Midterm 1

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	17	20	20	12	109

integrals?

1 sig fig

? **Problem 1**

A car with mass 1000 kg is driven at a speed of 40 km/hour on a level road. What constant force must be applied to stop it in a distance of 30 m?

$m = 1000\,kg$ $\quad v = 40\,\frac{km}{hr}$ $\quad v_f = 0$ $\quad \Delta X = 30\,m$ $\quad F = ?$

$F = ma$ ← must be constant; constant ↓

need a first

$X = X_0 + V_{0x}t + \frac{1}{2}at^2$

$v_f = v_i + at$

$v_f^2 = v_i^2 + 2ax$

$40\,\frac{km}{hr} \times \frac{1000\,m}{1\,km} \times \frac{1\,hr}{3600\,sec} = 11.11\,m/s$

$0 = (11.11\,m/s)^2 + 2a(30m)$

$\frac{-123.46}{60} = \frac{60a}{60}$

$a = -2.06\,m/s^2$

$v_f^2 = v_i^2 + 2ax$

$\frac{v_f^2 - v_i^2}{2x} = \frac{2ax}{2x}$

$a = \frac{v_f^2 - v_i^2}{2x} \rightarrow \frac{m^2/s^2}{m} = m/s^2$ ✓

√dimensions

+20

$F = ma$

$F = (1000\,kg)(-2.06\,m/s^2)$

$F = 2057.61\,N \approx 2000\,N$

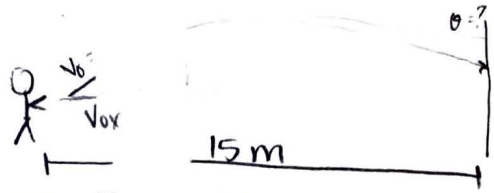
$F_{stopping}$ ←

$\sum F_x = F_{stopping} = ma_x$

$v = \frac{dx}{dt}$ $\quad X = 30$

$\int v\,dt = \int dx$

$vt = x$



★t in x + y directions is SAME

Problem

An arch… arrow with… ed 30 m/s at 60 degrees to the horizontal, and it hits a wall 15 mete… m the bow.

★x direction velocity is not changing → constant V_x

(a) How long … the arrow spend in … air?

t in air:

$\Delta X = V_{0x}t + \frac{1}{2}a_x t^2$

$\Delta Y = V_{0y}t + \frac{1}{2}a_y t^2$

$V_f = V_i + at$ $V_f^2 = V_i^2 + 2$…

$t = \frac{V_f - V_i}{a} \rightarrow t = V_f$… V_i…

$V_{0x} = V_0\cos 60° = 30\cos 60° = 15\ m/s$

$V_{0y} = V_0 \sin 60° = 30\sin 60° = 25.981\ m/s$

$15 = 15t + 0t^2$

$t = 1s$

$\Delta X = V_{0x}t + 0$

$15 = 15t$

$t = 1s$

$d = Vt$

$15 = 15t$

$\frac{V}{d} = t$

$\frac{0 - 25.981\ m/s}{-9.8\ m/s^2} = 2.65s$

do not know V_f, so cannot use

(b) What was the speed of the … it hit the wall?

$|\vec{v}|$

V_f $V_{fx} = 15\ m/s$ ★ since V_x doesn't change ($0 = a$ in x direction)

$V_f^2 = V_i^2 + 2ax$

$V_f = V_i + at$

★need V_{fy}

$= V_{oy}^2 + 2a_y y$ ★don't know Δy

$V_{fy} = V_{oy} + a_y t$

$V_{fy} = V_0 \sin 60° + (-9.8)(1s)$ units = m/s ✓

$V_{fy} = 25.981\ m/s - 9.8 = 16.181\ m/s$

$|v| = \sqrt{15^2 + 16.181^2}$

$|v| = 22.06\ m/s$ = speed → 22 m/s

(c) What was the angle between the arrow's velocity and the horizontal when it hit the wall?

direction of velocity (V_f)

