Name: **ID:**

Midterm #3 - P3A - Practice

Prof. Laszlo Bardoczi, November 26, 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 the correct numerical value (to 2 significant figures) and 0.5 point for correct SI units. An incorrect sign results in a -0.5 point penalty. A correct unit with an incorrect numerical value receives no credit.
- 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 car makes a turn at a speed of 40 mph (about 18 m/s) following a circular arc of radius 20 m. As the car turns, the seat pushes on the driver's shoulder to provide the needed centripetal force.

Relative to the driver's weight, what is the magnitude of the sideways force the driver feels from the seat?

Solution:

The required centripetal force is

$$F_c = \frac{mv^2}{r}.$$

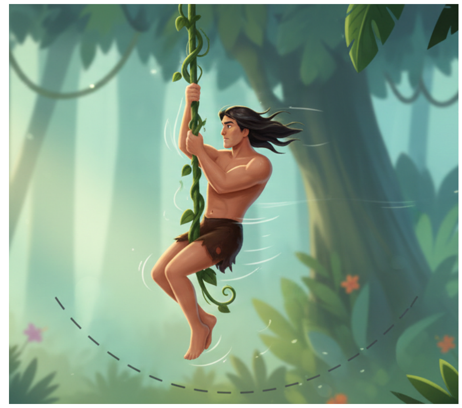
We compare this sideways force to the driver's weight mg:

$$\frac{F_c}{mg} = \frac{v^2}{rg} \approx 1.65.$$

Problem 2

Tarzan (mass 80 kg) swings on a rope of length 12 m. At the very bottom of the swing, his speed is measured to be 8 m/s. At this instant the rope is the *only* force supporting him, and the rope stretches slightly like a spring. It is observed that the rope extends by only 0.5% at the bottom of the swing.

Find the effective spring constant k of the rope.



Solution:

At the bottom of the swing, the tension must provide both weight support and centripetal force:

$$T = mg + \frac{mv^2}{L} = 1210.7 \text{ N}.$$

The rope stretches by 0.5%:

$$\Delta L = 0.005L = 0.06 \text{ m}.$$

Since the rope behaves like a spring:

$$T = k\,\Delta L \quad \longrightarrow \quad k = 2.02 \times 10^4 \text{ N/m}.$$

Problem 3

A bucket of water of mass 4.0 kg is lowered into a well by a light string. The string is wound around a solid cylindrical drum of mass 2.0 kg and radius 0.20 m. The drum rotates freely about a horizontal axle. When the bucket is released from rest, the string unwinds without slipping and the bucket accelerates downward.

Find the acceleration of the bucket as it falls.

Solution:

For the falling bucket:

$$mg - T = ma.$$

The tension produces a torque on the drum:

$$TR = I\alpha, \qquad a = R\alpha.$$

For a solid cylinder:

$$I = \frac{1}{2}MR^2.$$

So:

$$T = \frac{I\alpha}{R} = \frac{\frac{1}{2}MR^2}{R}\alpha = \frac{1}{2}MR\,\alpha = \frac{1}{2}Ma.$$

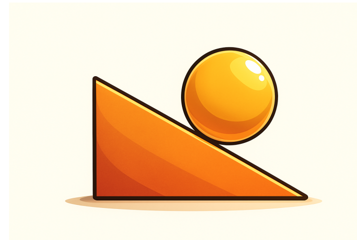
Substitute into the bucket equation:

$$mg - \frac{1}{2}Ma = ma \longrightarrow a = 7.84 \text{ m/s}^2$$

Problem 4

A spherical shell of mass 2.0 kg and radius 0.25 m is released from rest at the top of a slope inclined at 30°. The shell rolls down the incline *without slipping*.

Find the angular acceleration α of the spherical shell.



