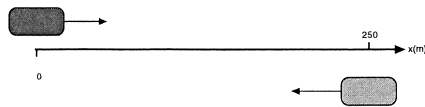


Your Name: \_\_\_\_\_

**PHY203**  
**Final Exam**  
**Chapters 1-11,15**  
**Mon., 12/19/22, 3-5 pm**

- Show work
- Use correct SI units
- Use scientific notation
- All answers with 3 significant figures
- use  $g = 9.81 \text{ m/s}^2$

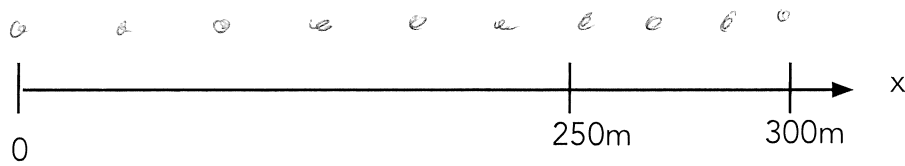
Solutions



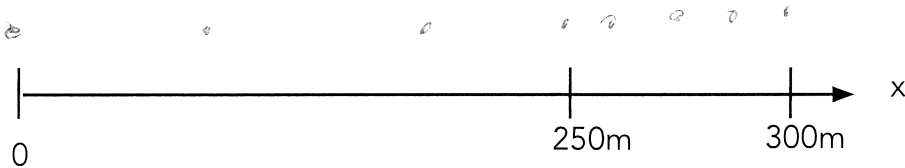
1. Two trains approach each other on parallel tracks. At  $t=0$  the train (A) on the left passes the  $x=0$  position with a constant speed of  $24.5 \text{ m/s}$ . The train (B) on the right is traveling towards train A with a speed of  $19.0 \text{ m/s}$ . When it reaches the  $x=250 \text{ m}$  position at  $t=0$ , it starts to accelerate with a magnitude of  $2.50 \text{ m/s}^2$ .

a. Produce motion diagrams of the trains between  $0 - 300\text{m}$ : **10**

Train A:



Train B:



b. Fill out the tables of known quantities for the two trains. Use the initial positions as either  $0$  or  $250\text{m}$  (for trains A or B) and the final position when the trains are side-by-side:

Train A:

Parameter	Known Value
$x_0$	0
$x_f$	
$v_0$	$24.5 \text{ m/s}$
$v_f$	$24.5 \text{ m/s}$
$a$	0
$t$	

Train B:

Parameter	Known Value
$x_0$	250
$x_f$	
$v_0$	$-19.0 \text{ m/s}$
$v_f$	
$a$	$-2.50 \text{ m/s}^2$
$t$	

c. Using the coordinate system depicted above, write an equation of motion (x vs. t) for train A: **10**

$$x_A = (24.5 \text{ m/s})t$$

d. Using the coordinate system depicted above, write an equation of motion (x vs. t) for train B (starting from when train B passes the x=250 m position): **20**

$$\begin{aligned} x_B &= 250 - 19.0t - \frac{1}{2}(2.50)t^2 \\ &= 250 - 19.0t - 1.25t^2 \end{aligned}$$

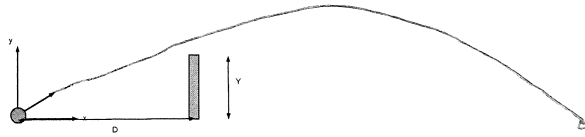
e. Find the time at which the centers of the trains are side-by-side. **10**

$$24.5t = 250 - 19.0t - 1.25t^2$$

$$1.25t^2 + 43.5t - 250 = 0$$

$$t = \frac{-43.5 \pm \sqrt{43.5^2 + 4 \cdot 250 \cdot 1.25}}{2 \cdot 1.25}$$

$$= 5.02 \text{ s}$$



2. A cannonball is shot from ground level at a castle wall. The castle wall is a horizontal distance  $D = 205$  m from the cannon. The initial speed of the ball is  $v_0$  and the initial angle the velocity of the ball makes with the horizontal is  $55.0^\circ$ . Take  $y = 0$  at ground level. Assume the ball just grazes the top of the wall on the way up after traveling for 1.50 s. (Ignore air resistance.)

a. On the above figure, make a sketch of the trajectory of the ball from start to when it hits the ground. **5**

b. Fill out the tables of known values. Take the "final" position as when it grazes the wall. **5**

Parameter	Known Value
$x_0$	0
$x_f$	205
$v_{x0}$	$v_0 \cos 55^\circ$
$v_{xf}$	"
$a_x$	0
$t$	1.50 s

