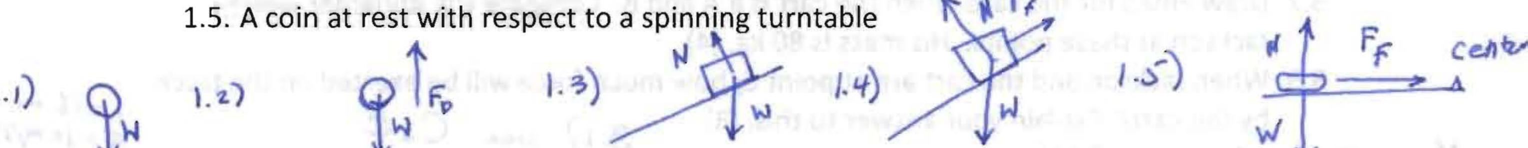
The King's University
Physics 241 Midterm Examination
November 28, 2014

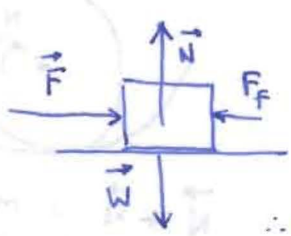
Instructions: You have 60 minutes to complete the following 3, 10 mark questions. Please use your time wisely and answer as completely as time permits. Please put your answers in the booklet supplied.

1. Draw free body diagrams and clearly label and identify any relevant forces.
   1.1. A sky-diver free-falling in a vacuum (2)
   1.2. A sky-diver free-falling in real air (2)
   1.3. A mass sliding down an incline when there is no friction (2)
   1.4. Same mass, same incline but WITH friction
   1.5. A coin at rest with respect to a spinning turntable



2. Erin's summer job was at Anna's restaurant. Her first task was to move a 100 kg crate of watermelons across the restaurant floor to the cooler. If μ = 0.60 and if Erin pushed the crate with a force of 800 N parallel to the floor would the crate move? If so, how fast would it be moving after 2 seconds? (You may assume kinetic and static coefficients are the same) (5)
   Erin thought that there must be simpler way. Maybe she could push or pull on the cart in a different way. Draw a FBD and develop an expression that shows how much force Erin needs to apply to get the crate moving. Show that there is a minimum possible force that one can apply and get the crate moving. NOTE – you don't need to find the minimum – just show why you think there is a minimum force. (5)

Part 1



$\vec F + \vec N + \vec F_f + \vec W = m\vec a$ $W = mg = -1000\,N$ $\mu = 0.60$

$$\begin{bmatrix}800\\0\end{bmatrix} + \begin{bmatrix}0\\N\end{bmatrix} + \begin{bmatrix}-\mu N\\0\end{bmatrix} + \begin{bmatrix}0\\-1000\end{bmatrix} = m\begin{bmatrix}a_x\\0\end{bmatrix}$$

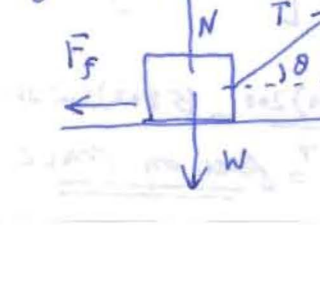
$\therefore N = 1000\,N,\ F_f = 600\,N$ $\therefore m a_x = 800 - 600 = 200N$

$m = 100\,kg$ $\therefore \underline{a = 2\,m/s^2}$ $\therefore \Delta v = a\Delta t$

in 2 seconds $v_f = (2m/s^2)\ldots = \underline{4\,m/s}$

Part 2

Erin pulls at an angle θ wrt floor



$\vec N + \vec F_f + \vec T + \vec W = m\vec a$

$$\begin{matrix}1)\\2)\end{matrix}\begin{bmatrix}0\\N\end{bmatrix} - \begin{bmatrix}\mu N\\0\end{bmatrix} + \begin{bmatrix}T\cos\theta\\T\sin\theta\end{bmatrix} - \begin{bmatrix}0\\mg\end{bmatrix} = m\begin{bmatrix}a_x\\0\end{bmatrix}$$

Set $a_x = 0$ and show that there is a min ~~F~~ T

2) $N = mg - T\sin\theta$; 1) $\mu N = T\cos\theta$ → combine eqns 1) & 2)

(#2 continued) $mg - N = T\sin\theta$ & $N = T\cos\theta/\mu$ ∴

$mg - \frac{T\cos\theta}{\mu} = T\sin\theta$; solve for T

$mg = T(\sin\theta + \frac{\cos\theta}{\mu})$ $T = \frac{mg}{(\sin\theta + \frac{\cos\theta}{\mu})}$

