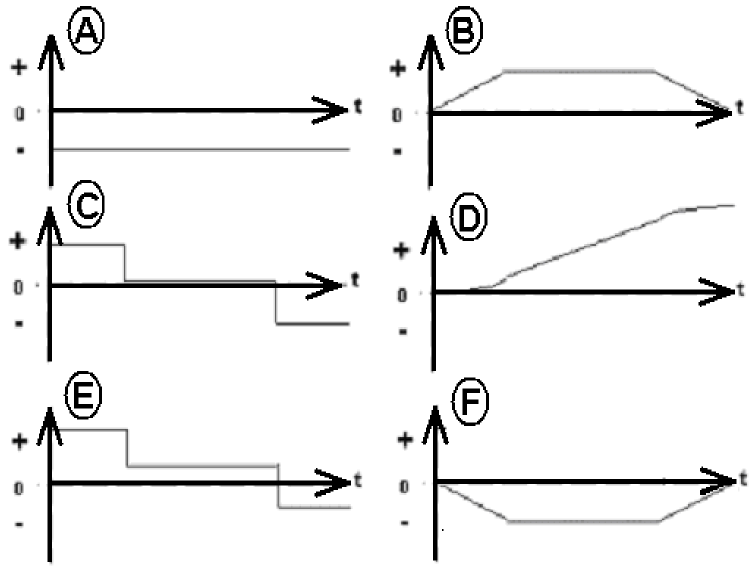
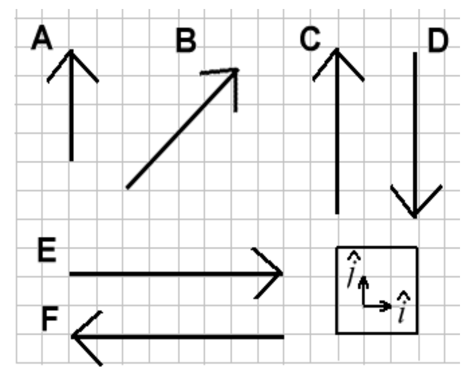
1. (30 points) *A worker is pushing a cart along the floor. At first, the worker has to push hard in order to get the cart moving. After a while, it is easier to push. Finally, the worker has to pull back on the cart in order to bring it to a stop before it hits the wall. The force exerted by the worker on the cart is purely horizontal. Take the direction the worker is going as positive. The cart begins moving at time t = 0.*



Above are shown graphs of some of the physical variables of the problem. Match the graphs
with the variables in the list below. You may use a graph more than once or not at all. Use N if the answer is none. (Note: the time axes are to the same scale, but the ordinates {"y axes"} are not.)

a.	*friction force exerted on the cart by the floor*	**A**
b.	*force exerted by the worker on the cart*	**E**
c.	*net force on the cart*	**C**
d.	*acceleration of the cart*	**C**
e.	*velocity of the cart*	**B**
f.	*force exerted by the cart on the worker*	**N (E** also OK**)**

2. (20 points) *In the figure at the right is shown a set of vectors on a grid. The grid spacing is such that each unit of the grid is 1 unit of whatever the vector represents. So for a displacement vector, interpret each grid unit as 1 cm. For a velocity vector, interpret each grid unit as 1 cm/s, etc. In a box at the lower right are shown the unit direction vectors* $\hat{i}$ *and* $\hat{j}$ *indicating the positive horizontal and vertical directions respectively.*



(The vectors A-F are intended to have integer values of their horizontal and vertical coordinates.) For each of the items below, specify the result, using the unit directions given for any vectors.

For each answer grading was: +1 for correct eqn., +1 for correct identification of vectors, +2 for correct answer, +1 for correct units and unit vectors.

(a) Take A, B, and F to be displacement vectors. What is the vector $2\vec{A} - \vec{B} + \vec{F}$?

2(0,4) – (4,4) + (-8,0) = (-12, 4) =

$$(-12\text{ cm})\hat{i} + (4\text{ cm})\hat{j}$$

(b) Take C and D to be initial and final velocity vectors respectively. What is the change in velocity, $\Delta\vec{v}$ *?*

$$\Delta\vec{v} = \vec{v}_f - \vec{v}_i = D - C$$

$$= (0.-6) - (0,6) = (0,-12) = -12\text{ cm/s }\hat{j}$$

(c) Take C and D to be initial and final velocity vectors respectively. If they have changed from one to the other at a constant acceleration, what is the average velocity during the change, $\langle\vec{v}\rangle$ *?*

$$<\vec{v}>=\frac{\vec{v}_i+\vec{v}_f}{2}=\tfrac{1}{2}(C+D)=0$$

(d) If an object makes a displacement given by the vector E in 2 s followed by the displacement F in 3 s, what is the object's average speed during the displacements?

