Practice for Midterm 2:

INTERACTIONS

Physics 203, Profs Yaverbaum, Song, Lu, & Bean

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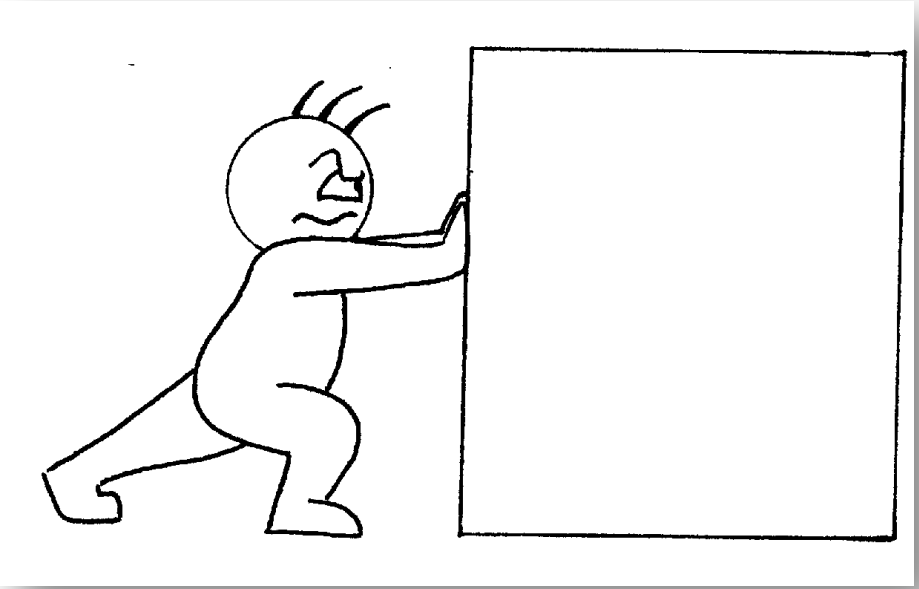


SOLUTIONS Part 2

1. Darn Cat's on Top of the Elevator Again!

A cat stands on a digital scale that is attached to the roof of an elevator. The elevator is accelerating upwards at a constant rate of 20 m/s^2. At a certain moment, the instantaneous velocity of the elevator is 40 m/s upwards relative to the ground. The scale reads 135N.

A. Draw a diagram of the situation, including ***all known and unknown quantities***.
B. Draw a system schema of this situation.
C. Draw an FBD of the cat.
D. Compute the mass of the cat.

At this exact moment, the elevator stops accelerating.

E. Compute the reading on the scale.
F. If it continues in this state of 5 seconds, how far will the elevator travel in those 5 seconds (from the perspective of the ground)?
G. How far will the cat travel in those 5 seconds (from the perspective of the ground)?

Suddenly, the elevator begins accelerating downwards at a rate of 12 m/s^2.

H. Compute the reading on the scale.
I. From the perspective of the ground, how far will the elevator travel in 5 seconds?
J. From the perspective of the ground, how far will the cat travel in 5 seconds?

A) [not provided]

B) [not provided]

C) [not provided]

D) Use NII: all forces are in the y-direction
V_0 is irrelevant
$\sum \vec{F}_y = m\vec{a}_y$
$N - mg = ma_y$
$135N - m(10) = m(20)$
$135N = 30m$
$m = 135/30 = 4.5$ kg

↑+

E) a = 0. looking for N
$\sum \vec{F}_y = m\vec{a}_y$
$N - mg = ma_y$
$N - (4.5)(10) = 0$
N = 45n (upwards)

F) a is zero, so v is constant, so
$V_0 = V = d/t$ and $V_0 = 40$ m/s (given)
$40 = d/5 \rightarrow d = 200$ m

G) Cat is moving with elevator
$d_{cat} = d_{elevator} = 200$ m

H) a = -12 m/s^2. Looking for N.
$\sum \vec{F}_y = m\vec{a}_y$
$N - mg = ma_y$
$N - 45 = (4.5)(-12) = -54$
N = -9n ← That's impossible. Cat loses contact with floor & goes into free fall. Therefore, reading on scale is ZERO.

