PHYS 1110-02 Fall 2026 Quiz 4

Brief Solutions

1. Ballistic pendulum

This scenario combines a collision with conservation of energy. The bullet embeds in the block, so the collision is totally inelastic: momentum is conserved but mechanical energy is not. Afterward the swing conserves mechanical energy, but the swing cannot easily be handled with kinematics, so we use energy. I'll use $m_1 = 0.012\,\text{kg}$ for the bullet, $m_2 = 1.80\,\text{kg}$ for the block, and $v_0 = 360\,\text{m/s}$ for the bullet's initial speed. The symbols K, p, and U_g are kinetic energy, momentum, and gravitational potential energy, and h is the height of the top of the swing.

A. Kinetic energy of the bullet before impact

$K_0 = \frac{1}{2}\, m_1 v_0^2 = \frac{1}{2}(0.012\,\text{kg})(360\,\text{m/s})^2 = 778\,\text{J}.$

B. Momentum of the bullet before impact

$p_0 = m_1 v_0 = (0.012\,\text{kg})(360\,\text{m/s}) = 4.32\,\text{kg·m/s}.$

C. Total momentum before the collision

The block is at rest and has no momentum, so the total is the bullet's momentum, $4.32\,\text{kg·m/s}$.

D. Type of collision

The bullet and block stick together, so this is a **totally inelastic** collision (choice c).

E. Total momentum right after the collision

Momentum is conserved in every collision, so it is still $4.32\,\text{kg·m/s}$.

F. Velocity of the combined bullet and block

The total momentum is the total mass times the common velocity:

$$v_1 = \frac{p}{m_1 + m_2} = \frac{4.32\,\text{kg·m/s}}{1.812\,\text{kg}} = 2.38\,\text{m/s}$$

in the direction of the bullet's original motion.

G. Kinetic energy after the collision

$K_1 = \frac{1}{2}(m_1 + m_2)v_1^2 = \frac{1}{2}(1.812\,\text{kg})(2.384\,\text{m/s})^2 = 5.15\,\text{J}.$

H. Is mechanical energy conserved in the collision?

No (choice b). The kinetic energy dropped from 778 J to 5.15 J. A collision in which the objects stick together always loses mechanical energy.

I. Is mechanical energy conserved in the swing?

Yes (choice a). The cables pull perpendicular to the motion, so they do no work. Only gravity does work, and gravity is a conservative force.

J. Kinetic energy at the top of the swing

At the top the block momentarily stops before swinging back, so $K_2 = 0$.

K. Change in gravitational potential energy

It **increases** (choice a). The block rises, and $U_g = mgy$ grows with height. Choosing different axes changes the value of U_g but not the fact that it increases as the block goes up.

L. Gravitational potential energy at the top of the swing

Mechanical energy is conserved in the swing, so $E_1 = E_2$, where 1 is the bottom of the swing and 2 is the top:

$$K_1 + U_{g1} = K_2 + U_{g2}$$

Since $K_2 = 0$, we have $U_{g2} = K_1 + U_{g1}$. If we put the zero of potential energy at the bottom of the swing, $U_{g1} = 0$ and

$$U_{g2} = K_1 = 5.15\,\text{J}.$$

M. Height of the top of the swing

With $U_{g1} = 0$ and $K_2 = 0$, the energy balance reads

$$\tfrac{1}{2}(m_1 + m_2)v_1^2 + 0 = 0 + (m_1 + m_2)gh$$

$$h = \frac{v_1^2}{2g} = \frac{(2.384\,\text{m/s})^2}{2(9.8\,\text{m/s}^2)} = 0.290\,\text{m}$$

The total mass cancels.

N. Momentum of the bullet right after embedding

The bullet now moves with the block at v_1, so $p_1 = m_1 v_1 = (0.012\,\text{kg})(2.384\,\text{m/s}) = 0.0286\,\text{kg·m/s}$.

O. Momentum change of the bullet

$$\Delta p = p_1 - p_0 = m_1 v_1 - m_1 v_0 = m_1(v_1 - v_0) = (0.012\,\text{kg})(2.384 - 360)\,\text{m/s} = -4.29\,\text{kg·m/s}$$

The negative sign means the bullet's momentum decreased.

P. Average force on the bullet

The momentum change equals the impulse, $\Delta p = F\Delta t$, so

$$F = \frac{\Delta p}{\Delta t} = \frac{-4.29\,\text{kg·m/s}}{5.00 \times 10^{-4}\,\text{s}} = -8580\,\text{N}$$

(using the unrounded Δp gives -8583 N). The magnitude is about 8.58×10^3 N, and the force points opposite the bullet's displacement.

Q. Block's velocity after an elastic collision

For an elastic collision in one dimension, the final velocity of object 2 is

$$v_{2f} = v_{2i}\frac{m_2 - m_1}{m_1 + m_2} + v_{1i}\frac{2m_1}{m_1 + m_2}$$

It doesn't matter which object is labeled 1 as long as the numbers are substituted consistently. Here object 1 is the bullet and object 2 is the block, with $v_{2i} = 0$:

$$v_{2f} = 0 + (360\,\text{m/s})\frac{2(0.012\,\text{kg})}{1.812\,\text{kg}} = +4.77\,\text{m/s}$$

The bullet would bounce back at -355 m/s.

R. Quantities conserved in an elastic collision

All four (a, b, c, d). Momentum is conserved in every collision. By definition, an elastic collision conserves kinetic energy, and since no potential energy changes during the collision, mechanical energy

is conserved too. The relative speed of the two objects is the same before and after, though their relative velocity reverses direction.

S. Quantities conserved if the bullet stops dead

Only **total momentum** (a). Kinetic energy is lost, so neither kinetic nor mechanical energy is conserved. The relative speed also changes: it was 360 m/s before, and afterward the bullet is at rest while the block moves at only about 2.4 m/s.

2. Rolling a tire

The tire rolls without slipping, so translational and angular quantities are related through the radius: $v = \omega r$, $a = \alpha r$, and $\Delta x = \Delta\theta\, r$. The radius is $r = 0.350$ m.

A. Initial angular speed

$$\omega_0 = \frac{v_0}{r} = \frac{1.20\,\text{m/s}}{0.350\,\text{m}} = 3.43\,\text{rad/s}.$$

B. Angular acceleration

$$\alpha = \frac{a}{r} = \frac{0.800\,\text{m/s}^2}{0.350\,\text{m}} = 2.29\,\text{rad/s}^2.$$

C. Angular displacement

$$\Delta\theta = \frac{\Delta x}{r} = \frac{4.00\,\text{m}}{0.350\,\text{m}} = 11.4\,\text{rad},$$

a bit under two full turns.