2}kx^2 - 1.18 = 1.35 + 2.35 \ \Longrightarrow\ \frac{1}{2}kx^2 = 4.88$$

$$\Longrightarrow\ k = 244 \text{ N/m}$$