Your Name: ______________________

**PHY203**
**Final Exam**
**Chapters 1-11,15**
~~?????????~~
Wed., May 7, 2025

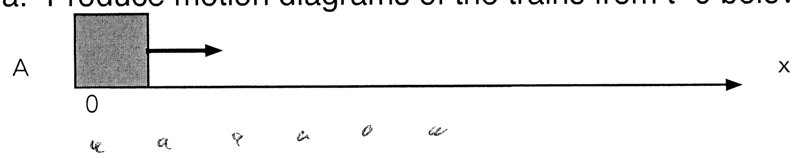
- Show work
- Use correct SI units
- Use scientific notation
- All answers with 3 significant figures
- use $g = 9.81\ m/s^2$

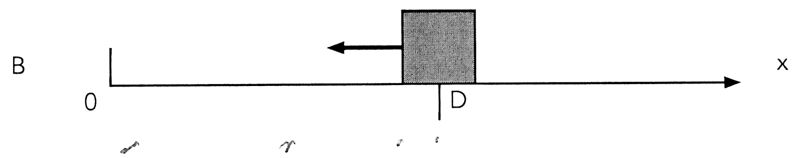
Solutions

MakeupFinalF24 S25

1. Two trains are traveling in opposite directions on parallel tracks. At t=0, train A passes the x =0 with a constant speed of 55.0 m/s. At t=0, train B accelerates from rest with a magnitude of 2.50 m/s² starting at D = 150. We want to find the time that the trains are side-by-side.

a. Produce motion diagrams of the trains from t=0 below each sketch: **10**




b. Fill out the tables of known quantities for the two trains:

Train A:

| Parameter | Known Value |
|---|---|
| $x_0$ | 0 |
| $x_f$ | |
| $v_0$ | 55.0 m/s |
| $v_f$ | 55.0 m/s |
| a | 0 |
| t | |

Train B:

| Parameter | Known Value |
|---|---|
| $x_0$ | 150 m |
| $x_f$ | |
| $v_0$ | 0 |
| $v_f$ | |
| a | $-2.50\ m/s^2$ |
| t | |

c. Write the equation for the position of train A as a function of time: **10**

$x_A = 55.0t$

d. Write the equation for the position of train B as a function of time: **20**

$x_B = 150 - \frac{1}{2}(2.50)t^2 = 150 - 1.25t^2$

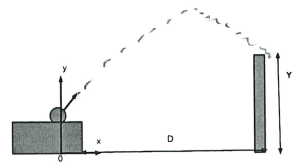
e. Find the time the trains are side-by-side. **10**

$$55t = 150 - 1.25t^2$$

$$1.25t^2 + 55t - 150 = 0$$

$$t = \frac{-55 \pm \sqrt{55^2 + 4 \cdot 1.25 \cdot 150}}{2.50}$$

$$= 2.58\ s$$



2. A cannonball is shot from a cliff of height H = 115 m at a castle wall. The castle wall is Y = 195 m high and a horizontal distance D = 205 m from the cannon. Take y = 0 at ground level. Assume the ball just misses the top of the wall on the way down. Assume the takeoff angle is 45.0° so $v_{xo}=v_{yo}$.

a. Make a sketch of the trajectory of the ball from start until it grazes the wall. **5**

b. Fill out the tables of known values. (Take the "final" position as when the ball grazes the top of the wall.) ~~**5**~~ 2

| Parameter | Known Value |
|---|---|
| $x_0$ | 0 |
| $x_f$ | 205 m |
| $v_{x0}$ | |
| $v_{xf}$ | |
| $a_x$ | 0 |
| t | |

| Parameter | Known Value |
|---|---|
| $y_0$ | 115 m |
| $y_f$ | 195 m |
| $v_{y0}$ | |
| $v_{yf}$ | |
| $a_y$ | −9.81 m/s² |
| t | |

c. Find the initial velocity of the cannonball in vector notation using the coordinate system above. ~~**20**~~ 25

x: $205 = v_{xo} t$  $v_{xo} = v_{yo} = \frac{205}{t}$

y: $195 = 115 + v_{yo} t - \frac{1}{2} g t^2$

$195 = 115 + 205 - \frac{1}{2} g t^2$

$\frac{1}{2} g t^2 = 125$, $t = 5.05$ s

$v_{xo} = v_{yo} = 205/t = 40.6$ m/s

$\vec{v_0} = (40.6\,\hat{i} + 40.6\,\hat{j})$ m/s

d. Find the acceleration, velocity, and position of the cannonball in vector notation at its highest point. **20**

