Your Name: ________________________

PHY203
Final Exam
Chapters 1-11,15
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Wed., May 8, 2024

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

Solutions

~~MakeupFinalF~~23

1. A car passes x=0 at t=0 traveling in the +x direction with a constant speed of 15.0 m/s. It travels at this speed for 25.0 s, then it accelerates in the +x direction with a magnitude of 3.00 m/s^2 for an additional 35.0 s. Finally, it slows down until coming to rest with an acceleration of magnitude 2.25 m/s^2.

a. For the first 25.0 s, fill out the table below:

Parameter	Known Value
x_0	0
x_f	
v_0	15.0 m/s
v_f	15.0 m/s
a	0
t	25.0 s

b. Find the distance the car has traveled after 25.0 s. **10**

$x = 0 + 15.0(25.0) + 0 = 375$ m

c. For the 25.0 s to 60.0 s, fill out the table below:

Parameter	Known Value
x_0	375 m
x_f	
v_0	15.0 m/s
v_f	
a	3.00 m/s^2
t	35.0 s

d. Find the speed of the car after 60.0 s. **10**

$V = 15.0 + 3.00(35.00) = 120$ m/s

e. Find the total distance the car has traveled after 60.0 s. **10**

$x = 375 + 15.0(35.0) + \frac{1}{2}(3.00)(35.0)^2 = 2.74 \times 10^3$ m

f. For the period of 60.0 s to when it stops, fill out the table below:

Parameter	Known Value
x_0	2737.5 m
x_f	
v_0	120 m/s
v_f	0
a	−2.25 m/s^2
t	

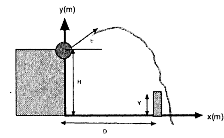
g. Find the total time the car has been traveling before it comes to rest. **10**

$0 = 120 - 2.25t$; $t = 53.3$ s $+ 60 = 113$ s.

h. Find the total distance the car has traveled when it has come to rest. **10**

$x = 2737.5 + 120(53.3) - \frac{1}{2}(2.25)(53.3)^2$

$= 5.94 \times 10^3$ m



2. A cannonball is shot from a cliff of height H = 115 m at a castle wall, as shown above. The castle wall is Y = 55.0 m high and a horizontal distance D = 205 m from the cannon. Take y = 0 at ground level. Assume the ball just grazes the top of the wall after traveling for 6.75 s

a. On the figure above, plot the trajectory of the cannonball. **5**

b. Fill out the tables of known values.

Take the final position as when the cannonball grazes the castle wall.

Parameter	Known Value
x_0	0
x_f	205 m
v_{x0}	
v_{xf}	
a_x	0
t	6.75 s

Parameter	Known Value
y_0	115 m
y_f	55.0 m
v_{y0}	
v_{yf}	
a_y	$-9.81\ m/s^2$
t	6.75 s

c. Find the initial velocity of the cannonball and write it in vector notation using the coordinate system above. **20**

x: $205 = 0 + v_{x0}(6.75) + 0$

$v_{0x} = 30.3\ m/s$

y: $55.0 = 115 + v_{y0}(6.75) - \frac{1}{2}g(6.75)^2$

$v_{y0} = 24.2\ m/s$

$\vec{v_0} = (30.3\hat{i} + 24.2\hat{j})\ m/s$

d. Find the acceleration, velocity, and position of the cannonball in vector notation just before it hits the ground on the other side of the wall. **25**

* $\vec{a} = -9.81\hat{j}\ m/s^2$

y: $0 = 115 + 24.2t - \frac{1}{2}gt^2$

$4.905t^2 - 24.2t - 115 = 0$

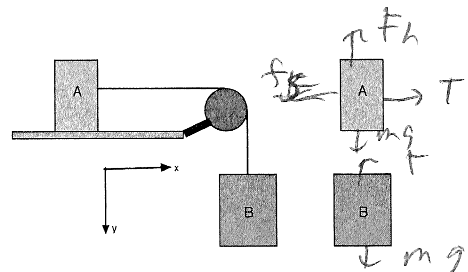
$t = \frac{24.2 \pm \sqrt{24.2^2 + 4 \cdot 4.905 \cdot 115}}{9.81} = 7.90\ s$

$v_y = 24.2 + at = 24.2 - g(7.90) = -53.3\ m/s$

* $\vec{v} = (30.3\hat{i} - 53.3\hat{j})\ m/s$

x: $x = 0 + 30.3(7.90) = 239\ m$

* $\vec{r} = 239\hat{i}\ m$



3. Blocks A and B are connected by a light string and attached over a massless pulley and are initially at rest. Assume a rough surface under block A with coefficient of static friction μ_s and masses M_A and M_B. The blocks are released and are just about to start sliding.

a. Draw free body diagrams on the blocks shown above and on the right. **5**

b. Write out Newton's 2nd Law for both blocks in x- and y-directions. **30**

A: x: $T - f_{s\,max} = m_A a = 0$

y: $m_A g - F_n = 0$

B: y: $m_B g - T = m_B a = 0$

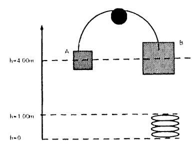
Assume that M_A =9.50 kg, M_B = 7.50 kg.

