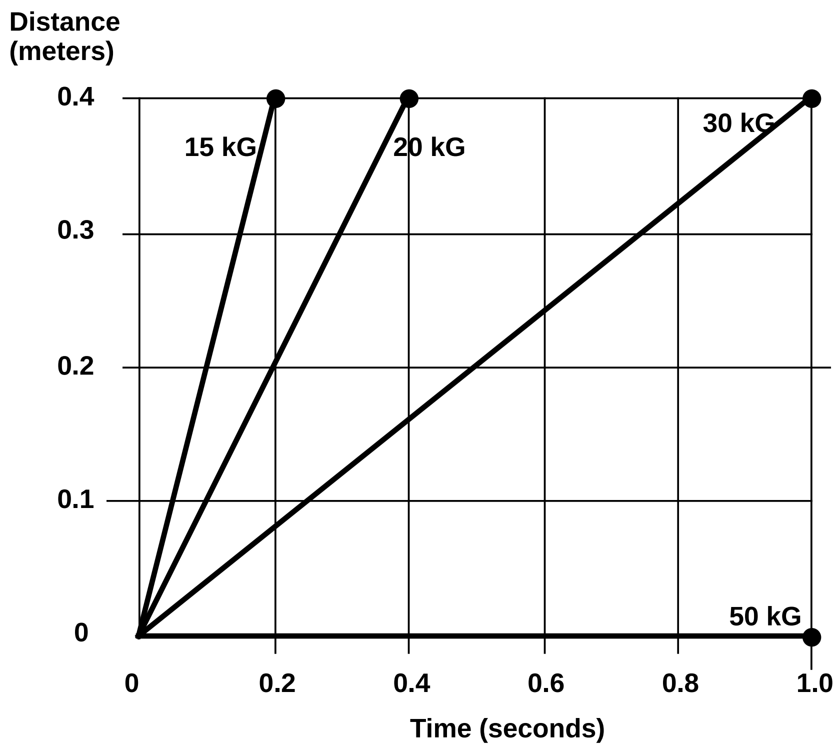
Exercise Physiology Problems:
Set #2 -- Basic Physics of Muscle Contraction -- <u>SOLUTIONS</u>

Imagine that someone is pressing (lifting from shoulder/chest to above head) a series of different weights. You record the time required to move the different weights -- notice that in each case the weight is moved the same distance (why?). You summarize your results as a graph (pleased note that we ignore the acceleration of the weight when the person first starts the press and when they finish the press).



Answer the following questions:
1. What does the distance 0 refer to (where is the weight)?

WHEN THE WEIGHT IS HELD IN THE LOW POSITION -- SINCE THIS IS A PRESS, IT IS SHOULDER HEIGHT. THIS REPRESENTS THE MINIMUM POTENTIAL ENERGY IN THIS CASE SINCE THE WEIGHTS ARE SIMPLY MOVED UP FROM THIS POSITION

2. Where is the 0.4 meter distance measured from -- it is 0.4 m from what (the floor? Mars?, the lifters shoulders?)

FROM THE SHOULDER (RESTING POSITION). THIS IS THE DISTANCE FACTOR IN THE WORK EQUATION -- IT IS HOW FAR YOU MOVE THE WEIGHT (FROM SHOULDER TO FULL ARM EXTENSION)

3. How far did the person move the 50 kG mass?

THE PERSON WAS NOT ABLE TO LIFT THE 50 KG MASS -- THEY SIMPLY HELD IT WHERE IT WAS

4. In these graphs, are the individual weights depicted as having constant or variable velocity during the press? Explain (put another way -- what does the slope of each line represent and what units does the slope have).

