Name: **ID:**

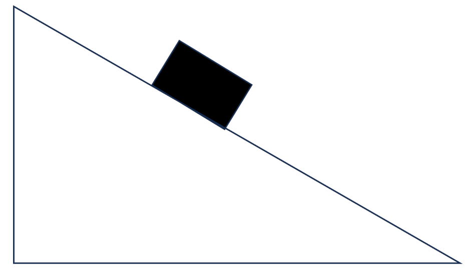
Midterm #2 - P3A - Practice A

Prof. Laszlo Bardoczi, November 6, 2025

- The exam is 40 minutes long and contains 8 calculation problems (1-2 steps each).
- You must solve 6 problems of your choice; 2 problems will not be graded.
- Each problem is worth up to 1 point: 0.5 point for a correct numerical value (to 2 significant figures); 0.5 point for correct SI units.
- The concepts and calculations are broken into 1-2 step individual problems to award "partial credit". Such credits are based solely on the boxed answers.
- Write final answers clearly in the designated boxes. Leave the boxes empty for the problems you do not wish to be graded. If all boxes are filled, Problems #7-8 will not be graded.
- A detachable formula sheet is provided at the end of the exam.
- At the end of the exam, submit only the front page, present your UCI ID for verification and sign in.
- Direct all grading questions to your TA.
- Cheating will result in an automatic failing grade for the course.

Q#	Answer	Q#	Answer
1		2	
3		4	
5		6	
7		8	

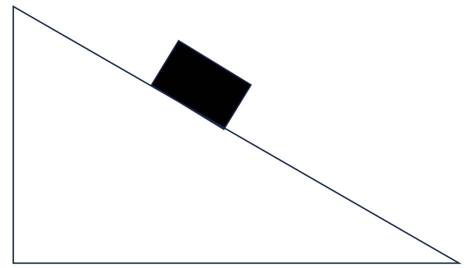
Problem 1



A block rests on a slope inclined at 30°. What is the minimum coefficient of static friction needed so that the block does not slip?

Problem 1

A block rests on a slope inclined at 30°. What is the minimum coefficient of static friction needed so that the block does not slip?



Solution:

For the block to be at rest, the component of gravity pulling it down the slope must be balanced by static friction. At the threshold of slipping,

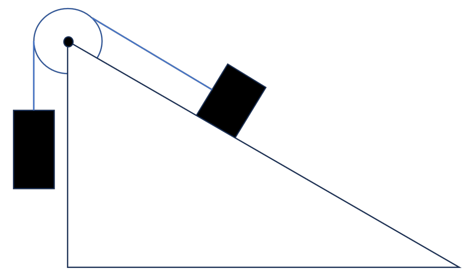
$$mg\sin\theta = \mu_s mg\cos\theta$$

Simplify:

$$\mu_s = \tan\theta = \tan(30^\circ) = 0.577 \approx 0.58$$

Thus, the slope will hold the block if $\mu_s \geq 0.58$.

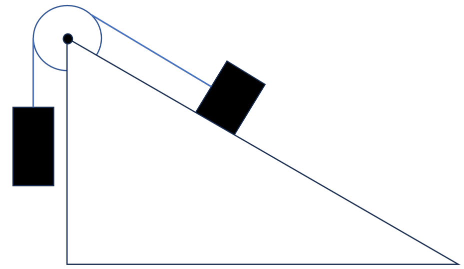
Problem 2



A block of mass m on a $45°$ slope is connected by a light rope over a frictionless pulley to a second hanging block of same mass. What is the minimum coefficient of static friction required so that neither block moves?

Problem 2

A block of mass m on a $45°$ slope is connected by a light rope over a frictionless pulley to a second hanging block of same mass. What is the minimum coefficient of static friction required so that neither block moves?



Solution:

The hanging block tends to move *down*, pulling the slope block *up* the incline. Static friction on the slope block therefore acts *down* the incline, opposing that motion.

For the slope block to remain at rest,

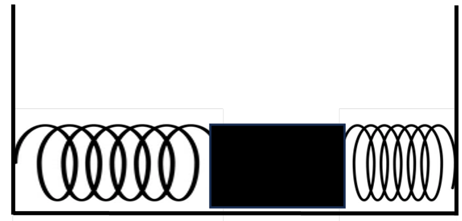
$$mg\sin\theta + \mu_s mg\cos\theta = mg$$

Simplify:

$$\sin\theta + \mu_s\cos\theta = 1 \quad \longrightarrow \quad \mu_s = 0.414$$

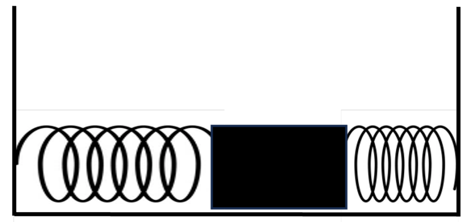
Problem 3

A block of mass 1.0 kg is attached between two identical horizontal springs, each with spring constant 200 N/m, on a frictionless surface. The block is pulled 0.10 m to the right (positive direction) and held at rest. What is the magnitude and direction of the net spring force acting on the block?



