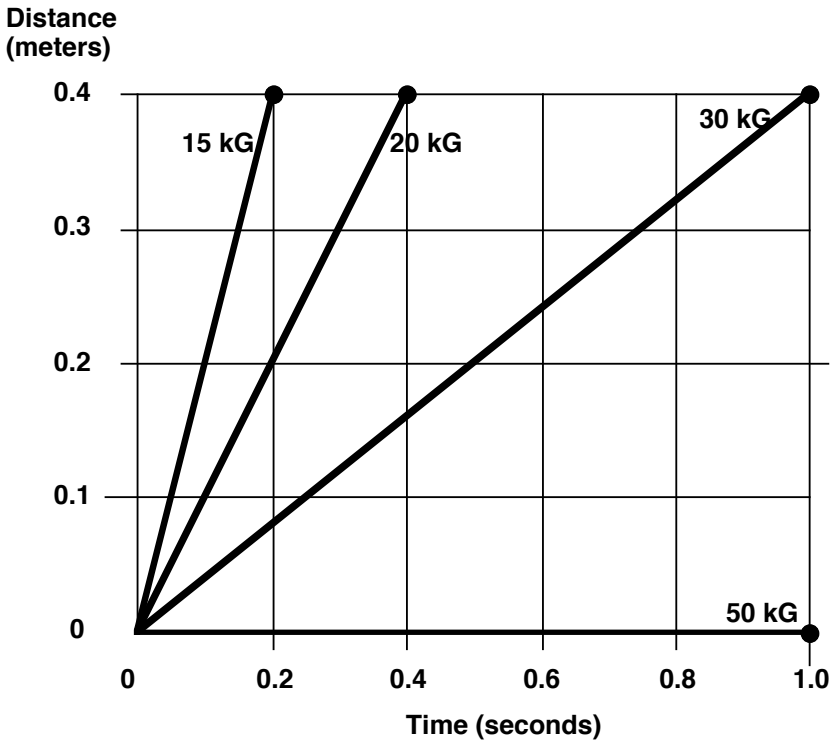
Basic Physics of Muscle Contraction -- ANSWERS

☹ **Note: although I cribbed these from my Exercise Physiology class for non-majors, they are worth doing so that you are familiar with distance, velocity, force and power diagrams for skeletal muscles.** ☺

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).



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?

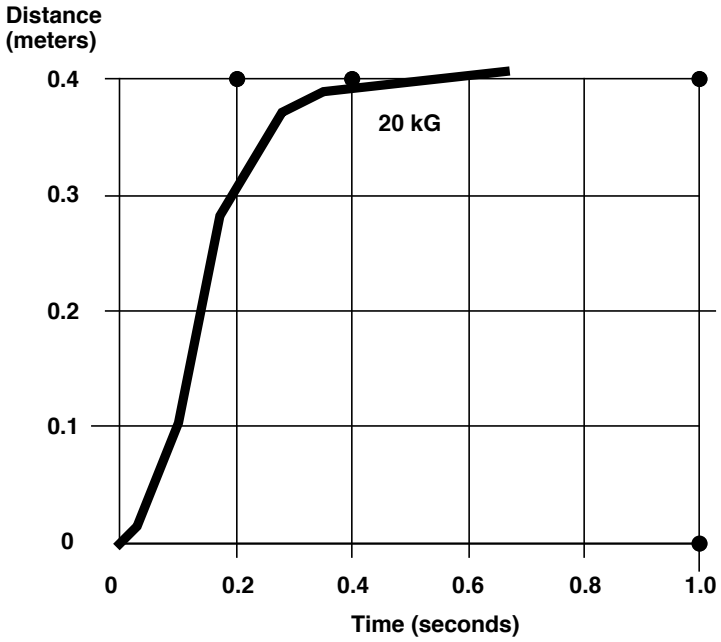
THE PERSON WAS NOT ABLE TO LIFT THE 50 KG MASS -- THEY SIMPLY HELD IT WHERE IT WAS

4. In these graphs, the individual weights are depicted as having a constant velocity during the press. What is the meaning (term for) the slope of each plot?