$\tan\theta = \frac{y\ component}{x\ component}$

$\tan\theta = \frac{V_{fy}}{V_{fx}}$

$\tan\theta = \frac{16.181}{15}$

$\theta = 47.2°$

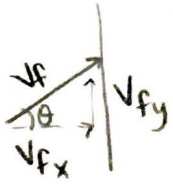
↓

47°

$V_{y\ final} = 16.181\ m/s$ → since ⊕, still ↗ trajectory

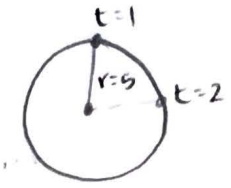
$V_{x\ final} = 15\ m/s$

$V_f = 22.06\ m/s$



+20

1 sig fig



$2t^2$

$4t^{1+1} \rightarrow 2t^2$

Problem 3

A particle moves in a circle of radius r = 5 m. During some time interval, its speed varies with time according to $v(t) = a + b/t^4$, where $a = 4$ m/s, $b = 16$ m s^3.

OK (a) Find the average speed between t=1 s and t=2 s.

$r = 5m$ $\quad |v|$

$v(t) = 4 + \frac{16}{t^4}$

$v_{avg} = \frac{\Delta x}{\Delta t}$ $\quad v = \frac{dx}{dt}$

$x(1) = 4(1) - \frac{16}{3}(1)^{-3} = -1.33\ m$ +10

$x(2) = 4(2) - \frac{16}{3}(2)^{-3} = 7.33\ m$

$\frac{dx}{dt} = 4 + 16t^{-4}$

$\int_0^x dx = \int_0^t 4 + 16t^{-4}\ dt$

$v_{avg} = \left| \frac{7.33 - (-1.33)}{2-1} \right| = 8.67\ m/s \approx 9\ m/s$ average speed

$x = 4t - \frac{16}{3}t^{-3}\Big|_0^t \rightarrow x = 4t - \frac{16}{3}t^{-3} - 0$

(b) Find the **total** acceleration at time t=2 s.

$t = 2$

$\vec{a}_{total} = \vec{a}_{tangential} + \vec{a}_{centripetal}$

$a_c = \frac{v^2}{R}$

$\frac{d}{dt}\left(v(t) = 4 + \frac{16}{t^4}\right)$ $\quad a(t) = \frac{dv}{dt}$

$\rightarrow 4 + 16t^{-4}$

$a(t) = 0 - 64t^{-5}$

$a(2) = -64(2)^{-5} = -2\ m/s^2$ ✓ ✓

$a_{tangential}$

$a_{centripetal} = \frac{v^2}{R}$

$v(2) = 4 + \frac{16}{2^4} = 5\ m/s$ ✓

$a_c = \frac{5^2}{5} = 5\ m/s^2 = a_c$

✗

$a_{total} = -2\ m/s^2 + 5\ m/s^2$

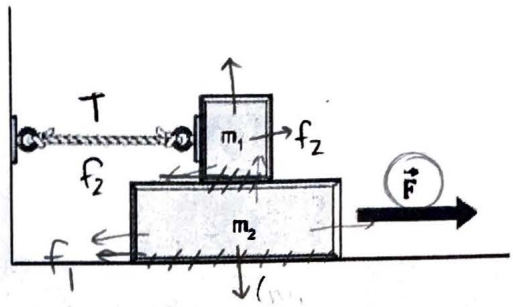
$a_{total} = 3\ m/s^2$

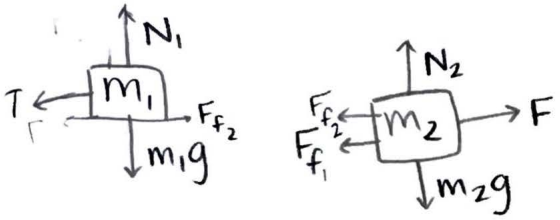
+7

a can also be used

Problem 4

(a) What force F is needed to pull mass m_2 with acceleration a if the coefficient of friction between the two blocks and between the block and the floor is μ? Express the answer in terms of the two masses and μ.