Solution:

For rolling without slipping:

$$a = \alpha R.$$

For translation along the incline:

$$mg\sin\theta - f = ma.$$

For rotation about the center:

$$fR = I\alpha.$$

Using $a = \alpha R$ and the spherical shell moment of inertia

$$I = \frac{2}{3}MR^2,$$

the force equations combine to:

$$mg\sin\theta = ma + \frac{I}{R^2}a = ma + \frac{2}{3}Ma.$$

Thus:

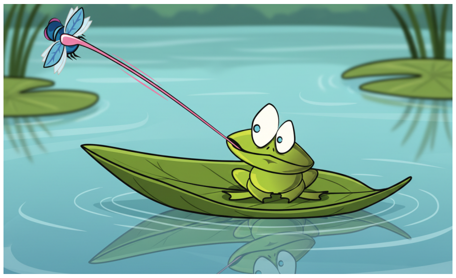
$$mg\sin\theta = \frac{5}{3}Ma \quad \Rightarrow \quad a = \frac{3}{5}g\sin\theta.$$

Then:

$$\alpha = \frac{a}{R} = \frac{3}{5}\frac{g\sin\theta}{R} = 11.76\ \text{rad/s}^2$$

Problem 5

A frog sits on a leaf floating on still water. The combined mass of the frog and the leaf is 0.20 kg.A fly of mass 0.005 kg is flying directly away from the frog at 1.0 m/s. The frog shoots out its tongue at a speed of 2 ms, catches the fly, and then pulls it back into its mouth. The mass of the tongue is 1 g. Assume water resistance is negligible so that no external forces act during the entire process.



Find the final speed of the leaf–frog–fly system after the frog finishes eating.

Solution:

Momentum is conserved because the leaf–frog–fly system is isolated.

$$p_i = m_{\text{fly}} v_{\text{fly}} = (0.005)(1.0) = 0.005 \text{ kg m/s}.$$

After eating, the frog and fly move together with mass:

$$m_{\text{tot}} = 0.20 + 0.005 = 0.205 \text{ kg}.$$

Conservation of momentum:

$$p_f = m_{\text{tot}} v_f = p_i.$$

Thus:

$$v_f = \frac{0.005}{0.205} \approx 0.0244 \text{ m/s}.$$

Problem 6

A female orca (killer whale) of mass 3200 kg is floating motionless in calm ocean water and is about to give birth. During birth, the newborn calf of mass 180 kg is expelled backward at a speed of 1.5 m/s (relative to the water). Assume no external forces act during the brief expulsion, so the orca–calf system is isolated.

Find the forward speed of the mother orca immediately after giving birth.

Solution:

Initial momentum is zero.
After the birth:

$$p_f = m_{\text{orca}}\, v_{\text{orca}} \;+\; m_{\text{calf}}(-1.5).$$

Momentum conservation:

$$0 = (3200)v_{\text{orca}} \;+\; (180)(-1.5).$$

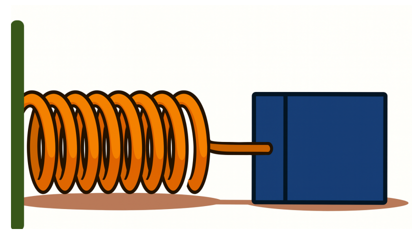
$$0 = 3200\, v_{\text{orca}} - 270.$$

$$v_{\text{orca}} = \frac{270}{3200} = 0.0844 \text{ m/s}.$$

Problem 7

A mass–spring oscillator consists of a 0.50 kg mass attached to a spring with spring constant 40 N/m. The oscillator moves with amplitude 0.20 m.

When the mass is at a displacement of 5 cm from equilibrium, what fraction of the *total mechanical energy* is kinetic energy?