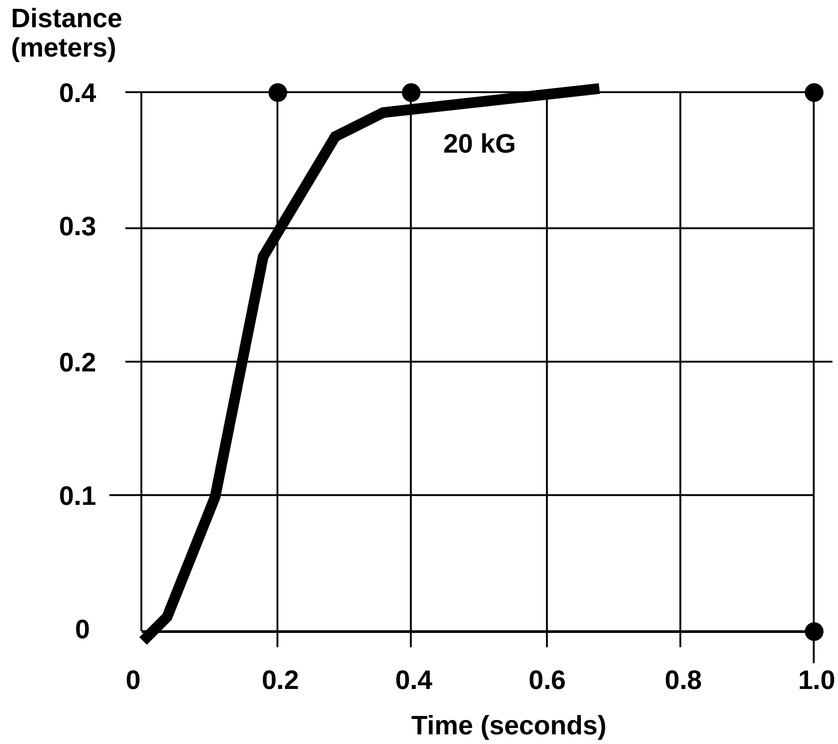
THE GRAPH IS A PLOT OF DISTANCE MOVED (Y -AXIS) VS TIME (X-AXIS). THE SLOPE OF SUCH A PLOT IS $\frac{\text{DISTANCE}}{\text{TIME}}$ OR **VELOCITY**. NOTICE THAT ALL LOADS HAVE DIFFERENT VELOCITIES. SINCE ALL OF THE PLOTS ARE STRAIGHT LINES, THEIR SLOPES AND THEREFORE THE VELOCITIES ARE CONSTANT. IN REALITY, THE PLOTS WOULD BE CURVES AND MANY LIGHT LOADS WOULD MOVE AT ESSENTIALLY THE SAME VELOCITY.

5. There are actually two types of acceleration operating on the weights -- one that is exerted by the muscles of the lifter (but which is not shown in the graph above -- ask me if you don't understand this) and an acceleration that is constant throughout each lift (and before and after the lift).
What is the constant acceleration acting on the weight?

THE CONSTANT ACCELERATION IS THE ACCELERATION DUE TO GRAVITY -- IT IS ACTUALLY WHAT IS GIVING THE MASSES THE QUANTITY WE CALL WEIGHT. THESE SAME MASSES IN OUTER SPACE WOULD BE SAID TO BE WEIGHTLESS

6. Sketch what you think (based on your own experience of lifting any heavy weight) is a more accurate depiction of the distance vs. time than the one shown above (note that you only need to make a graph for one weight and you do not need actual times and distances -- thus I am asking for a **qualitative** graph as compared to the **quantitative** graph shown above).

SEE ANSWER TO NUMBER 4. HERE'S WHAT IT WOULD REALLY LOOK LIKE:



7. Do you think friction with the air should be an important consideration in our problem? Why?

NO, AIR IS NOT VERY DENSE AND WE ARE NOT MOVING THE WEIGHT EXCEPTIONALLY FAST. WE WILL LEARN THAT DRAG (FRICTION WITH A FLUID) ONLY MATTERS WITH REALLY VISCOUS FLUIDS OR AT HIGHER VELOCITIES

Some useful formulas and the names of some units (**Know all of these**) -- units are in parentheses and commonly used symbols are boldfaced :

Force (**n**ewtons) = **m**ass (**kG**) * **a**cceleration (meters/sec^2)

Work or **E**nergy (**j**oules) = **F**orce (**n**ewtons) * **d**istance (**m**eters)

Power (**w**atts) = **w**ork or **e**nergy (**j**oules) / **t**ime (**s**econds)

acceleration due to gravity = 9.8 m / s^2

8. Find: The force that our athlete is lifting against in each case. (Note that force is one manifestation of what we call weight; instead of pounds you will calculate the mks units of weight.)

USE EQUATION A ABOVE: F = MA

A IN EACH CASE IS 9.8 M/S^2 (SEE #5 SINCE WE ARE ONLY CONCERNED ABOUT THE FORCE REQUIRED TO MOVE THE MASS). THUS SOLVING FOR EACH MASS:

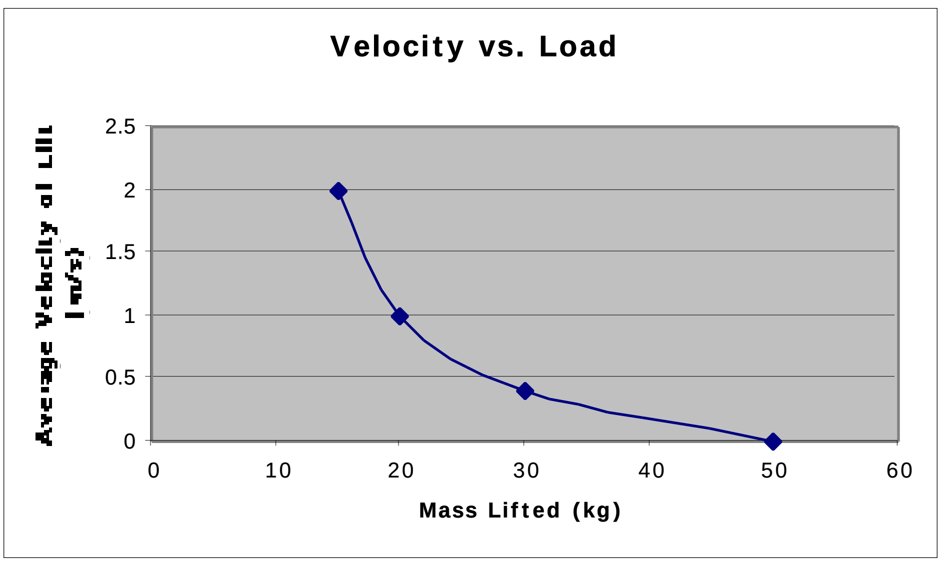
mass	force
15	147
20	196
30	294
50	490

9. Using the data given on the graph, you should realize that the velocity is constant for each lift. Find the velocity (m/s) for each lift.

RECALL THAT VELOCITY IS THE DISTANCE MOVED PER TIME. SO:

Time (s)	Distance (m)	V (m/s)	mass
0.2	0.4	2	15
0.4	0.4	1	20
1	0.4	0.4	30
	0	0	50

10. Make a plot of velocity (m/s) vs. mass lifted (kg).



11. Find the work (joules) done in each lift (we are only interested in difference in energy between the resting point and the top of the lift).

FIRST WE NEED TO FIND THE FORCE FOR EACH LOAD. RECALL THAT F = MA

NOW IN EACH CASE ACCELERATION IS 9.8 M/S^2 SINCE WE ARE ONLY CONCERNED ABOUT THE FORCE REQUIRED TO MOVE THE MASS (SEE #5). THUS SOLVING FOR EACH MASS:

mass	time	f (= mass * acc to gravity)
15	0.2	147
20	0.4	196
30	1	294
50		490

NOW SINCE WORK IS FORCE THROUGH DISTANCE, THE ONLY THING YOU NEED TO DO IS MULTIPLY THE FORCE BY HOW FAR THE MASS MOVED (0.4 M -- SEE DISCUSSION IN QS# 1 AND 2) THUS:

mass	time	f (= mass * acc to gravity)	distance moved	**W (J)**
15	0.2	147	0.4	**58.8**
20	0.4	196	0.4	**78.4**
30	1	294	0.4	**117.6**
50		490	0	**0**

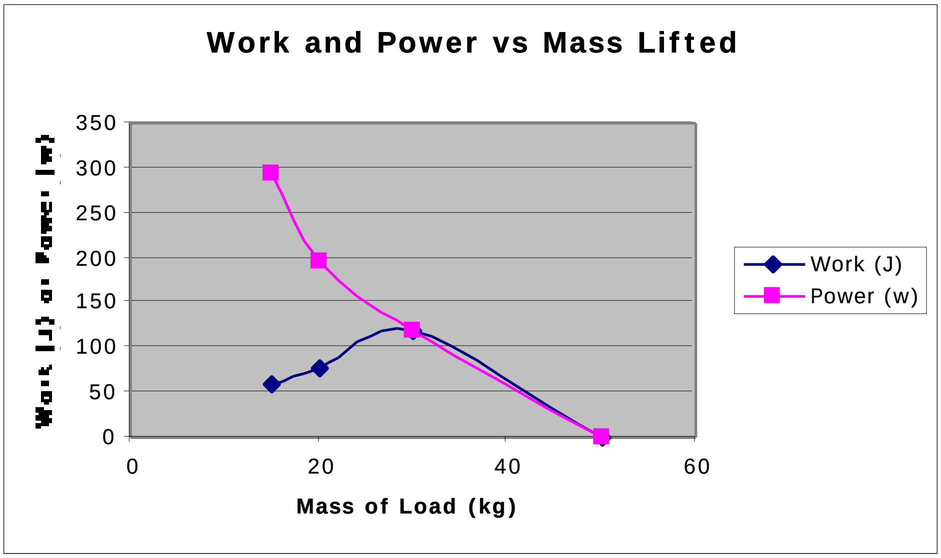
NOTICE THAT IN THE CASE OF THE 50 KG LOAD THAT THE MASS DID NOT MOVE AND THEREFORE NO **EXTERNAL** WORK WAS DONE. IN EVERY CASE HERE WE ARE CALCULATING EXTERNAL WORK DONE.

12. Find the power in watts exerted by lifter with each weight. Make a graph of power vs. mass lifted.

POWER IS SIMPLY WORK DIVIDED BY TIME -- TO GET IN MKS UNITS, (WATTS) WORK MUST BE IN JOULES AND TIME IN SECONDS:

TIME (S)	WORK (J)	POWER (W)
0.2	58.8	294
0.4	78.4	196
1	117.6	117.6
	0	0

HERE IS A GRAPH THAT SHOWS BOTH THE WORK AND POWER AS A FUNCTION OF THE LOAD (IN KG):


Work and Power vs Mass Lifted
350
300
250
200
150
100
50
0
0
20
40
60
Mass of Load (kg)
Work (J)
Power (w)