Midterm 2

Solutions

Physics 1A (Lec 3)

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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	20	20	20	20	20	120

Duh!

Problem 1

A skater with mass 70 kg standing on ice throws a stone of mass 5 kg with a velocity of 8 m/s in a horizontal direction. Find the distance over which the skater will move back if the coefficient of friction between the skates and the ice is 0.02

[1] $p_i = 0$

$p_f = 70(v_{mf}) + 5(8)$

=> Immediately after throwing, velocity of man is:

$v_{mf} = -40/70 \text{ m/s} = \underline{-0.57 \text{ m/s}}$

[2] Now use work energy theorem to find distance

$W_{fric} = F_f \Delta x$

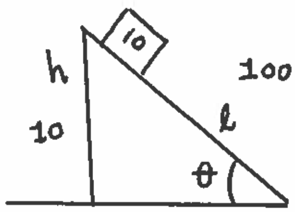
$W_{fric} = \Delta KE$

$-mg\mu \Delta x = 0 - \frac{1}{2} m v_{mf}^2$

$\Delta x = \frac{v_{mf}^2}{2g\mu} = \frac{(0.57)^2}{2(9.8)(0.02)} = \boxed{0.83 \text{ m}}$

Problem 2

A box with a mass of 10 kg slides down an inclined plane 10 meters high and 100 meters long. (The distance is measured along the inclined plane, *not* along the horizontal.) The coefficient of friction is 0.04. Find the speed of the box at the base of the plane.



$\cos(\theta) = \frac{a}{h}$

$a = \sqrt{\ell^2 - h^2}$

[1] Work Energy Theorem (again)

$W = \Delta KE$

$W_g + W_f = \Delta KE$

$mgh - \mu mg\cos(\theta)\ell = \frac{1}{2}mv_f^2$

$\Rightarrow \quad gh - \mu g\sqrt{\ell^2 - h^2} = \frac{1}{2}v_f^2$

thus $v_f = \sqrt{2g(h - \mu\sqrt{\ell^2 - h^2})}$

$= \sqrt{2(9.8)[10 - 0.04\sqrt{100^2 - 100}]}$

$v_f = 13.1$ m/s

Problem 3

A 3-kg block of wood rests on a table. A 9-gram bullet is shot straight up through a hole in the table below the block. The bullet lodges in the block, and the block flies 20 cm above the tabletop. Find the initial speed of the bullet.

[1] Identify: inelastic collision

B = Block
b = bullet

$P_i = (0.009) v_{bi}$

$P_f = (3.009) v_{bBf} \Rightarrow v_{bi} = \frac{3.009}{0.009} v_{bBf}$

[2] We don't know v_{bBf} but we can figure it out from conservation of energy (or kinematics) given that the Block-bullet reach a max height of 0.20 m.

$$\frac{1}{2} m_{Bb} v_{bBf}^2 = m_{Bb} g h_{max}$$

$$v_{bBf} = \sqrt{2 g h_{max}}$$

$$= \sqrt{2(9.8)(.20)} = 2.0 \text{ m/s}$$

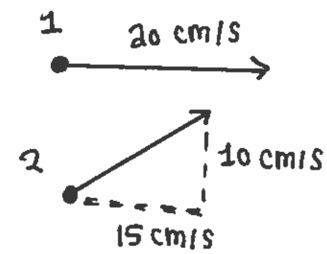
[3] Plug back into Equation from [1]

$$v_{bi} = 2 \times \frac{3.009}{.009} \text{ m/s}$$

$$= 662 \text{ m/s}$$

Problem 4

Two identical balls undergo a collision at the origin of coordinates. Before the collision their x and y velocity components are v_x= 20 cm/s, v_y= 0 (for the first ball) and u_x= 15 cm/s, u_y = 10 cm/s (for the second ball). After the collision, the fist ball is standing still. Find the scalar velocity components of the second ball V_x and V_y .



! Although not clear : this is an inelastic collision!

ENERGY IS NOT CONSERVED!

[1] Conservation of Momentum :

P_{ix}: $m(.20) + m(.15)$

P_{fx}: $m(v_{2fx})$

$\Rightarrow$ v_{2fx} = 0.35 m/s

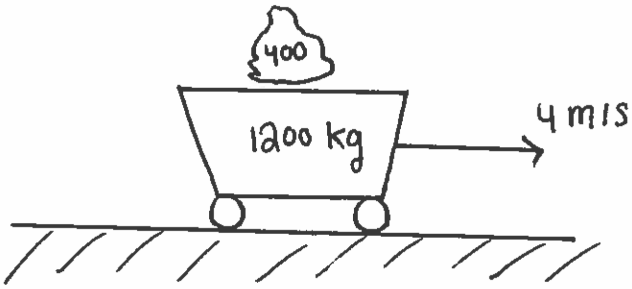
P_{iy}: $m(.10)$

P_{fy}: $m(v_{2fy})$

$\Rightarrow$ v_{2fy} = 0.10 m/s

Problem 5

A coal car is essentially an open box on wheels, moving on two rails. An empty 1200-kg coal car is coasting on a level track at 4 m/s. Suddenly 400 kg of coal is dumped into it from directly above it. The coal initially has zero horizontal velocity. Find the final speed of the car.



Inelastic Collision!

momentum only conserved

[1]

$p_i = (1200)(4)$

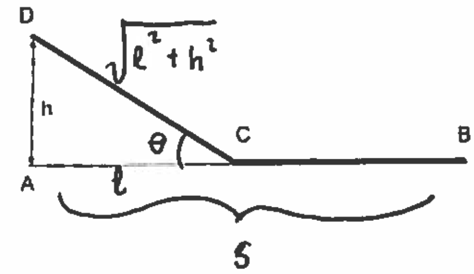
$p_f = (1200+400)v_{fx}$

thus $v_{fx} = \dfrac{(1200)(4)}{(1600)} = 3 \text{ m/s}$

$$\cos(\theta) = \frac{a}{H} = \frac{\ell}{\sqrt{\ell^2+h^2}}$$

Problem 6

A sled slides down an icy hill of height |AD|=*h*. It starts at point D, and it stops at point B. The distances are |AB|=s, |AC|=*l*. Express all answers in terms of *h, l, s,* and the acceleration of free fall *g*.



(a) Determine the coefficient of friction

We can use the work energy theorem (again)

$$W = \Delta KE \Rightarrow W_g + W_{f\,(\text{over } |DC|)} + W_{f\,(\text{over } |CB|)} = \tfrac{1}{2} m v_f^2 \quad (v_f \to 0)$$

- $F_f\,(\text{over } |DC|) = -\mu m g \cos(\theta)$
- $F_f\,(\text{over } |CB|) = -\mu m g$

$$\Rightarrow \; mgh - \mu mg\cos\theta\,|DC| - \mu mg\,|CB| = 0$$

$$h - \mu\left(\frac{\ell}{\sqrt{\ell^2+h^2}}\right)\sqrt{\ell^2+h^2} - \mu(s-\ell) = 0$$

$$h - \mu(\ell - (s-\ell)) = 0 \qquad \boxed{\mu = h/s}$$

(b) Find the acceleration over the path DC.

You can find a in a million different ways ...

I personally used : ↘ $\hat{x}$

$$\sum F = ma$$

where $\sum F_x = mg\sin(\theta) - \mu mg\cos(\theta)$

$$ma = mg\frac{h}{\sqrt{h^2+\ell^2}} - \mu mg\frac{\ell}{\sqrt{h^2+\ell^2}}$$

$$\boxed{a = \frac{gh}{\sqrt{h^2+\ell^2}}\left(1 - \frac{\ell}{s}\right)}$$