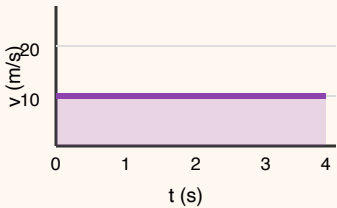


ENERGY DAY 2: WORK FROM GRAPHS

 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.

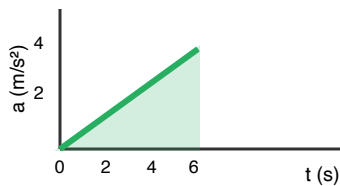
THE BIG IDEA

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:

$\Delta v =$ _____ 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.

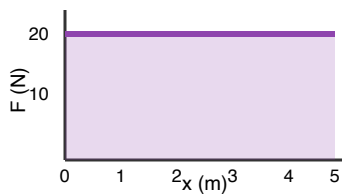
WORK FROM A GRAPH

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 x height = _____ x _____ = _____ J

Equation method:

$$W = Fd = \underline{\hspace{1cm}} \times \underline{\hspace{1cm}} = \underline{\hspace{1cm}} \text{ J}$$

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.

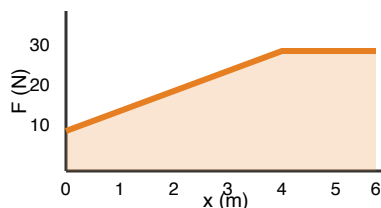
CALCULUS CORNER – STRIPS OF WORK

Check the units of one strip under an $F-x$ curve: its height is a force (N), its width is a small displacement (m), so each strip carries $(N)(m) = J$ — a small parcel of work. Adding the strips accumulates joules, exactly the way strips under a $v-t$ curve accumulated meters in Unit 1.

Tomorrow we shrink the strip width toward zero and the sum becomes the work integral, $W = \int F(x) dx$. The area idea doesn't change — only the notation sharpens.

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

On Day 4 you'll investigate springs in the lab. Here's a preview of what you'll find:

Pushing a box (constant F)



Rectangle $\rightarrow W = Fd$

Stretching a spring (F increases)



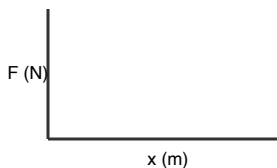
Triangle $\rightarrow W = \frac{1}{2}Fd$

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 $\frac{1}{2} \times \text{base} \times \text{height}$.

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:

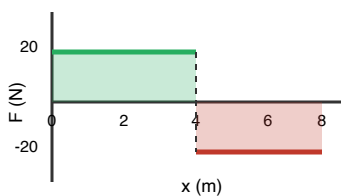


Calculate work done on the bow:

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: _____

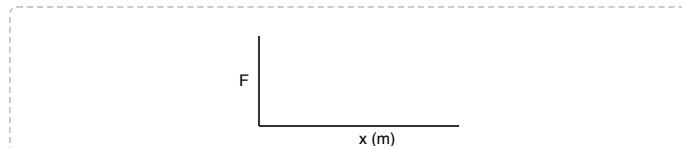
Net work (0 to 8 m): _____

PRACTICE & HOMEWORK

1 Quick Graphs

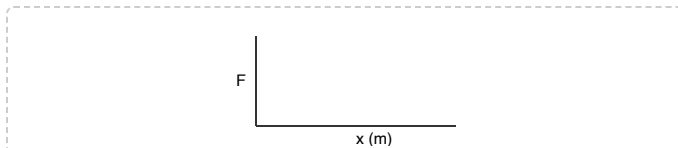
Find the work done in each case.

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



$W =$ _____

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



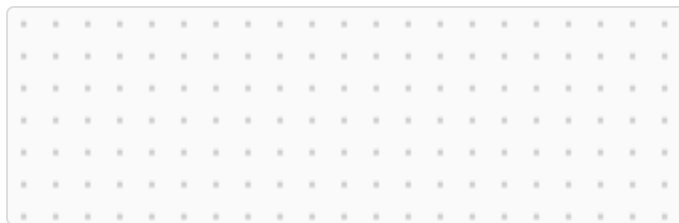
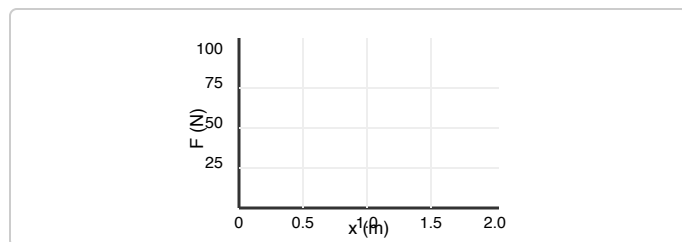
$W =$ _____

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 the strips become an integral: $W = \int F(x) dx$, the tool that handles ANY force curve. Then on Day 4 you'll measure a real spring's F–x line in the lab — and the area under it gives you a formula for **stored energy**.

The triangle is about to become very important.