$a = -9.81\,\hat{j}$ m/s²

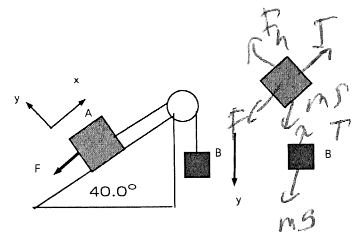
y: B: $0 = 40.6 - gt$, $t = 4.14$ s

y: C: $0 = 40.6^2 - 2g\Delta y$, $\Delta y = 84.0$

$y = 84.0 + 115 = 199$

x: $x = 40.6(4.14) = 168$ m

$\vec{v} = 40.6\,\hat{i}$ m/s  $\vec{r} = (168\,\hat{i} + 199\,\hat{j})$ m




3. Blocks A and B are connected by a light string and attached over a massless pulley and are initially at rest. Assume masses $m_A$ and $m_B$. A force, F, is applied to block A, parallel to the ramp, as shown. The ramp under block A is frictionless and makes an angle of 40.0° with respect to the horizontal.

a. Draw free body diagrams of the blocks on the figures above and to the right. **10**

b. Write out Newton's 2nd Law for both blocks in x- and y-directions using the coordinate systems given above. **30**

A: x: $T - F - m_A g \sin 40.0^\circ = m_A a$

y: $F_n - m_A g \cos 40^\circ = 0$

B: y: $m_B g - T = m_B a$

Assume that $m_A$ =6.50 kg, $m_B$ = 8.00 kg, and F = 17.5 N.

c. Find the magnitude of the acceleration of the blocks (and the tension in the string) **10**

Combine A: x and B: y:

$m_B g - F - m_A g \sin 40^\circ = (m_A + m_B) a$

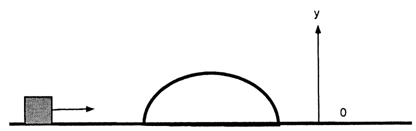
$$a = \frac{8g - 17.5 - 6.5 g \sin 40^\circ}{14.5}$$

$= 1.38 \text{ m/s}^2$

From B: y: $T = m_B g - m_B a$

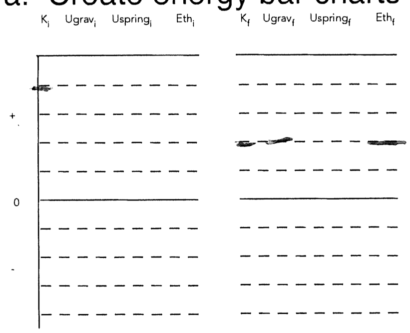
$= 8.00(g - 1.38)$

$= 67.4 \text{ N}$




4. A block of mass 6.50 kg slides along a frictionless track with a speed of 18.5 m/s. It then slides up a rough, spherical portion of the track with a radius of 7.00 m. At the top of the rounded section of track, the block has lost 500 J of energy due to friction and is still moving. Take y = 0 at the level section of track.

a. Create energy bar charts from the level section to the top of the rounded portion: **5**




b. Find the speed of the block at the top of the rounded section. **20**

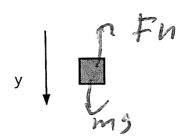
$$\frac{1}{2} m v_i^2 = \frac{1}{2} m v_f^2 + mgh + 500$$

$$v_f^2 = v_i^2 - 2gh - \frac{2 \cdot 500}{m}$$

$$= 18.5^2 - 2g(7.00) - \frac{1000}{6.50}$$

$$v_f = 7.15 \text{ m/s}$$

c. On the figure below, draw a free body diagram of the block at the top of the rounded section. **5**