$$\text{av. speed}=\frac{\text{total distance}}{\text{total time}}=\frac{16\text{ cm}}{5\text{ s}}=3.2\text{ cm/s}$$

3. (15 points) *I have seen it stated that different animals tend to have approximately the same numbers of heartbeats in their average lifespans. Using this idea and what you know about humans and dogs, estimate the typical heart rate (in beats per minute) of a dog. Is your result plausible?*

Be sure to clearly state your assumptions and how you came to the numbers you estimated, since grading on this problem will be mostly based on your reasoning, not on your answer.

From people we know, we can estimate a human lifetime as about 70 years (+2 for reasonable number, +1 for a reason). I have had a dog or recall that one dog year is 7 human years. This means a dog lives about 10 years. (+2 for reasonable number, +1 for reason)

I take my pulse and get about 70/minute. (+2 for reasonable number, +1 for reason)

If the total number of hearbeats is the same, since a human lives 7X as long a dog must beat 7X as fast to compenstate. (+3 argument) This gives about 500 beats/minute for a dog. (+2 calculated answer)

This would be almost 10 per second. I have held a dog, and although their heart beats faster than mine, not THAT fast. This is much too fast and the stated principle is wrong. (+1)

(1 point is deducted for too many sig. figs.)

4. (10 points) *In this class, students sometimes say that we emphasize equations less than in a traditional physics class. Do you think this is true? Explain why you agree or disagree. Then pick one equation we use in this course, explain what it says in words and describe two ways to use it.*

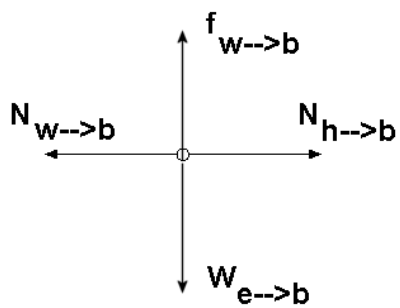
There are many ways to answer this. This was graded as follows:

Explanation	+2
A correct equation	+2
Stating the equation in words	+2
Giving two uses	2(+2)

5. (25 points) *You are holding your physics book against the wall by pressing on it as shown in the figure at the right.*

(a) You are pressing hard enough so that the book doesn't move. Draw a free-body diagram for the book, being sure to identify for each force the kind of force, what object is causing it, and what object is feeling it. (6 pts)

There are (at least) 4 forces acting on the book: a normal force from the hand, a normal force from the wall, the object's weight, and some friction force upward. The friction force might either be from the hand to the book or from the wall to the book (or both). But some upward force is needed, otherwise the book will begin to accelerate downward. Here is the FBD:



(Grading: +1 for each force, +1 for good labels, +1 for no extra forces, -1 if the forces can't balance, e.g., no upward force.)

(b) Which forces in your diagram have equal magnitude? How do you know?

By Newton's second law, the horizontal forces must balance and the vertical forces must balance. Therefore:

$$N_{w\to b} = N_{h\to b}$$
$$W_{e\to b} = f_{w\to b}$$

(+1 fore each relation, +1 for a reason for each)

(c) You begin to get tired and the book begins to slide down. The book begins to slide down, and you respond so it slides down at a constant velocity. How do each of the forces you have identified change from their magnitudes in part (a)? Explain how you know.

All the forces must be the same. (+2) Here is the chain of reasoning.

N2 implies that if it is sliding at a constant velocity all the forces balance so $W = f$. (+2) The weight W doesn't change so the frictional force must also be the same and not change. (+2) Since the frictional force of w→b is proportional to the normal force from w→b ($f = \mu N$) the normal force from the wall must also be the same (+2). Since N2 says the horizontal forces still balance, the normal force of the hand must equal the normal force of the wall. Since the normal force from the wall is unchanged, so must the normal force of the hand. (+2)

(d) If the book has a mass of 2 kg, the coefficient of friction between the sliding book and the wall is 0.4, how hard do you have to press on the book if it is sliding down with a speed of 2 cm/s?

Using g = 10 N/kg, the weight is (2 kg) (10 N/kg) = 20 N. (+1) The frictional force keeping it from accelerating must therefore also be 20 N. (+1) Since the coefficient of friction is 0.4 and $f = \mu N$,(+1) we must have (20 N) = (0.4) N so

$N_{w\to b}$ = (20 N) / (0.4) = 50 N. (+1)

Since the normal force of the wall must equal the normal force of the hand, this is how hard you have to push – 50 N. (+1)