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# Physics 111 - Class 8C
# Work & Kinetic Energy III

October 29, 2021

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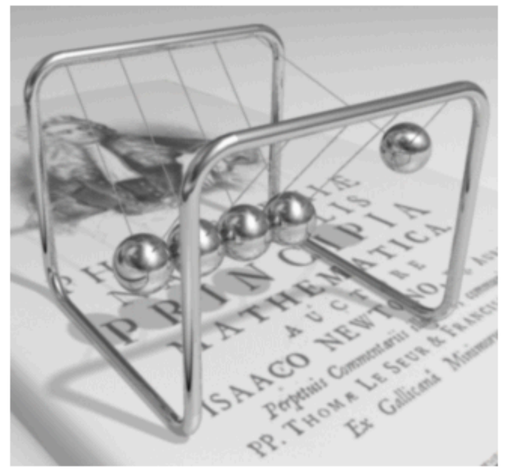
# Class Outline

- Logistics / Announcements
- Chapter 7 Intro
- Clicker Questions
- Activity: Worked Problems

# Logistics/Announcements

- Lab this week: Lab 5
- HW7 due this week on Thursday at 6 PM
- Learning Log 7 due on Saturday at 6 PM
- HW and LL deadlines have a 48 hour grace period
- Test/Bonus Test: Test 3 available this week (Chapters 5 & 6)
    - Test Window: Friday 6 PM - Sunday 6 PM



Physics 111

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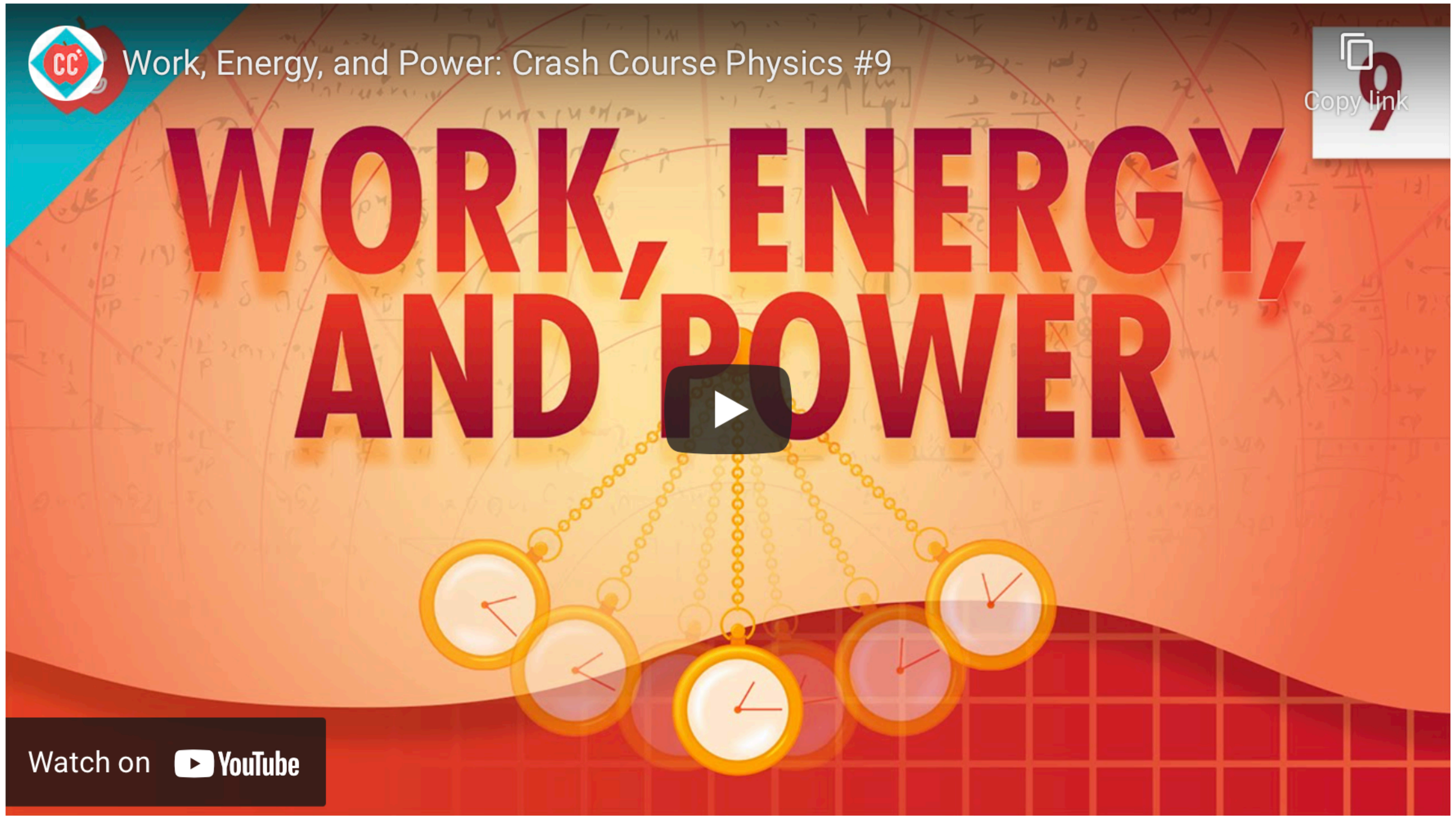
**Work, Energy, and Power**