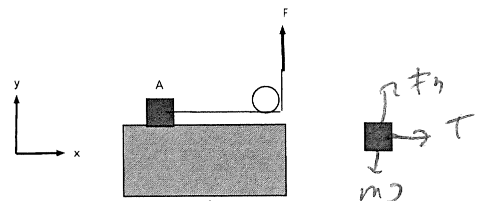

d. Write out Newton's 2[nd] Law in the y-direction for the block at the top of the rounded section and find the magnitude of the normal force on the block. **20**

$$mg - F_n = ma = \frac{mv^2}{r}$$

$$F_n = m\left(g - \frac{v^2}{r}\right)$$

$$= 6.50\left(g - \frac{7.15^2}{7}\right)$$

$$= 16.3 \text{ N}$$




5. Block A on a frictionless table is attached to a light string wrapped around a pulley. The string is being pulled straight up by a force F.
Given $M_A$, and M and R for the pulley (a solid disk).
a. Draw a free body diagram for the block above and to the right. **5**

b. Write out Newton's $2^{nd}$ Law for block A in all directions and the torque equation for the pulley. **30**

$x$: $T = ma$

$y$: $F_n - mg = 0$

$\tau$: $(F - T)R = I\alpha = I\dfrac{a}{R}$

Given $M_A$=5.50 kg, M=4.00 kg, R=0.500 m, and F=85.0 N.
c. Find the magnitude of the acceleration of the block. **15**

$T = ma$

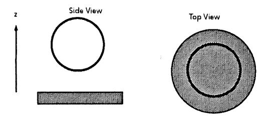
$(F - T)R = \frac{1}{2}MR^2\frac{a}{R}$

$F = ma + \frac{1}{2}Ma$

$= a\left(m + \frac{M}{2}\right)$

$a = \dfrac{85}{\left(5.50 + \frac{4.00}{2}\right)} = \dfrac{85}{7.5}$

$= 11.3\ m/s^2$




6. A hollow sphere is held above a solid disk that is initially spinning in a clockwise direction as viewed from above with an angular speed of 8.50 rad/s. The sphere is initially spinning in a counterclockwise direction with an angular speed of 2.50 rad/s The disk has a mass of 3.50 kg and a radius of 2.00 m. The sphere has a mass of 3.00 kg and a radius of 1.50 m. The sphere is released and falls onto the disk and sticks to it such that the centers of sphere and disk line up. Take the z-direction as positive "up" as shown.

a. List the known quantities below:

| Parameter | Known Value |
|---|---|
| $r_{Disk}$ | 2.00 m |
| $r_{Sphere}$ | 1.50 m |
| $M_{disk}$ | 3.50 kg |
| $M_{Sphere}$ | 3.00 kg |
| $\omega_{oDisk}$ | $-8.50\hat{k}$ rad/s |
| $\omega_{oSphere}$ | $+2.50\hat{k}$ rad/s |

b. Find the moment of inertia of the solid disk about its axis. **5**

$$I = \frac{1}{2}Mr^2 = \frac{1}{2}(3.50)(2.00)^2 = 7.00\ kg\ m^2$$

c. Find the moment of inertia of the hollow sphere about its axis. **5**

$$I = \frac{2}{3}Mr^2 = \frac{2}{3}(3.00)(1.50)^2 = 4.50\ kg\ m^2$$

d. Find the angular momentum of the disk before the sphere falls on it <u>in vector notation</u>. **10**

$$\vec{L} = I\vec{\omega} = (7.00)(-8.50\hat{k}) = -59.5\hat{k}\ kg\ m^2/s$$

e. Find the angular momentum of the sphere before the collision in vector notation. **10**

$$\vec{L} = (4.50)(2.50\hat{k}) = 11.2\hat{k}\ kg\ m^2/s$$

f. Find the angular speed of the disk/sphere system after the collision. **20**

$$L_{tot} = 11.2 - 59.5 = -48.2$$

$$+48.2 = (I_1 + I_2)\omega_f$$

$$\omega_f = \frac{48.2}{(7.00 + 4.50)} = 4.20\ rad/s$$