Problem 3

A block of mass 1.0 kg is attached between two identical horizontal springs, each with spring constant 200 N/m, on a frictionless surface. The block is pulled 0.10 m to the right (positive direction) and held at rest. What is the magnitude and direction of the net spring force acting on the block?

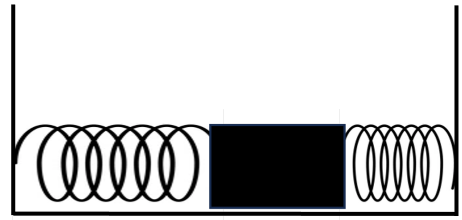


Solution:

Each spring is stretched or compressed by the same amount Δx_0. The right spring is stretched, pulling left, and the left spring is compressed, also pushing left — both act in the same direction, toward equilibrium.

$$F_{\text{net}} = F_{\text{left}} + F_{\text{right}} = -k\Delta x_0 - k\Delta x_0 = 2k\Delta x_0 = -40\,\text{N}$$

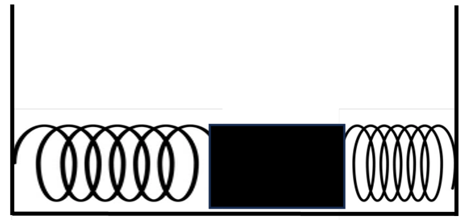
Problem 4



A 1.0 kg block is released from rest after being displaced 0.10 m on a frictionless surface between two identical springs, each with 200 N/m. What is the maximum velocity of the block during its oscillation?

Problem 4

A 1.0 kg block is released from rest after being displaced 0.10 m on a frictionless surface between two identical springs, each with 200 N/m. What is the maximum velocity of the block during its oscillation?



Solution:

The block performs harmonic oscillation about the equilibrium point. Because both springs act together, the effective spring constant is

$$k_{\text{eff}} = 2k.$$

The displacement as a function of time is

$$x(t) = \Delta x_0 \cos(\omega t),$$

where

$$\omega = \sqrt{\tfrac{k_{\text{eff}}}{m}} = \sqrt{\tfrac{2k}{m}}.$$

Differentiate to find the velocity:

$$v(t) = \frac{dx}{dt} = -\omega \Delta x_0 \sin(\omega t).$$

The **maximum velocity** occurs when $\sin(\omega t) = \pm 1$, giving

$$v_{\max} = \omega \Delta x_0 = \sqrt{\tfrac{2k}{m}}\, \Delta x_0 = 2.0\,\text{m/s}.$$

Problem 5

A small metal sphere of mass $m = 1.0\,\mathrm{kg}$ falls through air under the influence of gravity and a drag force proportional to its velocity: $F_D = -bv$, where b is the drag constant. On Earth, the drag constant is $b_E = 0.10\,\mathrm{kg/s}$, while on the Moon's, due to its extremely thin atmosphere, it is only $b_M = 1.0 \times 10^{-4}\,\mathrm{kg/s}$. Gravity is six times weaker on the Moon compared to the Earth. Find the ratio of the terminal velocity on the Moon to that on Earth.

Problem 5

A small metal sphere of mass $m = 1.0\,\text{kg}$ falls through air under the influence of gravity and a drag force proportional to its velocity: $F_D = -bv$, where b is the drag constant. On Earth, the drag constant is $b_E = 0.10\,\text{kg/s}$, while on the Moon's, due to its extremely thin atmosphere, it is only $b_M = 1.0 \times 10^{-4}\,\text{kg/s}$. Gravity is six times weaker on the Moon compared to the Earth. Find the ratio of the terminal velocity on the Moon to that on Earth.

Solution:

At terminal speed, the net force is zero:

$$mg = bv_t \quad \Longrightarrow \quad v_t = \frac{mg}{b}.$$

The ratio is therefore

$$\frac{v_{t,M}}{v_{t,E}} = \frac{(g_M/b_M)}{(g_E/b_E)} = \frac{g_M}{g_E}\frac{b_E}{b_M} = 165$$

Interpretation: The terminal velocity on the Moon is about 160 times greater than on Earth—so in practice, the ball would fall almost as if there were no air resistance.