## Required Videos

**1. Introduction to Work with Examples**

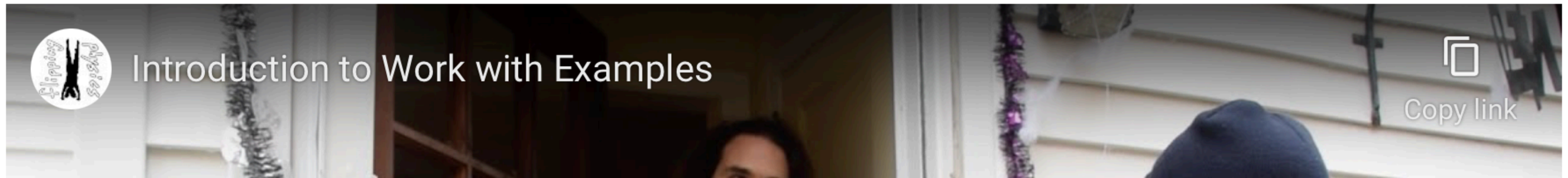


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**Figure 7.1** A sprinter exerts her maximum power with the greatest force in the short time her foot is in contact with the ground. This adds to her kinetic energy, preventing her from slowing down during the race. Pushing back hard on the track generates a reaction force that propels the sprinter forward to win at the finish. (credit: modification of work by Marie-Lan Nguyen)

## Chapter Outline



In this chapter, we discuss some basic physical concepts involved in every physical motion in the universe, going beyond the concepts of force and change in motion, which we discussed in Motion in Two and Three Dimensions and Newton's Laws of Motion. These concepts are work, kinetic energy, and power. We explain how these quantities are


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# Energy

- In the first part of the course, we talked about the <u>motion of objects and systems</u> (Kinematics) and “tools of the trade” like trigonometry, derivatives, integrals, and vector decomposition.
- In the second part of the course, we talked about <u>*how Forces affect the motion of objects and systems.*</u>
- In the last part of the course, we will talk about Energy; <u>which is a very helpful accounting tool to help us understand what happens when Forces are applied to other objects</u>.