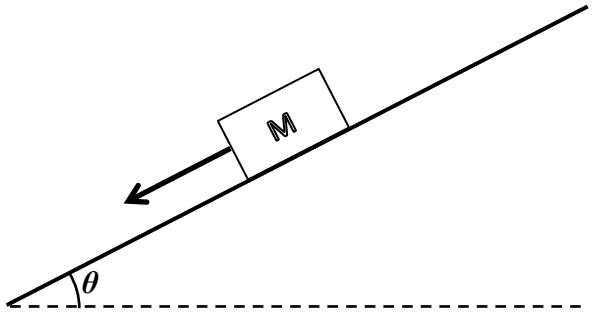
I) $a_E = -12$ m/s^2. Looking for d.
What is V_0? V was 40 m/s at the beginning of part (D). Has it changed? No, because the elevator was not accelerating in parts E & F. Therefore,
$V_0 = 40$ m/s
$d = \frac{1}{2}at^2 + v_0t = \frac{1}{2}(-12)5^2 + 40(5) = 50$ m (UP)

J) Cat is in free fall, so $a_c = -10$ m/s^2
Prior to elevator's downward acceleration, cat was moving with elevator, so V_0 cat = V_0 elevator.
$V_0 = 40$ m/s
$d = \frac{1}{2}at^2 + v_0t = \frac{1}{2}(-10)5^2 + 40(5) = 75$ m (UP)

Although both cat & elevator are accelerating downwards, their upward initial velocity keeps them moving up long enough that their final position is above their initial position.

3. Slippy Slide

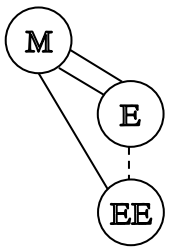
Mass M is ***sliding*** down a ***rough*** track. The track forms an angle $\boldsymbol{\theta}$ with the horizontal. The mass has a coefficient of kinetic friction with the track of μ_k.



Your goal: find an expression for the ***a***, acceleration of the mass, in terms of the ***given variables***.

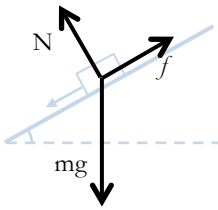
A. Create a system schema for this situation.
B. Create a ***pure*** FBD of the mass.
C. Create a coordinate system ***in which the x-axis lines up with the direction of acceleration***.
D. Create a ***component*** FBD of the mass.
E. Write down Newton's 2nd Law. Apply it to the mass on the y-axis.
F. What is the acceleration of the mass on the y-axis?
G. Solve for the magnitude of the normal force between the track and the mass, in terms of ***m***, ***g***, and $\boldsymbol{\theta}$.
H. Write down Newton's 2nd Law; apply it to the mass on the x-axis.
I. Solve for ***a***, in terms of the ***given variables***.

A.

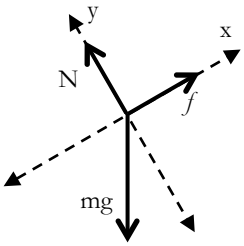


Mass is sliding, so it has both normal & friction with track, so we draw two connecting lines.

B.

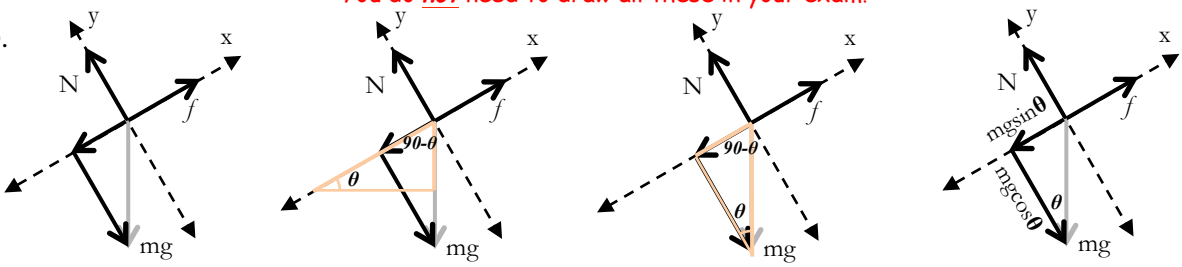


C.

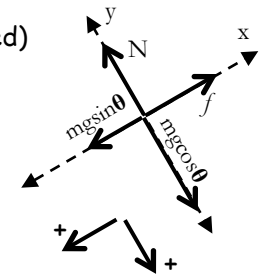


The diagrams below are steps to find theta in the right triangle with mg.
You do ***not*** need to draw all these in your exam!

D.



D. (finished)



E. $\sum \vec{F}_y = m\vec{a}_y$

$-N + mg\cos\theta = ma_y$

F. $a_y = 0$

G. $-N + mg\cos\theta = 0$

$N = mg\cos\theta$

H. $\sum \vec{F}_x = m\vec{a}_x$

$mg\sin\theta - f_k = ma_x$

and, $||fk|| = \mu_k N = (\mu_k)mg\cos\theta$

so,

$mg\sin\theta - (\mu_k)mg\cos\theta = ma_x$

$g\sin\theta - (\mu_k)g\cos\theta = a_x$

$$g(\sin\theta - (\mu_k)\cos\theta) = a_x$$

Look how friggin' easy that was once we got the FBD figured out!