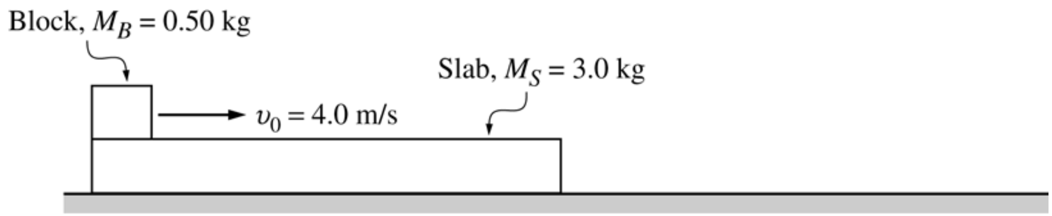
PHYSICS C: MECHANICS
SECTION II
Time—45 minutes
3 Questions

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 small block of mass $M_B = 0.50$ kg is placed on a long slab of mass $M_S = 3.0$ kg as shown above. Initially, the slab is at rest and the block has a speed v_0 of 4.0 m/s to the right. The coefficient of kinetic friction between the block and the slab is 0.20, and there is no friction between the slab and the horizontal surface on which it moves.

(a) On the dots below that represent the block and the slab, draw and label vectors to represent the forces acting on each as the block slides on the slab.

At some moment later, before the block reaches the right end of the slab, both the block and the slab attain identical speeds v_f.

(b) Calculate v_f.

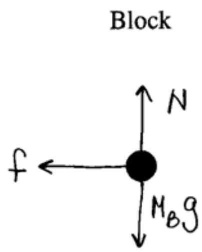
(c) Calculate the distance the slab has traveled at the moment it reaches v_f.

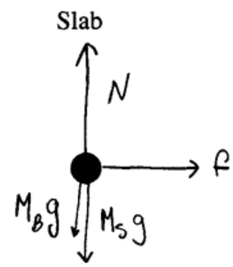
(d) Calculate the work done by friction on the slab from the beginning of its motion until it reaches v_f.

Question 1

15 points total | **Distribution of points**

(a) 4 points





For the block force diagram:

For correctly labeled horizontal force (friction to the left, no other forces or vectors) — 1 point

For correctly labeled vertical forces (normal up <u>and</u> weight down; gravity alone not accepted) — 1 point

For the slab force diagram:

For correctly labeled horizontal force (friction to the right, no other forces or vectors) — 1 point

For correctly labeled vertical forces (normal up <u>and</u> combined weight down; combined weight can be shown with two arrows <u>or</u> identifying weight as $W_S + W_B$ or $M_S g + M_B g$; gravity alone not accepted) — 1 point

(b) and (c)

These two parts were scored together because of the different approaches that could be used to answer them.

<u>Momentum approach to part (b); Newton's second law and kinematics approach to part (c)</u>

(b) 3 points

For any statement of conservation of momentum — 1 point

No net external forces act on the two-block system, so linear momentum is conserved.

For a correct momentum equation — 1 point

$M_B v_0 = (M_B + M_S) v_f$

$$v_f = \frac{M_B}{M_B + M_S} v_0 = \frac{0.50 \text{ kg}}{0.50 \text{ kg} + 3.0 \text{ kg}} 4.0 \text{ m/s}$$

For the correct answer — 1 point

$v_f = 0.57 \text{ m/s}$

Question 1 (continued)

Distribution of points

Momentum approach (continued)

(c) 6 points

For a correct expression for the friction force (awarded if found in the solution to any of parts (a) through (d)) — 1 point

$f = \mu mg$ or $f = \mu N$

For correct substitution of $m = M_B$ for the friction force on the block — 1 point

$f = \mu M_B g$

For recognizing that the friction force on the slab is equal in magnitude to the friction force on the block and for an equation relating this force to the acceleration of the slab — 1 point

$f = M_S a_S$

For a correct expression for the acceleration of the slab or its numerical value — 1 point

$$a_S = \frac{\mu M_B g}{M_S} = 0.33 \text{ m/s}^2$$

For a correct kinematic equation for the slab — 1 point

$\upsilon_f^2 = \upsilon_0^2 + 2a_S x$, where $\upsilon_0 = 0$

$$x = \frac{\upsilon_f^2}{2a_S} = \frac{\upsilon_f^2}{2}\frac{M_S}{\mu M_B g}$$

For correct substitutions consistent with earlier values — 1 point

$$x = \frac{(0.57 \text{ m/s})^2}{2}\frac{3.0 \text{ kg}}{0.20(0.50 \text{ kg})\left(9.8 \text{ m/s}^2\right)}$$

x = 0.49 m or 0.50 m, depending on use of $g = 9.8$ or 10 m/s^2 and where substitution and rounding took place

Question 1 (continued)

	Distribution of points
Newton's second law and kinematics approach to part (b); kinematics approach to part (c)	
(b) 7 points	
For a correct expression for the friction force (awarded if found in the solution to any of parts (a) through (d)) $f = \mu mg$ or $f = \mu N$	1 point
For correct substitution of $m = M_B$ $f = \mu M_B g$	1 point
For recognizing that the friction force on the slab is equal in magnitude to the friction force on the block and for an equation relating this force to the acceleration of the slab $f = M_S a_S$	1 point
For a correct expression for the acceleration of the slab or its numerical value $a_S = \dfrac{\mu M_B g}{M_S} = 0.33 \text{ m/s}^2$	1 point
For a correct expression for the acceleration of the block or its numerical value $a_B = \dfrac{\mu M_B g}{M_B} = \mu g = 2.0 \text{ m/s}^2$	1 point
For a solution of the following simultaneous kinematic equations for the block and the slab, such as by setting the times equal and solving for v_f $v_f = v_0 - a_B t$ for the block $v_f = a_S t$ for the slab $v_f = \dfrac{a_S v_0}{a_S + a_B} = \dfrac{(0.33 \text{ m/s}^2)(4.0 \text{ m/s})}{0.33 \text{ m/s}^2 + 2.0 \text{ m/s}^2}$	1 point
For the correct answer $v_f = 0.57 \text{ m/s}$	1 point
(c) 2 points	
For a correct kinematic equation for the slab $v_f^2 = v_0^2 + 2a_S x$, where $v_0 = 0$ $x = \dfrac{v_f^2}{2a_S} = \dfrac{v_f^2}{2}\dfrac{M_S}{\mu M_B g}$	1 point
For correct substitutions consistent with earlier values $x = \dfrac{(0.57 \text{ m/s})^2}{2}\dfrac{3.0 \text{ kg}}{0.20(0.50 \text{ kg})(9.8 \text{ m/s}^2)}$ $x = 0.49$ m or 0.50 m, depending on use of $g = 9.8$ or 10 m/s^2 and where substitution and rounding took place	1 point

Question 1 (continued)

Distribution of points

(d) 2 points

For a correct expression for the work done — 1 point

$W = Fd = \mu M_B g x$ OR $W = \Delta K = \frac{1}{2} M_S v_f^2$

For consistent substitution from parts (b) and (c) — 1 point

$W = 0.20(0.5\text{ kg})\left(9.8\text{ m/s}^2\right)(0.50\text{ m})$ OR $W = \frac{1}{2}(3.0\text{ kg})(0.57\text{ m/s})^2$

$W = 0.49\text{ J}$ (or $W = 0.50\text{ J}$ using $g = 10\text{ m/s}^2$)