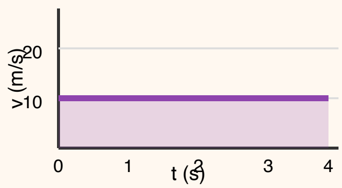
WORK & ENERGY DAY 2: GRAPHICAL ANALYSIS

⏱ Warm-Up (3 min) — Unit 1 Review

An object's velocity is shown below. Find the displacement from $t = 0$ to $t = 4$ s.



Method:

Displacement = __________ **m**

THE PATTERN: AREA = ACCUMULATION

You just found displacement by calculating **area under the v–t curve**. This isn't a coincidence—it's a deep pattern in physics.

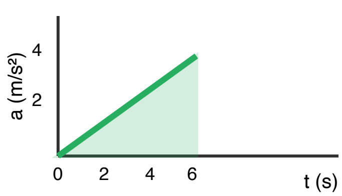
THE BIG IDEA

Area under a graph = accumulated effect of what's on the y-axis

Graph	Area represents...	Why?
v vs t	Displacement	Velocity accumulates into position
a vs t	Change in velocity (Δv)	Acceleration accumulates into velocity
F vs x	**Work**	**Force accumulates into energy transfer**

WE DO **Acceleration Graph**

A car's acceleration is shown. Find the change in velocity from $t = 0$ to $t = 6$ s.



Shape: ________________

Area formula:

Δv = __________ **m/s**

PART 2: FORCE VS. POSITION GRAPHS

Yesterday you learned $W = Fd\cos\theta$. That equation only works when **force is constant**.

What if force changes as the object moves? The graph gives us the answer.

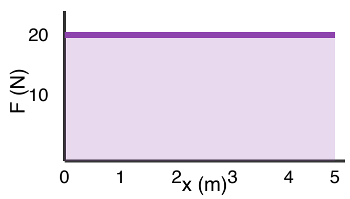
WORK FROM A GRAPH

Work = Area under the Force vs. Position graph

(with sign: area above x-axis is +, area below is –)

WE DO **Constant Force (Sanity Check)**

A constant 20 N force pushes a box from $x = 0$ to $x = 5$ m.



Graphical method:

Shape: rectangle

Area = base × height = _____ × _____ = _____ J

Equation method:

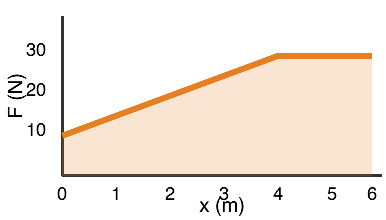
$W = Fd =$ _____ × _____ = _____ J

Same answer. The graph method works.

Why bother with graphs? Because real forces often *change*. A bow gets harder to pull back. A spring resists more the farther you stretch it. The equation $W = Fd$ breaks down—but the graph still works.

YOU DO **Variable Force**

A force varies as shown. Find the total work done from $x = 0$ to $x = 6$ m.



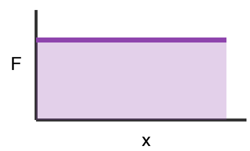
Break into shapes:

Total Work = __________ **J**

PART 3: THE SHAPE THAT MATTERS MOST

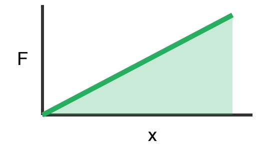
Tomorrow you'll investigate springs. Here's a preview of what you'll find:

Pushing a box (constant F)



Rectangle → $W = Fd$

Stretching a spring (F increases)



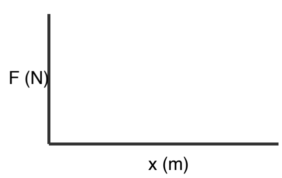
Triangle → $W = \frac{1}{2}Fd$

Notice: When force grows linearly from zero, you get *half* the work you'd expect from just $F \times d$. The triangle's area is $\frac{1}{2} \times$ base $\times$ height.

SKILL **Archer's Bow**

An archer pulls back a bowstring. The force required increases linearly from 0 N to 180 N as the string is pulled back 0.6 m.

Sketch the F vs. x graph:

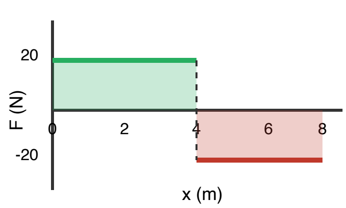


Calculate work done on the bow:

Where does this energy go?

AP SKILL **Negative Area**

A force acts on an object as shown. The object moves from $x = 0$ to $x = 8$ m.



Work from 0 to 4 m: ________

Work from 4 to 8 m: ________

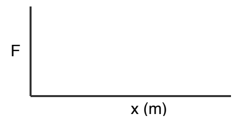
Net work (0 to 8 m): ________

PRACTICE & HOMEWORK

1 Quick Graphs

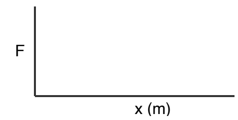
Find the work done in each case.

A. Constant 15 N force, object moves 4 m.



W = ________

B. Force increases from 0 to 40 N over 5 m.



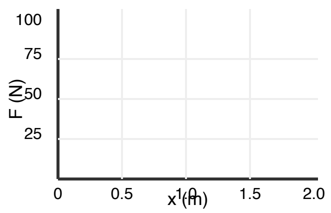
W = ________

2 Bungee Cord

A bungee cord requires increasing force to stretch. The data below shows force vs. stretch distance.

x (m)	0	0.5	1.0	1.5	2.0
F (N)	0	25	50	75	100

Plot F vs. x and find total work to stretch it 2.0 m:



Calculation:

W = __________ J

3 Compare Methods

A 50 N force (constant) pushes a crate 8 m. Calculate work **both** ways and verify they match.

Using $W = Fd$:

Using area under F–x graph:

🧩 Looking Ahead

Tomorrow you'll measure how force changes as you stretch a spring. You'll discover that the F vs. x graph is a straight line through the origin—and the area under it gives you a formula for **stored energy**.

The triangle is about to become very important.