# Friday's Class

## 7.4 Power

# HW 7 Reflection

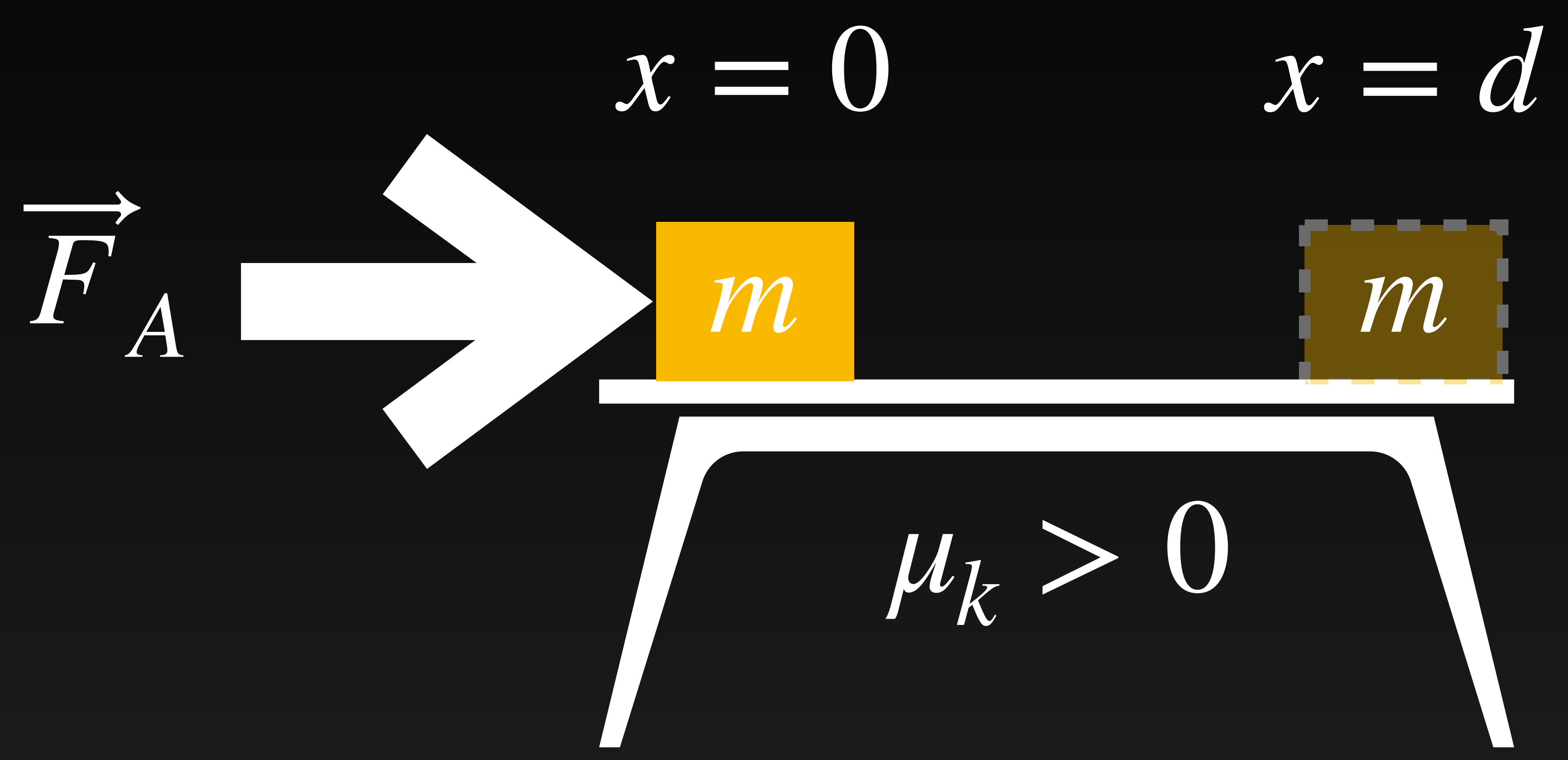

**Most confusing things:**

Work-Energy Theorem

Power

HW 7.8 Power of a Sprinter: Why doesn't kinematics way work?

# Deriving the Work-Energy Theorem




A package of mass **m** on a table is being pushed to the right, starting at **x = 0** and ending up at **x = d**. Analyze the situation and calculate the work done.

