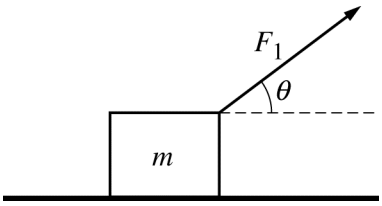
PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in the pink booklet in the spaces provided after each part, NOT in this green insert.



Mech. 1.

A block of mass m is pulled along a rough horizontal surface by a constant applied force of magnitude F_1 that acts at an angle θ to the horizontal, as indicated above. The acceleration of the block is a_1. Express all algebraic answers in terms of m, F_1, θ, a_1, and fundamental constants.

(a) On the figure below, draw and label a free-body diagram showing all the forces on the block.

(b) Derive an expression for the normal force exerted by the surface on the block.

(c) Derive an expression for the coefficient of kinetic friction μ between the block and the surface.

(d) On the axes below, sketch graphs of the speed v and displacement x of the block as functions of time t if the block started from rest at $x = 0$ and $t = 0$.

(e) If the applied force is large enough, the block will lose contact with the surface. Derive an expression for the magnitude of the greatest acceleration a_{max} that the block can have and still maintain contact with the ground.

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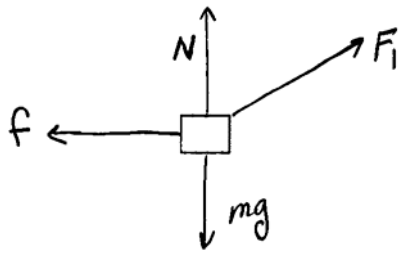
Question 1

15 points total **Distribution of points**

(a) 4 points



For each of the forces shown above with arrow correctly drawn and labeled, 1 point was awarded — 4 points

For each incorrect or extraneous vector, such as acceleration or velocity, a point was deducted, with the minimum possible score being 0.

(b) 2 points

$\sum F_y = 0$

For the correct y component of F_1 — 1 point

$N + F_1 \sin\theta - mg = 0$

For the correct answer — 1 point

$N = mg - F_1 \sin\theta$

(c) 3 points

$\sum F_x = ma$

For showing correct expressions for the horizontal forces and setting them equal to ma_1 — 1 point

$F_1 \cos\theta - \mu N = ma_1$

For substituting the expression for N from part (b) — 1 point

$F_1 \cos\theta - \mu(mg - F_1 \sin\theta) = ma_1$

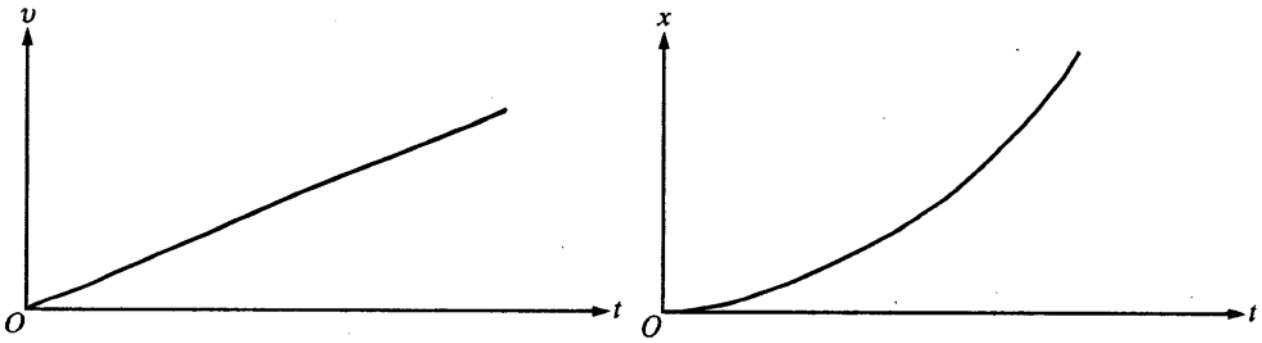
For the correct answer — 1 point

$\mu = \dfrac{F_1 \cos\theta - ma_1}{mg - F_1 \sin\theta}$

Question 1 (continued)

Distribution of points

(d) 3 points



For a linear relationship on the v versus t graph with positive slope and with $v = 0$ at $t = 0$ — 1 point

For a parabolic relationship on the x versus t graph that is concave upward, with $x = 0$ at $t = 0$ — 1 point

For the two graphs being consistent with each other — 1 point

(e) 3 points

For indicating that $N = 0$ is the condition for the maximum acceleration of the block before it loses contact — 1 point

For indicating that the friction force is zero — 1 point

$f = \mu N = 0$

$\sum F_x = F_{\max}\cos\theta = ma_{\max}$

$a_{\max} = \dfrac{F_{\max}\cos\theta}{m}$

$\sum F_y = F_{\max}\sin\theta - mg = 0$

$F_{\max} = \dfrac{mg}{\sin\theta}$

Substituting $F_{\max}$ into the expression for $a_{\max}$ above

$a_{\max} = \dfrac{mg}{\sin\theta}\dfrac{\cos\theta}{m}$

For the correct answer — 1 point

$a_{\max} = g\cot\theta$

Note: Since F_1 is a variable quantity in this problem and since the initial directions included F_1 as a quantity that could be used in expressions for the answers, the expression $a_{\max} = \dfrac{F_1\cos\theta}{m}$ was also acceptable for the answer point.