Midterm 2

Physics 1A (Lec 5)

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Disc: Friday 1pm Nathan

Time to complete the exam: 90 min

Each problem is worth 20 points. If a problem has parts (a) and (b), they are 10 points each. It is not sufficient to present the final answer. You need to show the solution and justify your steps at the level of detail that would be sufficient for your fellow classmate (or grader) to understand how you arrived at the final answer. Please write your solutions in the spaces below each question. You can use the back sides of the pages as scrap paper. Numerical answers need not have more significant figures than the numbers provided in the problem.

1	2	3	4	5	6	total
20	18	20	20	20	20	118

Problem 1

A man standing on a cart at rest throws a stone with a mass of 4 kg in a horizontal direction. The cart with the man rolls backwards. Its velocity was 0.2 m/s immediately after the stone was thrown. The cart with the man has a mass 100 kg. Find the kinetic energy of the stone in 0.5 second after it was thrown (assuming it did not hit any obstacle).

$m_{stone} = 4kg$

$V_{initi} = 0.2$

$M_{cart} = 100kg$

$0 = 4(V_{stone}) - 100(0.2)$

$\frac{20}{4} = V_{stone\ initial}$

$V_{is} = 5\ m/s$

$V_y = V_0 + at$

$V_y = -9.8(0.5)$

$= -4.9 m/s$

Δx		Δy	
V_0	5	V_0	0
V	5	V	-4.9
a	0	a	-9.8
Δt	0.5	Δt	0.5

$V_{t=0.5} = \sqrt{5^2 + 4.9^2}$

$= 7.0007 m/s$

$KE = \frac{1}{2} m v^2$

$= \frac{1}{2}(4)(7.0007)^2$

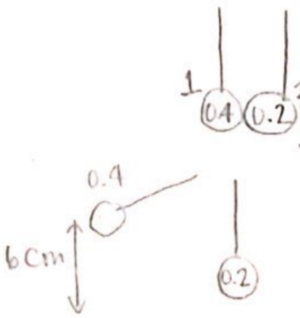
$= 98.02J$ ✓

18/20

Problem 2

Two small balls are suspended on parallel threads of the same length so that they touch each other in the vertical position. The mass of the first ball is 0.4 kg and the mass of the second ball is 200 g. The first ball is deflected so that its centre of mass rises to a height of 6 cm, and it is then released.

(a) To what maximal height will the 200 g ball rise if the collision is elastic?



for 0.4 kg ball

$mgh = \frac{1}{2}mv_f^2$

$\frac{1}{2}mv_f^2 = (0.4)(9.8)(0.06)$

$KE_{0.4} = 0.2352J$

$v_1 = \sqrt{\frac{2(KE)}{m_1}} = 1.084 m/s$

$m_1v_1 = m_2v_2 - m_1v_1'$

$0.4336 = m_2v_2 - m_1v_1$

$KE_{1\,initial} = KE_2' + KE_1'$

$\frac{0.2352}{0.4336} = \frac{\frac{1}{2}m_2v_2^2 + \frac{1}{2}m_1v_1^2}{m_2v_2 - m_1v_1}$

$1.085 = m_2v_2 + m_1v_1$

substitute

$\frac{1.085 - 0.4v_1}{0.2} = v_2$

$0.4336 = (0.2)\frac{(1.085 - 0.4v_1)}{0.2} - (0.4)v_1$

$0.4336 = 1.085 - 0.4v_1 - 0.4v_1$

$0.8v_1 = 0.6514$ $v_1 = 0.814 m/s$

Solved on previous blank ← page

X -2

(b) To what maximal height will the balls rise if they stick together when they collide?

$m_1v_1 = (m_1 + m_2)v'$

$\frac{m_1v_1}{m_1 + m_2} = v'$

$\frac{(0.4)(1.084)}{0.4 + 0.2} = v'$

$v' = 0.7227$

$KE_{ini} = U_g$

$\frac{1}{2}(m_1 + m_2)(0.7227)^2 = mgh$

$\frac{(m_1 + m_2)(0.7227)^2}{2(m_1 + m_2)g} = h$

$h = \frac{0.7227^2}{2(9.8)}$

$h = 0.0266m$

$h = 2.66 cm$

✓

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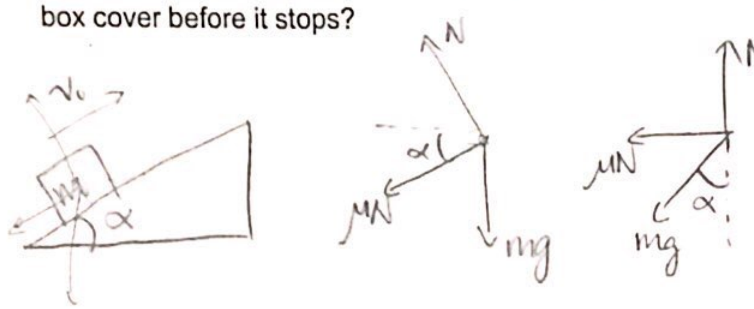
20/20

Problem 3

A small box of mass *m* is kicked up an inclined plane with an initial velocity v_0. The inclined plane makes an angle α with the horizontal. The friction coefficient is μ. What distance will the box cover before it stops?