c. Find the coefficient of static friction. **15**

Combine: $m_B g - f_{s\,max} = 0$

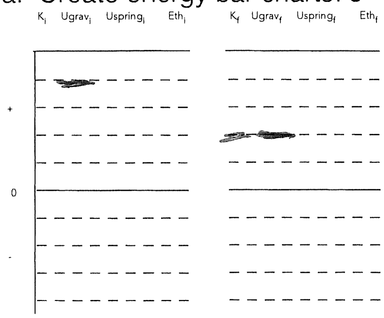
$m_B g = \mu_s F_n = \mu_s m_A g$

$\mu_s = \frac{m_B g}{m_A g} = \frac{7.50}{9.50} = 0.789$



4. Two blocks with masses m_A and m_B are connected by a light string and suspended over a massless pulley. Assume the initial height of both blocks is h= 4.00 m. The blocks are released. (Ignore the size of the blocks.) We want to find the speeds of the blocks after they have traveled 3.00 m. At 3.00 m block B just makes contact with the spring, which is still uncompressed at that point.

a. Create energy bar charts: **5**



b. Assume m_A = 5.00 kg and m_B = 7.50 kg. Find the initial energy of the blocks before they start moving. **5**

$$U_g = (5.00 + 7.50)\,g\,(4.00) = 490\ J$$

c. Use Conservation of Energy to find the speeds of the blocks after they have traveled 3.00 m. **20**

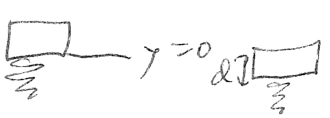
$$490.5 = \frac{1}{2}(12.5)v^2 + g[5\cdot 7 + 7.5\cdot 1]$$

$$= 6.25v^2 + 416.9$$

$$6.25v^2 = 73.6$$

$$v = 3.43\ m/s$$

d. After block B has traveled 3.00 m (and is just touching the spring), the string breaks and the block lands on the spring which has a spring constant of k=800 N/m. Find the maximum compression of the spring. **20**



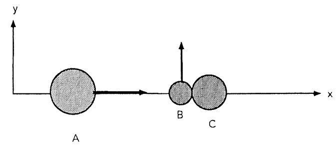
$$\frac{1}{2}mv_B^2 = \frac{1}{2}kd^2 - mgd$$

$$\frac{1}{2}(7.5)(3.43)^2 = \frac{800}{2}d^2 - (7.5)g(d)$$

$$0\ \cancel{44.1} = 400d^2 - 73.6d - 44.1$$

$$d = \frac{73.6 \pm \sqrt{73.6^2 + 4\cdot 400\cdot 44.1}}{800}$$

$$= 0.437\ m$$



5. A disk (A) of mass 8.50 kg is traveling on a frictionless surface in the +x direction with a speed of 12.5 m/s. At t=0, the disk breaks into 2 pieces, B and C. Piece B (mass of 5.00 kg) travels off in the +y-direction with a speed of 9.50 m/s.

a. List the known quantities before and after the breakup:

Parameter	Known Value
M_A	8.50 kg
V_A	12.5 m/s $\hat{i}$

Parameter	Known Value
M_B	5.00 kg
V_B	9.50 $\hat{j}$ m/s
M_C	3.50 kg

b. Find the linear momentum of disk A before the breakup and write it in vector notation. **10**

$$\vec{P_A} = (8.50)(12.5)\,\hat{i} = 106 \text{ kg m/s } \hat{i}$$

c. Find the linear momentum of piece B after the breakup and in vector notation. **10**

$$\vec{P_B} = (5.00)(9.50)\,\hat{j} = 47.5 \text{ kg m/s } \hat{j}$$

d. Find the velocity of piece C after the breakup and write it in vector notation. **20**

$$106\,\hat{i} = 47.5\,\hat{j} + (v_{cx}\hat{i} + v_{cy}\hat{j})(3.50)$$

$$x: \quad 106 = 3.50\, v_{cx} \; ; \quad v_{cx} = 30.3 \text{ m/s}$$

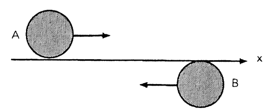
$$y: \quad 0 = 47.5 + v_{cy}(3.5) \; ; \quad v_{cy} = -13.6 \text{ m/s}$$

$$\vec{v_c} = (30.3\,\hat{i} - 13.6\,\hat{j}) \text{ m/s}$$

e. Find the angle the velocity of piece C makes with the x-axis. **10**

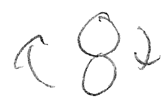
$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{-13.6}{30.3}\right) = -24.1^\circ$$

$$(\text{or } 336^\circ)$$



6. Two disks of radius 0.750 m and mass 0.500 kg are traveling towards each other with speeds of 4.50 m/s, as shown above. When the disks touch, the disks stick together and they start rotating without any further translation. A sketch of the initial situation including a coordinate system is given above. Take the +z-axis as out of the paper.

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



b. Find the linear momenta of disks A and B before the collision and write them in vector notation. **10**

$\vec{p}_A = (.500)(4.50)\,\hat{i} = 2.25\,\hat{i}$ kg m/s

$\vec{p}_B = (.500)(-4.50)\,\hat{i} = -2.25\,\hat{i}$ kg m/s

c. Find the angular momentum of the 2-disk system in vector notation about the collision point before the collision. (Hint: you can treat the disks as point masses for this calculation.) **15**

$\vec{L}_A = \vec{r} \times \vec{p} = rmv = (.75)(2.25)$

$= -1.69$ kg m²/s $\hat{k} = \vec{L}_B$

$\vec{L}_{tot} = -3.38$ kg m/s $\hat{k}$

d. Find the moment of inertia of the 2-disk system just after the collision. (Hint: you can treat the disks as point masses for this calculation.) **10**

$I = 2(mr^2) = 2(.500)(.750)^2$

$= 0.562$ kg m²

e. Find the angular speed of the 2-disk system just after the collision. **10**

$L = I\omega$

$3.38 = 0.562\,\omega$

$\omega_f = 6.01$ rad/s