T is smallest when $\sin\theta + \frac{\cos\theta}{\mu}$ is biggest, so, if $\mu = 0.6$

⇒ $\sin\theta + \frac{\cos\theta}{0.6} = M(\theta)$ you can plot $M(\theta)$ or use calculus

$M'(\theta) = \cos\theta - \frac{\sin\theta}{0.6} = 0$ ∴ $\cos\theta = \frac{\sin\theta}{0.6}$ ⇒ $\frac{\sin\theta}{\cos\theta} = \tan\theta = 0.6$ ∴ $\theta = 31°$

∴ minimum force to move is when $\theta = 31°$ ∴ $T_{min} = 514N$

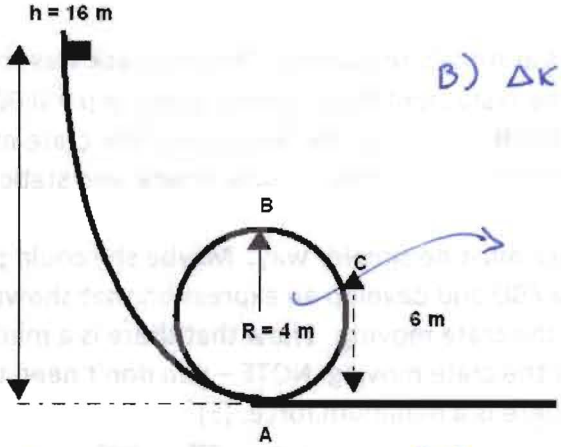
3. After retiring from a grueling career as a physics prof, Doc Martin opened an amusement park. The main attraction was the Loop-a-Tron (shown below).In the Loop-a-Tron, a 500 kg cart and rider are released from rest at a height 16 m above ground. The objective is to successfully loop-the-loop. Remembering the class of 2014 (and partly motivated by revenge) he gave Jackson a lifetime pass on the Loop-a-tron! You may assume that there is no friction on the track and that air resistance can be ignored
   3.1. How fast will Jackson be going at points A and B? (3)
   3.2. Draw FBD's for the case when the cart is a A and B. Compare the apparent weight of Jackson at these points. His mass is 80 kg. (4)
   3.3. When Jackson and the cart are at point C, how much force will be exerted on the track by the cart? Explain your answer to this. (3)

M_J = Jackson's mass = 80 kg
M_c = 500 kg
m = 580 kg

3.1) use CoE $h = 16$ m, $g = 10$ m/s²

A) $\Delta K = -\Delta V = mgh$ ∴ $v = \sqrt{2gh} = 17.9$ m/s

B) $\Delta K = -\Delta V = mg(h-2R)$ ∴ $v = 12.7$ m/s



The End!

3.2)

A

$\vec{N} + \vec{W} = m\vec{a}$

$\begin{bmatrix} 0 \\ N \end{bmatrix} - \begin{bmatrix} 0 \\ m_J g \end{bmatrix} = \begin{bmatrix} 0 \\ mv^2/r \end{bmatrix}$

∴ $N = m_J g + \frac{mv^2}{r}$
$= (800N) + 80\frac{(17.9)^2}{4}$
$= 800N + 6408N = 7208N$!
(about 9 g's)

B

$\begin{bmatrix} 0 \\ -N \end{bmatrix} + \begin{bmatrix} 0 \\ -mg \end{bmatrix} = \begin{bmatrix} 0 \\ -\frac{mv^2}{r} \end{bmatrix}$

∴ $N = \frac{mv^2}{r} - mg$
$= 80\frac{(12.7)^2}{4} - 800N$
$= 2425N$ (down)
$= 3g$'s !!

3.3

get $v(c) = \sqrt{2g(h-6)} = 14.1$ m/s

$\vec{N} + \vec{W} = m\vec{a}$
θ = angle of F_{cen} wrt horizontal
$\theta = \tan^{-1}(2/4)$
$\theta = 26.6°$

rotate your coordinate system by θ so the N points along x axis. ∴ $W = \begin{bmatrix} -W\sin\theta \\ -W\cos\theta \end{bmatrix}$

$\vec{N} + \vec{W} = F_{net} = \begin{bmatrix} -mv^2/r \\ -mg\cos\theta \end{bmatrix}$

∴ $N = \frac{mv^2}{r} - W\sin\theta = \frac{(580)200}{4} - (5800)\sin 26.6°$
⇒ $26400N$ = force on track