Solution:

Total mechanical energy:

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(40)(0.20)^2 = 0.80 \text{ J}.$$

Spring potential energy at $x = \frac{1}{4}A$:

$$x = \tfrac{1}{4}(0.20) = 0.05 \text{ m}.$$

$$U = \tfrac{1}{2}kx^2 = \tfrac{1}{2}(40)(0.05)^2 = 0.05 \text{ J}.$$

Thus the kinetic energy is:

$$K = E - U = 0.80 - 0.05 = 0.75 \text{ J}.$$

Fraction of the total energy:

$$\frac{K}{E} = \frac{0.75}{0.80} \approx 0.94 \quad \text{or} \quad 94\%$$

Problem 8

On the ISS, Captain Holmes investigates a damaged data-storage that Dr. Chaos claims "just drifted into the wall by accident." However, Holmes finds the drone embedded 3.0 cm deep inside a block of insulating material. The insulation resists motion with a constant friction force of 45 N, and the drone has mass 0.40 kg.

Holmes then examines Chaos's spring-powered drone launcher. The spring's label claims a spring constant of 600 N/m, and Holmes measures the maximum compression to be 0.10 m.

Calculate the minimum spring constant that could explain the hard drive's penetration into the wall. Is Dr. Chaos lying?

Solution:

Energy absorbed by the insulator:

$$W_{\text{fric}} = Fd = (45)(0.030) = 1.35 \text{ J}.$$

This must equal the drone's impact kinetic energy, which must have come from the launcher spring:

$$E_{\text{spring}} = \tfrac{1}{2}kx^2 = K_{\text{impact}} \quad \longrightarrow \quad k = \frac{1.35}{0.005} = 270 \text{ N/m}.$$

Compare with the labeled value:

$$k_{\text{calculated}} = 270 \text{ N/m}, \qquad k_{\text{label}} = 600 \text{ N/m}.$$

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

$$F_g = mg$$

$$F_s = -k\,\Delta x$$

$$K = k_1 + k_2$$

$$\frac{1}{K} = \frac{1}{k_1} + \frac{1}{k_2}$$

$$F_T = \text{constant along the rope}$$

$$F_N = mg\cos\theta$$

$$F_{\mu,s} \leq \mu_s N$$

$$F_{\mu,k} = \mu_k N$$

$$F_D = -\tfrac{1}{2}C_d\,\rho A v^2$$

$$F_D = -6\pi\,\eta\,r\,v$$

$$F_{\text{thrust}} = \dot{m}\,v_{\text{exhaust}}$$

$$a = \frac{F_{\text{net}}}{m}$$

Circular Motion, Rotation

$$\tau = rF\sin(\theta)$$

$$\tau = I\alpha$$

$$f = \frac{1}{T}$$

$$v = \frac{2\pi r}{T} = 2\pi r f$$

$$\omega = w\pi f$$

$$\omega = \omega_\circ + \alpha t$$

$$\phi = \omega t$$

$$\phi = \omega t + \frac{1}{2}\omega t^2$$

$$a_{\text{cp}} = \frac{v^2}{r}$$

$$F_{\text{cp}} = m\,\frac{v^2}{r}$$

$$I = mr^2$$

$$I = \tfrac{1}{2}mR^2$$

$$I = \tfrac{2}{5}mR^2$$

$$I = \tfrac{2}{3}mR^2$$

$$I = \tfrac{1}{12}mL^2$$

$$I = \tfrac{1}{3}mL^2$$

Momentum

$$p = mv$$

$$dp/dt = F(t)$$

$$p_f - p_i = J$$

$$\Delta p_1 + \Delta p_2 = 0$$

$$(v_1)_f = \frac{m_1 - m_2}{m_1 + m_2}\,(v_1)_i$$

$$(v_2)_f = \frac{2m_1}{m_1 + m_2}\,(v_1)_i$$

Energy

$$K = \tfrac{1}{2}mv^2$$

$$U = mgh$$

$$U = \tfrac{1}{2}kx^2$$

$$E = K + U$$

$$W = Fx$$

$$W = \int F(x)dx$$

$$W = \Delta K$$

$$W = \Delta E$$

$$P = \frac{dW}{dt} = Fv$$