Problem 6

A small block rests on the flat surface of a cart. The coefficient of static friction between the block and the cart is 0.20. The cart begins to accelerate horizontally. What is the maximum acceleration the cart can have before the block starts to slip?

Problem 6

A small block rests on the flat surface of a cart. The coefficient of static friction between the block and the cart is 0.20. The cart begins to accelerate horizontally. What is the maximum acceleration the cart can have before the block starts to slip?

Solution:

When the cart accelerates, the block tends to slide backward. Static friction provides the forward force that accelerates the block together with the cart.

The maximum possible static friction is

$$f_{s,\text{max}} = \mu_s mg.$$

The fictitious force due to the accelerating frame:

$$f_f = ma.$$

Newton's 2nd law at the threshold of slipping:

$$ma_{\text{max}} = \mu_s mg.$$

Simplify:

$$a_{\text{max}} = \mu_s g = (0.20)(9.8) = 1.96\,\text{m/s}^2.$$

Interpretation: If the cart accelerates faster than $2\,\text{m/s}^2$, static friction will no longer be able to hold the block in place, and it will begin to slip.

Problem 7

The human jaw acts as a lever system. Suppose the jaw muscle (masseter) attaches to the mandible at a point 2.5 cm from the jaw hinge, and the bite force is exerted by the teeth at a point 7.0 cm from the hinge. If the muscle exerts an upward force of $F_m = 600\,\mathrm{N}$, what is the bite force F_b at the teeth, assuming static equilibrium?

Problem 7

The human jaw acts as a lever system. Suppose the jaw muscle (masseter) attaches to the mandible at a point 2.5 cm from the jaw hinge, and the bite force is exerted by the teeth at a point 7.0 cm from the hinge. If the muscle exerts an upward force of $F_m = 600\,\mathrm{N}$, what is the bite force F_b at the teeth, assuming static equilibrium?

Solution:

The jaw rotates about the hinge. In equilibrium, the net torque about the hinge is zero:

$$\tau_{\text{muscle}} = \tau_{\text{bite}}.$$

Each torque is the product of force and its lever arm:

$$F_m r_m = F_b r_b.$$

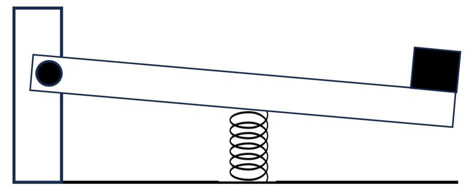
Solve for the bite force:

$$F_b = \frac{r_m}{r_b} F_m = 214\,\mathrm{N}.$$

Interpretation: Because the teeth are farther from the hinge than the muscle attachment, the jaw provides a *mechanical disadvantage*: a large muscle force produces a smaller bite force. In carnivores, the muscle attaches farther from the hinge, increasing leverage and bite strength.

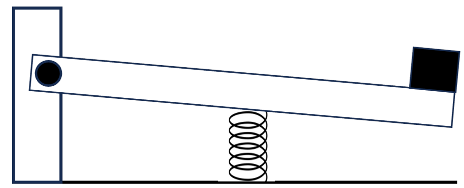
Problem 8

A massless plank of length $L = 2.0\,\mathrm{m}$ is hinged at its left end and supports a weight of mass $m = 10.0\,\mathrm{kg}$ at its right end. Halfway along the plank, at $L/2$, a vertical spring supports the plank. The system is in static equilibrium, and the plank dips downward no more than $\Delta x = 0.10\,\mathrm{m}$ at the end. What must the spring constant k be to satisfy this condition?



Problem 8

A massless plank of length $L = 2.0\,\text{m}$ is hinged at its left end and supports a weight of mass $m = 10.0\,\text{kg}$ at its right end. Halfway along the plank, at $L/2$, a vertical spring supports the plank. The system is in static equilibrium, and the plank dips downward no more than $\Delta x = 0.10\,\text{m}$ at the end. What must the spring constant k be to satisfy this condition?



Solution:

Let the hinge be the pivot. The weight produces a clockwise torque about the hinge, while the spring force (acting upward at $L/2$) produces a counterclockwise torque.

$$\tau_{\text{spring}} = \tau_{\text{weight}}$$

$$F_s\left(\tfrac{L}{2}\right) = (mg)(L)$$

The spring force is related to its compression by Hooke's law:

$$F_s = k\Delta x_{\text{spring}}.$$

The vertical deflection at the end of the plank (L) is $\Delta x = 0.10\,\text{m}$, so at the midpoint ($L/2$), the deflection (and thus spring compression) is roughly half as large:

$$\Delta x_{\text{spring}} = \frac{\Delta x}{2} = 0.05\,\text{m}.$$

Substitute into the torque balance:

$$(k\Delta x_{\text{spring}})\left(\tfrac{L}{2}\right) = (mg)(L)$$

Simplify:

$$k\Delta x_{\text{spring}} = 2mg \quad\Longrightarrow\quad k = \frac{2mg}{\Delta x_{\text{spring}}}.$$

Substitute numerical values:

$$k = \frac{2(10.0)(9.8)}{0.05} = \frac{196}{0.05} = 3920\,\text{N/m}.$$

$$\boxed{k = 3.9 \times 10^3\,\text{N/m}}$$

Interpretation: A spring constant of about 4,000 N/m keeps the end of the plank from dipping more than 10 cm. This type of analysis models how limbs, beams, or bridges distribute loads between supports.