# Deriving the Work-Energy Theorem

**WORK-ENERGY THEOREM**

The net work done on a particle equals the change in the particle's kinetic energy:

$$W_{\text{net}} = K_B - K_A. \tag{7.9}$$

# Power

Then, we can define the **instantaneous power** (frequently referred to as just plain **power**).

**POWER**

Power is defined as the rate of doing work, or the limit of the average power for time intervals approaching zero,

$$P = \frac{dW}{dt}. \qquad \boxed{7.11}$$

If the power is constant over a time interval, the average power for that interval equals the instantaneous power, and the work done by the agent supplying the power is $W = P\Delta t$. If the power during an interval varies with time, then the work done is the time integral of the power,

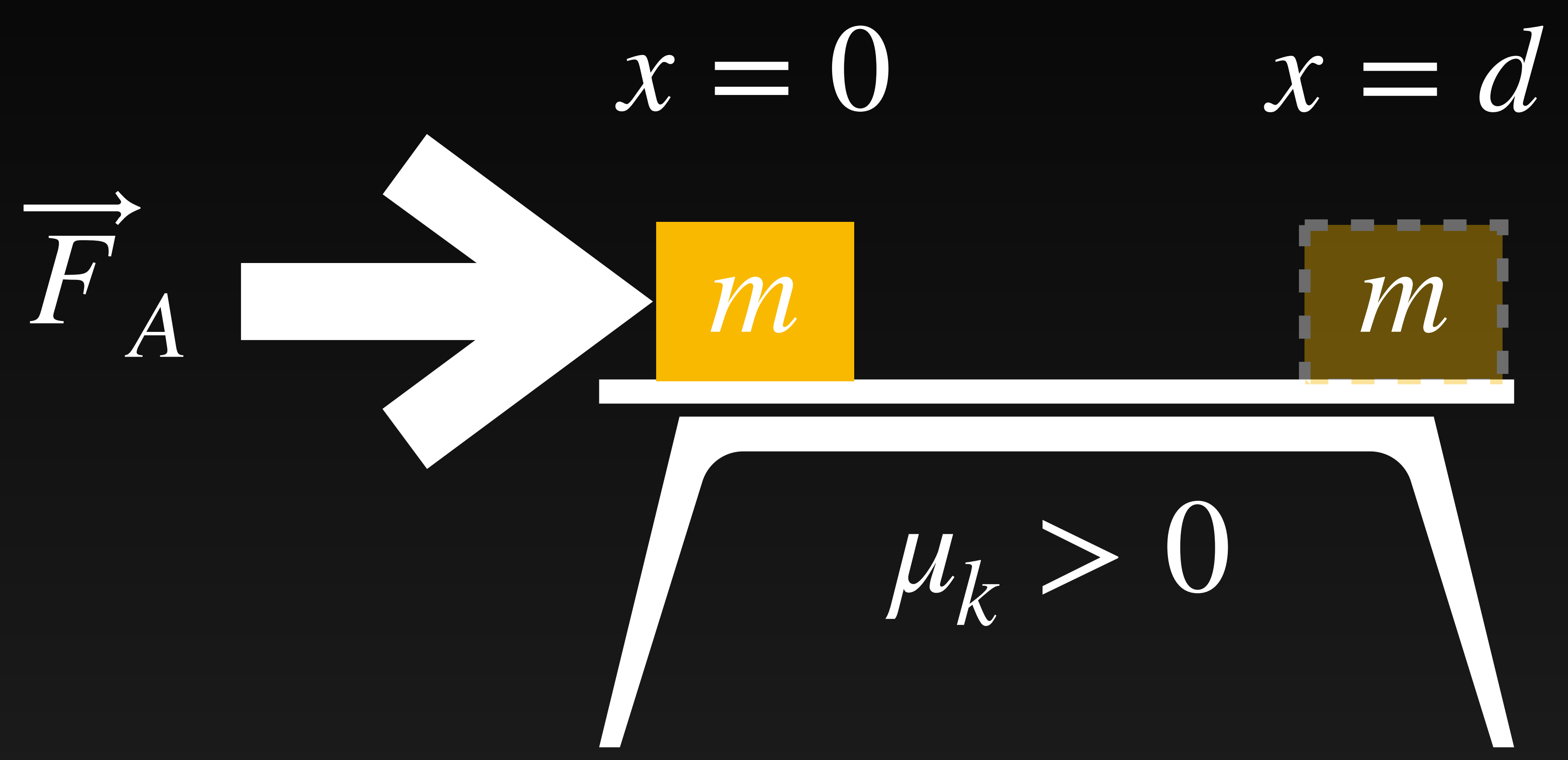
$$W = \int Pdt.$$

# Average Power

We express the relation between work done and the time interval involved in doing it, by introducing the concept of power. Since work can vary as a function of time, we first define **average power** as the work done during a time interval, divided by the interval,

$$P_{\text{ave}} = \frac{\Delta W}{\Delta t}. \tag{7.10}$$

# Power required to move an object

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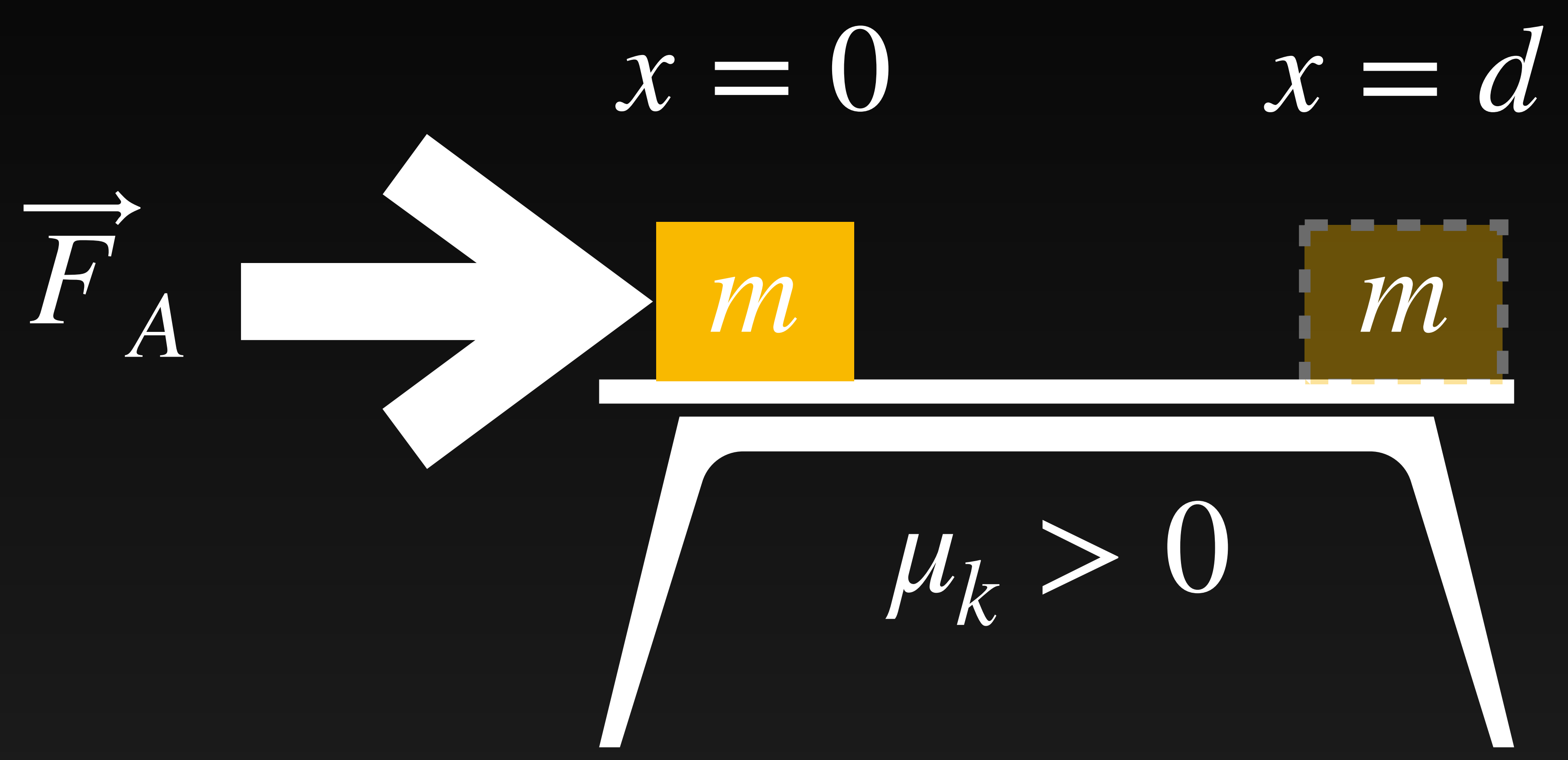
# Power required to move an object