Parameter	Known Value
$y_0$	0
$y_f$	
$v_{y0}$	$v_0 \sin 55^\circ$
$v_{yf}$	
$a_y$	$-9.81 \text{ m/s}^2$
$t$	1.50 s

c. Find the initial velocity of the cannonball in vector notation. **20**

$$x: 205 = 0 + v_0 \cos 55.0^\circ (1.50 \text{ s})$$

$$v_0 = \frac{205}{(\cos 55^\circ)(1.50)} = 238 \text{ m/s}$$

$$v_{0x} = 238 \cos 55^\circ = 137 \text{ m/s}$$

$$v_{0y} = 238 \sin 55^\circ = 195 \text{ m/s}$$

$$\vec{v}_0 = (137\hat{i} + 195\hat{j}) \text{ m/s}$$

d. Find the velocity of the cannonball in vector notation just as it grazes the top of the wall. **10**

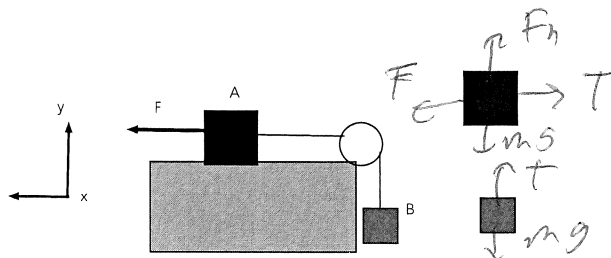
$$v_y = 195 - g t = 195 - g (1.5) = 180 \text{ m/s}$$

$$\vec{v} = (137\hat{i} + 180\hat{j}) \text{ m/s}$$

e. Find the height of the castle wall **10**

$$y: H = 0 + 195(1.5) - \frac{1}{2}g(1.5)^2$$

$$= 281 \text{ m}$$



3. Blocks A and B are connected by a light string and attached over a massless pulley. Assume a frictionless surface under block A and masses  $m_A$  and  $m_B$ . A horizontal force,  $F$ , is applied to block A as shown. The blocks are moving.

- Draw free body diagrams of the blocks on the figures above and to the right. **10**
- Write out Newton's 2nd Law for both blocks in the x- and y-directions. **30**

$$\begin{aligned}
 &A: \quad x: \quad F - T = m_A a \quad \checkmark \\
 &\quad \quad y: \quad F_n - m_A g = 0 \\
 &B: \quad \quad T - m_B g = m_B a \quad \checkmark
 \end{aligned}$$

Assume that  $m_A = 6.50 \text{ kg}$ ,  $m_B = 8.00 \text{ kg}$ , and  $F = 200 \text{ N}$ .

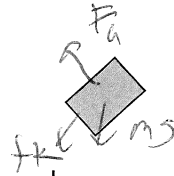
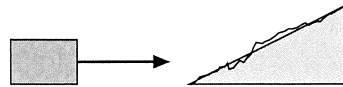
c. Find the magnitude of the acceleration of the blocks. **10**

Combine equations!

$$F - m_B g = (m_A + m_B) a$$

$$a = \frac{200 - 8.00g}{14.5}$$

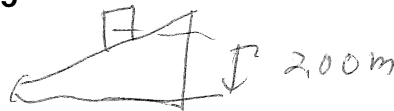
$$= 8.38 \text{ m/s}^2$$



4. A 7.50 kg block approaches a rough ramp which makes an angle of  $50.0^\circ$  with respect to the horizontal. The block has a speed of 15.5 m/s just before it hits the ramp. The coefficient of kinetic friction of the ramp is 0.300. The end of the problem is the block at a height of 2.00 m and it is still moving.

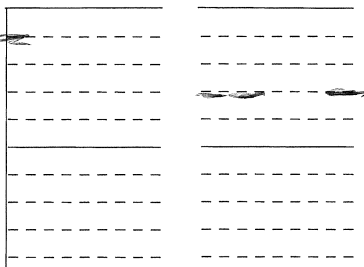
a. Draw a free body diagram of the block while it is sliding on the ramp. **5**

b. Sketch the final situation below, after the block has slid to a height of 2.00 m on the ramp and is still moving: **5**



c. Create energy bar charts: **10**

$K_i$   $U_{grav,i}$   $U_{spring,i}$   $E_{th,i}$       $K_f$   $U_{grav,f}$   $U_{spring,f}$   $E_{th,f}$



d. Use Conservation of Energy to find the speed of the block at height 2.00 m. **30**

$$\sin 50^\circ = \frac{2.00 \text{ m}}{\Delta s}, \quad \Delta s = 2.61 \text{ m}$$