Physics 3A Formula Sheet

Vectors

$$\vec{A} = A_x\hat{i} + A_y\hat{j}$$
$$|\vec{A}| = \sqrt{A_x^2 + A_y^2}$$
$$A_x = |\vec{A}|\cos\theta$$
$$A_y = |\vec{A}|\sin\theta$$
$$\tan\theta = \frac{A_y}{A_x}$$
$$\vec{B} = B_x\hat{i} + B_y\hat{j}$$
$$\vec{A} + \vec{B} = (A_x + B_x, A_y + B_y)$$
$$\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y = |\vec{A}||\vec{B}|\cos\phi$$

Trigonometry

$$\sin\theta = \cos(90^\circ - \theta)$$
$$\cos\theta = \sin(90^\circ - \theta)$$
$$\sin(2\theta) = 2\sin\theta\cos\theta$$
$$F_x = |\vec{F}|\cos\theta$$
$$F_y = |\vec{F}|\sin\theta$$

Geometry Essentials

$$c^2 = a^2 + b^2$$
$$C = 2\pi r; A = \pi r^2; s = r\theta$$
$$A = 4\pi r^2; V = \frac{4}{3}\pi r^3$$

Diffusion and Proportional Reasoning

$$r_{\text{rms}} = d\sqrt{mn}$$
$$r_{\text{rms}}^2 = d^2mn$$
$$D = \tfrac{1}{2}vd$$
$$r_{\text{rms}} = \sqrt{2mDt}$$

$$y = Cx^n$$
$$\frac{y_2}{y_1} = \frac{Cx_2^n}{Cx_1^n}$$

Kinematics

$$\Delta x = v\Delta t$$
$$v_{\text{avg.}} = \Delta x/\Delta t$$
$$a = \Delta v/\Delta t$$
$$x(t) = x_0 + vt$$
$$v(t) = v_0 + at$$
$$x(t) = x_0 + v_0t + \frac{1}{2}at^2$$
$$x(t) = \int v(t)\,dt$$
$$v(t) = \int a(t)\,dt$$

$$v(t) = \frac{dx}{dt}$$
$$a(t) = \frac{dv}{dt}$$
$$\frac{d}{dt}[t^n] = nt^{n-1}$$
$$\int_{t_1}^{t_2} t^n\,dt = \frac{t_2^{n+1} - t_1^{n+1}}{n+1}$$
$$y(t) = v_{y0}t - \frac{1}{2}gt^2$$

$$t_{\text{flight}} = \frac{2v_{y0}}{g}$$
$$y_{\max} = \frac{v_{y0}^2}{2g}$$
$$x_{\text{final}} = \frac{2v_{x0}v_{y0}}{g}$$
$$x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$
$$x_{\text{end}} = \frac{v_{x0}}{g}\left(v_{y0} + \sqrt{v_{y0}^2 - 2gy_{\text{end}}}\right)$$
$$t_{\text{flight}} = \frac{v_{y0} + \sqrt{v_{y0}^2 - 2gy_{\text{end}}}}{g}$$
$$v_y = -\sqrt{v_{y0}^2 - 2gy_{\text{end}}}$$

Interacting Systems

$$F_g = mg$$
$$F_s = -k\,\Delta x$$
$$K = k_1 + k_2$$
$$\frac{1}{K} = \frac{1}{k_1} + \frac{1}{k_2}$$
$$F_T = \text{constant along the rope}$$
$$F_N = mg\cos\theta$$
$$F_{\mu,s} \leq \mu_s N$$
$$F_{\mu,k} = \mu_k N$$
$$F_D = -\tfrac{1}{2}C_d\,\rho A v^2$$
$$F_D = -6\pi\,\eta\,r\,v$$
$$F_{\text{thrust}} = \dot{m}\,v_{\text{exhaust}}$$
$$a = \frac{F_{\text{net}}}{m}$$

Torque

$$\tau = rF\sin(\theta)$$
$$\alpha = \frac{\tau_{\text{net}}}{I}$$