$F_f = \mu N$

$F_{f_1} = \mu(m_1 + m_2)g$ * b/c both masses are acting ↓

$F_{f_2} = \mu m_1 g$

m_1: $\Sigma F_x = -T + F_{f_2} = 0$ since at rest

$\Sigma F_y = N_1 - m_1 g = 0 \rightarrow N_1 = m_1 g$

+10

m_2: $\Sigma F_x = F - F_{f_2} - F_{f_1} = m_2 a \rightarrow F - \mu m_1 g - \mu(m_1 + m_2)g = m_2 a$

$\Sigma F_y = N_2 - m_2 g - (m_1 + m_2)g = 0$ since no motion in y direction

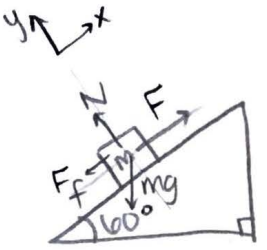
$F = m_2 a + \mu m_1 g + \mu(m_1 + m_2)g$

(b) What is the force of tension T in the string?

$\Sigma F_x = -T + F_{f_2} = 0$

$F_{f_2} = T$ +10

$\boxed{T = \mu m_1 g}$



m = 10 kg

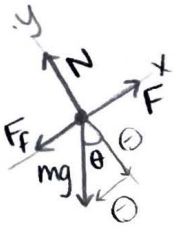
2 sig figs

Problem 5

A 10-kg block is pulled up an inclined plane by a force parallel to the inclined plane that makes angle 60 degrees with the horizontal. The force of ~~250~~ 150 N is required to make it move with an acceleration of ~~30 m/s²~~ $3\ m/s^2 = a$.

$F = 150N$

(a) What is force of friction?



$F = 150N \Rightarrow a = 3\ m/s^2$

x component

$\Sigma F_x = -F_f + F - mg\sin\theta = ma_x$

$\Sigma F_y = N - mg\cos\theta = 0$ since no motion in y direction

$N = mg\cos\theta$

$F_f = \mu N$

$-F_f + F - mg\sin\theta = ma_x$

$-F_f = ma_x + mg\sin\theta - F$

$-F_f = (10)(3) + (10)(9.8)\sin 60° - 150$

$-F_f = -35.13N$

$F_f = 35.13N \rightarrow 35N$ ✓

(b) What is the coefficient of friction?

$\mu = ?$

$F_f = \mu N$

$N = mg\cos\theta$

$\mu = \frac{F_f}{N}$

$\mu = \frac{35.13N}{(10)(9.8)\cos 60°}$

$\mu = .717 \rightarrow .72 = \mu$ ✓

12/20

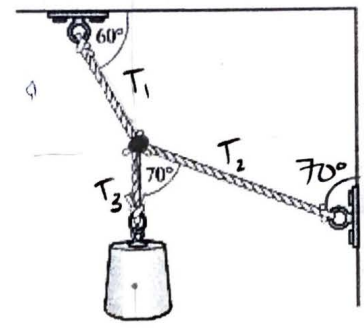
1 sig fig

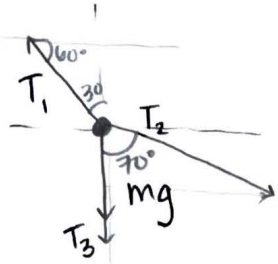
?

Problem 6

$F_{T\,max}$

Each cord can support a maximum tension of 200 N. What is the greatest mass that can be supported as shown in the Figure?





$-T_1\cos 60°$

$*T_3 = mg$ $\quad m_{max} = ?$

$T_1 \neq T_2 = T_3 = 200\,N$

$\Sigma F_x = -T_1 \sin 30° + T_2 \sin 70° = 0$

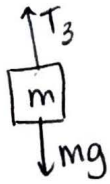
$\Sigma F_y = T_1 \cos 30° - T_2 \cos 70° - T_3 = 0$

$T_1 \cos 30° - T_2 \cos 70° - mg = 0$

Trig -3

-5

$$\frac{T_1 \cos 30° - T_2 \cos 70°}{g} = \frac{mg}{g}$$



$$\frac{T_1 \cos 30° - T_2 \cos 70°}{g} = m$$

$$\frac{200\cos 30 - 200\cos 70}{9.8} = m$$

$\frac{N}{m/s^2}$ $\frac{kg \cdot m/s^2}{m/s^2} = kg$ ✓

$m = 10.694\,kg \rightsquigarrow 11\,kg$

$T_3 = mg$

$\frac{200}{g} = m$

$m = 20.41\,kg$ if only vertical direction BUT must account for x direction for $T_1 + T_2$, as well