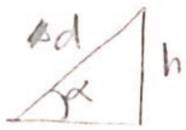


$$m\cancelto{0}{a_y} = N - mg\cos\alpha$$

$$N = mg\cos\alpha$$

$$\therefore F_{fric} = \mu mg\cos\alpha$$

$$KE - W_{fric} = U_g$$



$$\sin\alpha = \frac{h}{\Delta d}$$

$$h = d\sin\alpha$$

$$W_{fric} = \mu mg\cos\alpha\,\Delta d$$

$$\frac{1}{2}mv_0^2 - \mu mg\cos\alpha\,\Delta d = mgh$$

$$\frac{1}{2}mv_0^2 - \mu mg\cos(\alpha)d = mg\,d\sin(\alpha)$$

$$v_0^2 - 2\mu g\cos(\alpha)d = 2g\,d\sin(\alpha)$$

$$v_0^2 = 2g\,d\sin(\alpha) + 2\mu g\cos(\alpha)\,d$$

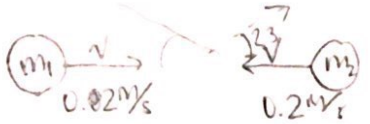
$$v_0^2 = d(2g\sin(\alpha) + 2\mu g\cos(\alpha))$$

$$\boxed{d = \frac{v_0^2}{2g(\sin\alpha + \mu\cos\alpha)}}$$

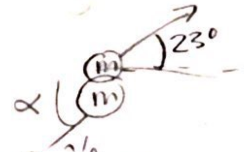
✓

Problem 4

Two identical balls traveling parallel to the x-axis have equal speeds of 20 cm/s, and their velocities are in the opposite directions. They undergo a perfectly elastic collision. After the collision, one ball is moving at an angle of 23 degrees to the x-axis. Find its speed.



afte collision



initial momentum

x: 0

y: 0

initial p = final p

initial KE = final KE

final momentum

x: $mv_1\cos 23 - mv_2\cos(\alpha)$

y: $mv_1\sin 23 - mv_2\sin(\alpha)$

$mv_1\cos 23 = mv_2\cos(\alpha)$

$mv_1\sin 23 = mv_2\sin(\alpha)$

square both equations, then add them

$m^2v_1^2\cos^2 23 + m^2v_1^2\sin^2 23 = m^2v_2^2\cos^2(\alpha) + m^2v_2^2\sin(\alpha)$

$m^2v_1^2\cos^2 23 + m^2v_1^2\sin^2 23 = m^2v_2^2$

$m^2v_1^2 = m^2v_2^2$

$mv_1 = mv_2$

$v_1 = v_2$

elastic: $\Delta KE = 0$

⇓

$\frac{1}{2}m(0.2)^2 + \frac{1}{2}m(0.2)^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2$

$\frac{2}{25} = v_1^2 + v_2^2$

$\frac{2}{25} = v_1^2 + v_1^2$

$\frac{2}{25} = 2v_1^2$

$\frac{1}{25} = v_1^2$

$\boxed{v_1 = \frac{1}{5}\ m/s}$

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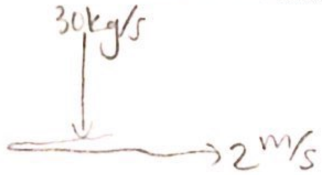
Problem 5

Sand drops at a rate of 30 kg/s onto a belt conveyer moving horizontally at 2 m/s. Determine the force needed to drive the conveyer, neglecting friction.



$$\frac{dm\vec{v}}{dt} = F$$

$$F = m\frac{d\vec{v}}{dt} + \vec{v}\frac{dm}{dt}$$

$\vec{v}$ is constant, so $\frac{d\vec{v}}{dt} = 0$

$$F = \vec{v}\frac{dm}{dt}$$

$\frac{m}{s^2} \cdot kg$

$mga = T$

$\frac{mkg}{s^2}$

m/s

$$\frac{dm}{dt} = 30\,kg/s$$

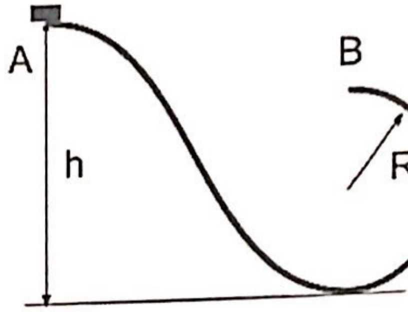
$$F = 2(30)$$

$$\boxed{F = 60N}$$

20

Problem 6

A small block slides from point A down a curve leading to a half-circle of radius *R*. What is the minimal height h for which the block reaches the top of the semicircle, point B? (Hint: in class we considered the case *h*=2*R*, and we determined that the block detached from the groove at some intermediate point. Obviously, in the present case, the height *h* must exceed 2*R*.)



top of circle

mg N

$ma_c = mg + \cancel{N}$

$\frac{mv^2}{R} = mg + \cancel{N}$

$v^2 = \frac{(mg + \cancel{N})R}{m}$

$v = \sqrt{\frac{(mg + \cancel{N})R}{m}}$

$v = \sqrt{\frac{mgR}{m}}$

$v = \sqrt{gR}$

the ball must be going @ $\sqrt{gR}$ m/s at the top of the circle to reach point B

to reach the top of semicircle

$mgh = mg(2R) + \frac{1}{2}mv_f^2$

$mgh = mg(2R) + \frac{1}{2}m(\sqrt{gR})^2$

$gh = g(2R) + \frac{1}{2}gR$

$h = 2R + \frac{1}{2}R$

$\boxed{h = \frac{5}{2}R}$

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