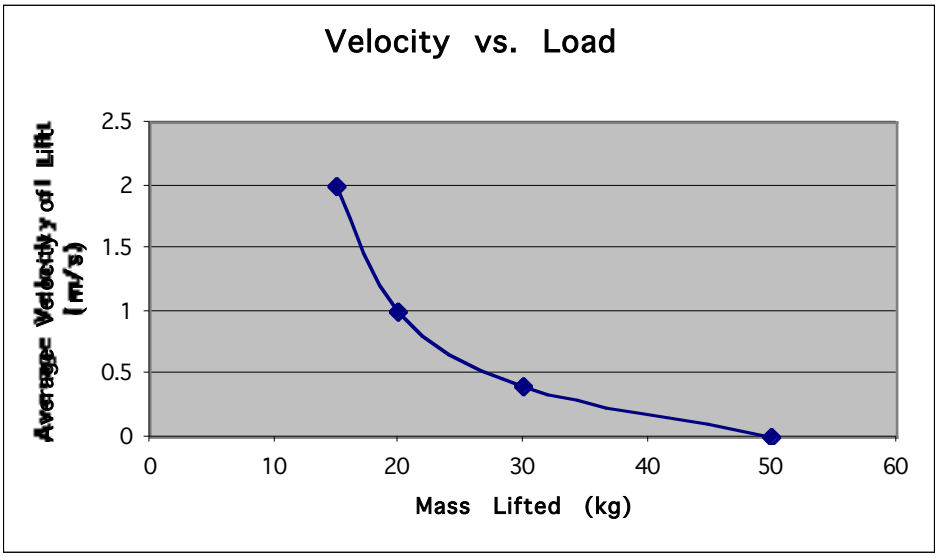
THE GRAPH IS A PLOT OF DISTANCE MOVED (Y -AXIS) VS TIME (X-AXIS). THE SLOPE OF SUCH A PLOT IS $\frac{\text{DISTANCE}}{\text{TIME}}$ OR **VELOCITY**. NOTICE THAT ALL LOADS HAVE DIFFERENT VELOCITIES. SINCE ALL OF THE PLOTS ARE STRAIGHT LINES, THEIR SLOPES AND THEREFORE THE VELOCITIES ARE CONSTANT. IN REALITY,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

5. Based on your own experience of lifting any heavy weight, sketch what you think 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.

HERE'S WHAT IT WOULD REALLY LOOK LIKE:



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



7. 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**

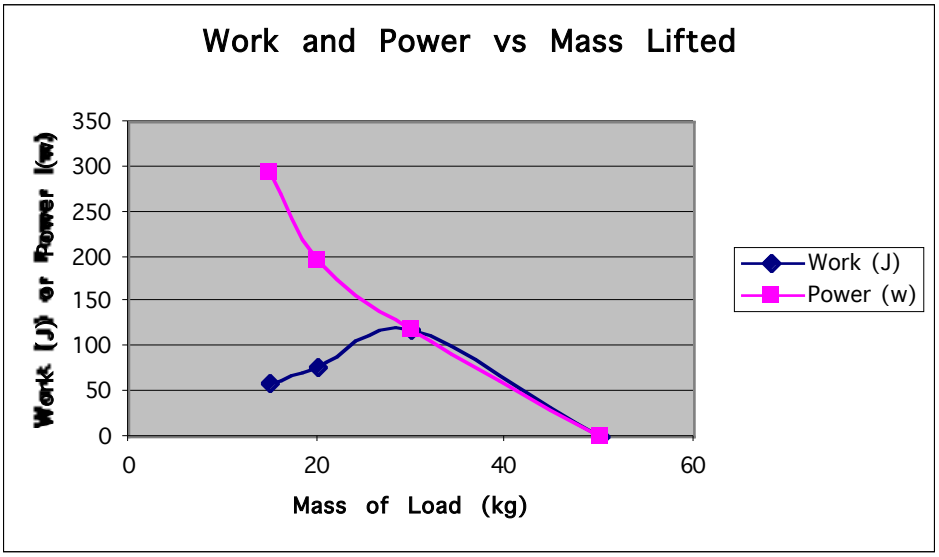
NOTICE THAT IN THE CASE OF THE 50 KG LOAD THAT THE MASS DID NOT MOVE AND THEREFORE NO **EXTERNAL** WORK WAS DONE. IN EVERY CASE HERE WE ARE CALCULATING EXTERNAL WORK DONE.

8. 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):



9. Which contractions have at least some isometric component?

ALL OF THESE CONTRACTIONS HAVE ISOMETRIC COMPONENTS. THE 50 KG LOAD IS OBVIOUSLY F_O AND IS TOTALLY ISOMETRIC. HOWEVER, SINCE MUSCLES CONTAIN SERIES ELASTICITY, EVEN ISOTONIC CONTRACTIONS ALWAYS HAVE AN INITIAL ISOMETRIC COMPONENT WHEN THE CONTRACTILE ELEMENTS SHORTEN AND THE ELASTIC ELEMENTS LENGTHEN. THE FORCE ACTING ON THE LOAD GRADUALLY INCREASES TO THAT OF THE CONTRACTILE ELEMENTS AS THE SERIES ELASTANCE STRETCHES. WHEN THE FORCE ACTING ON THE LOAD EXCEEDS THE LOAD, THE ISOTONIC COMPONENT FINALLY BEGINS.