$$\frac{1}{2} m v_i^2 = \frac{1}{2} m v_f^2 + mgh + \mu_k \Delta s$$

$$\mu_k = 0.300 \cos 50^\circ \Delta s$$

$$v_f^2 = v_i^2 - 2gh - 2\mu_k g \cos 50^\circ \Delta s$$

$$= 15.5^2 - 2g [h + \mu_k \cos 50^\circ \Delta s]$$

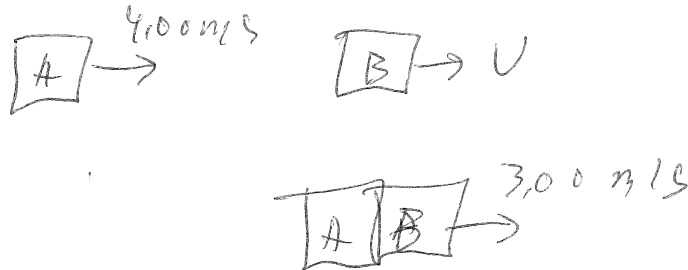
$$= 15.5^2 - 2g [2 + 0.300 \cos 50^\circ (2.61)]$$

$$= 15.5^2 - 2g (2.50)$$

$$v_f = 13.8 \text{ m/s}$$

5. Football player A (mass 110 kg) is traveling in the +x-direction with a speed of 4.00 m/s towards football player B (mass 95.0 kg) who is traveling in the +x-direction with an unknown speed,  $v$ , before they collide. The players collide, stick together, and continue to travel in the +x-direction with a speed of 3.00 m/s.

a. Draw sketches of the situation before and after the collision. 5



b. List the known quantities before the collision: 5

Parameter	Known Value
$M_A$	110 kg
$v_A$	4.00 m/s
$M_B$	95.0 kg
$v_B$	$v$

c. List the known quantities after the collision: 5

Parameter	Known Value
$M_{AB}$	205 kg
$v_{AB}$	3.00 m/s

d. Find the magnitude of the initial momentum of players A and B in terms of numbers and variables before the collision: **10**

$$p_A = (110)(4.00) = 440 \text{ kg}\cdot\text{m/s}$$

$$p_B = 95.0 \text{ V}$$

e. Find the magnitude of the final momentum of players A+B in terms of numbers and variables after the collision: **5**

$$p_{AB} = (205)(3.00) = 615 \text{ kg}\cdot\text{m/s}$$

f. Find the speed of player B before the collision. **10**

$$440 + 95V = 615$$

$$95V = 175$$

$$V = 1.84 \text{ m/s}$$

g. Determine quantitatively if the collision was elastic or inelastic. **10**

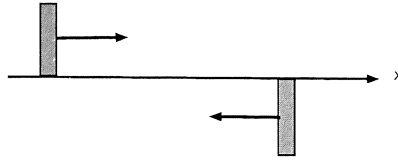
$$K_i = \frac{1}{2}(110)(4.00)^2 + \frac{1}{2}(95)(1.84)^2$$

$$= 880 + 161$$

$$= 1041 \text{ J}$$

$$K_f = \frac{1}{2}(205)(3.00)^2 = 922.5 \text{ J}$$

$$K_i \neq K_f \quad \text{inelastic}$$



6. Two sticks of length 0.800 m and mass 0.600 kg are traveling towards each other on a horizontal, frictionless table with speeds of 4.50 m/s, as shown above. When the ends touch, the ends stick together and the sticks start rotating about their ends without any further translation. A sketch of the initial situation is given above. Take the z-axis as “out of the page”.

a. Sketch the final situation as the sticks are rotating about a common center. 5



b. List the known quantities before the collision: 5

Parameter	Known Value
L <sub>1</sub>	0.400 m
L <sub>2</sub>	0.400 m
M <sub>1</sub>	0.600 kg
M <sub>2</sub>	0.600 kg
v <sub>1</sub>	4.50 m/s
v <sub>2</sub>	-4.50 m/s

c. List the known quantities after the collision: 5

Parameter	Known Value
L	1.60 m
M	1.20 kg
V <sub>CM</sub>	0

d. Find the angular momentum in vector notation of the 2-stick system about the collision point before the collision. (Hint: you can treat the sticks as point masses with the mass of each at the center of mass for this calculation.) **15**

$$L_1 = L_2 = r m v = (0.400)(0.600)(4.50) = 1.08$$

$\vec{r} \times \vec{v}$  rth had rule  $-\vec{z}$  direction

$$\vec{L}_{\text{tot}} = -2.16 \hat{z} \text{ kg m}^2/\text{s}$$

e. Find the moment of inertia of the stuck-together 2-stick system about the axis of rotation after the collision. **10**

$$L = \frac{1}{2} M v^2 = \frac{1}{2} (1.20)(4.50)^2$$

$$= 0.236 \text{ kg m}^2$$

f. Find the angular speed of the 2-stick system just after the collision. **10**

$$2.16 = (0.236) \omega$$

$$\omega = 9.14 \text{ rad/s}$$