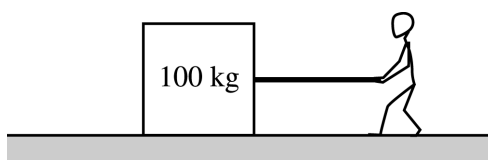**PHYSICS C**
Section II, MECHANICS
Time—45 minutes
3 Questions

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.

The 100 kg box shown above is being pulled along the *x*-axis by a student. The box slides across a rough surface, and its position *x* varies with time *t* according to the equation $x = 0.5t^3 + 2t$, where *x* is in meters and *t* is in seconds.

(a) Determine the speed of the box at time $t = 0$.

(b) Determine the following as functions of time *t*.

   i. The kinetic energy of the box

  ii. The net force acting on the box

 iii. The power being delivered to the box

(c) Calculate the net work done on the box in the interval $t = 0$ to $t = 2$ s.

(d) Indicate below whether the work done on the box by the student in the interval $t = 0$ to $t = 2$ s would be greater than, less than, or equal to the answer in part (c).

____Greater than   ____Less than   ____Equal to

Justify your answer.

Question 1

15 points total

**Distribution
of points**

(a)   3 points

For indicating speed as the time derivative of position   1 point

$$v = \frac{dx}{dt}$$

For taking the correct derivative   1 point

$$v = 1.5t^2 + 2$$

For finding the correct initial speed at $t = 0$ 1 point

$$v_0 = 2 \text{ m/s}$$

(b)   6 points

 i. (1 point)

$$K = \frac{1}{2}mv^2$$

For correctly substituting for the mass and the expression for v found in (a)   1 point

$$K = \frac{1}{2}(100)(1.5t^2 + 2)^2 = 50(1.5t^2 + 2)^2$$

 ii. (3 points)

$$F_{net} = ma$$

For indicating acceleration as the time derivative of the velocity   1 point

$$a = \frac{dv}{dt}$$

For taking the correct derivative   1 point

$$a = 3t$$

For the correct expression   1 point

$$F_{net} = (100)(3t) = 300t$$

Question 1 (cont'd.)

Distribution of points

iii. (2 points)

For the correct equation relating power to force and velocity   1 point
$$P = Fv$$
For substituting expressions for F and v found in previous parts   1 point
$$P = (300t)(1.5t^2 + 2) = 450t^3 + 600t$$

Alternate method   *Alternate points*

For indicating power as the time derivative of kinetic energy   *1 point*
$$P = \frac{dK}{dt}$$
For substituting the expression for kinetic energy from (b)i.   *1 point*
$$P = \frac{d}{dt}\left(112.5t^4 + 300t^2 + 200\right) = 450t^3 + 600t$$

(c)   4 points

For a statement that the work done on the box is equal to the change in its kinetic energy   2 point
$$W = \Delta K$$
For finding v at 2 seconds   1 point
$$v = (1.5)(2)^2 + 2 = 8 \text{ m/s}$$
Substituting, using the value of v_0 from part (a):
$$W = \frac{1}{2}(100 \text{ kg})\left((8 \text{ m/s})^2 - (2 \text{ m/s})^2\right)$$
For the correct answer with correct unit   1 point
$$W = 3000 \text{ J}$$

Alternate method   *Alternate points*

For a statement that the work done by the box is equal to the integral of power over time   *1 point*
$$W = \int P\,dt$$
For substituting the expression for power found in (b)iii   *2 points*
$$W = \int_0^2 (450t^3 + 600t)\,dt$$
$$W = \frac{450}{4}\left(t^4\right)\Big|_0^2 + \frac{600}{2}\left(t^2\right)\Big|_0^2$$
$$W = 1800 \text{ J} + 1200 \text{ J}$$
For the correct answer with unit   *1 point*
$$W = 3000 \text{ J}$$

**Distribution
of points**

(d)   2 points

For checking the box that the work done by the student is greater than in part (c)   1 point
For a reasonable justification recognizing that the student had to perform work against   1 point
     friction, such as $W_{student} = \Delta KE + W_{friction}$