A package of mass **m** on a table is being pushed to the right, starting at **x = 0** and ending up at **x = d**. Analyze the situation and calculate the work done.

The power involved in moving a body can also be expressed in terms of the forces acting on it. If a force $\vec{\mathbf{F}}$ acts on a body that is displaced $d\vec{\mathbf{r}}$ in a time *dt*, the power expended by the force is

$$P = \frac{dW}{dt} = \frac{\vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}}{dt} = \vec{\mathbf{F}} \cdot \left(\frac{d\vec{\mathbf{r}}}{dt}\right) = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}, \tag{7.12}$$

where $\vec{\mathbf{v}}$ is the velocity of the body. The fact that the limits implied by the derivatives exist, for the motion of a real body, justifies the rearrangement of the infinitesimals.

# HW 7.8

## Power of a Sprinter

A $90kg$ sprinter accelerates uniformly from rest to reach their maximum speed of $11m/s$ in 2 seconds.

What is their power output when their speed is $8m/s$?

| $P =$ | number (rtol=0.05, atol=1e-08) | $W$ | ? |
|---|---|---|---|

# Key Equations

| | |
|---|---|
| Work done by a force over an infinitesimal displacement | $dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} = \left\|\vec{\mathbf{F}}\right\| \left\|d\vec{\mathbf{r}}\right\| \cos\theta$ |
| Work done by a force acting along a path from *A* to *B* | $W_{AB} = \int_{\text{path}AB} \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$ |
| Work done by a constant force of kinetic friction | $W_{\text{fr}} = -f_k \left\|l_{AB}\right\|$ |
| Work done going from *A* to *B* by Earth's gravity, near its surface | $W_{\text{grav},AB} = -mg\,(y_B - y_A)$ |
| Work done going from *A* to *B* by one-dimensional spring force | $W_{\text{spring},AB} = -\left(\frac{1}{2}k\right)\left(x_B^2 - x_A^2\right)$ |
| Kinetic energy of a non-relativistic particle | $K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$ |
| Work-energy theorem | $W_{\text{net}} = K_B - K_A$ |
| Power as rate of doing work | $P = \frac{dW}{dt}$ |
| Power as the dot product of force and velocity | $P = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}$ |

# Clicker Questions

# CQ.8.9

A boy pushes his little sister on a sled. The sled accelerates from $0$ to $3.2\ \mathrm{m/s}$. If the combined mass of his sister and the sled is $40.0\ \mathrm{kg}$ and $18\ \mathrm{W}$ of power were generated, how long did the boy push the sled?

a) $205\ \mathrm{s}$

b) $128,\ \mathrm{s}$

c) $23\ \mathrm{s}$

d) $11\ \mathrm{s}$

A

B

C

D

E

# CQ.8.9

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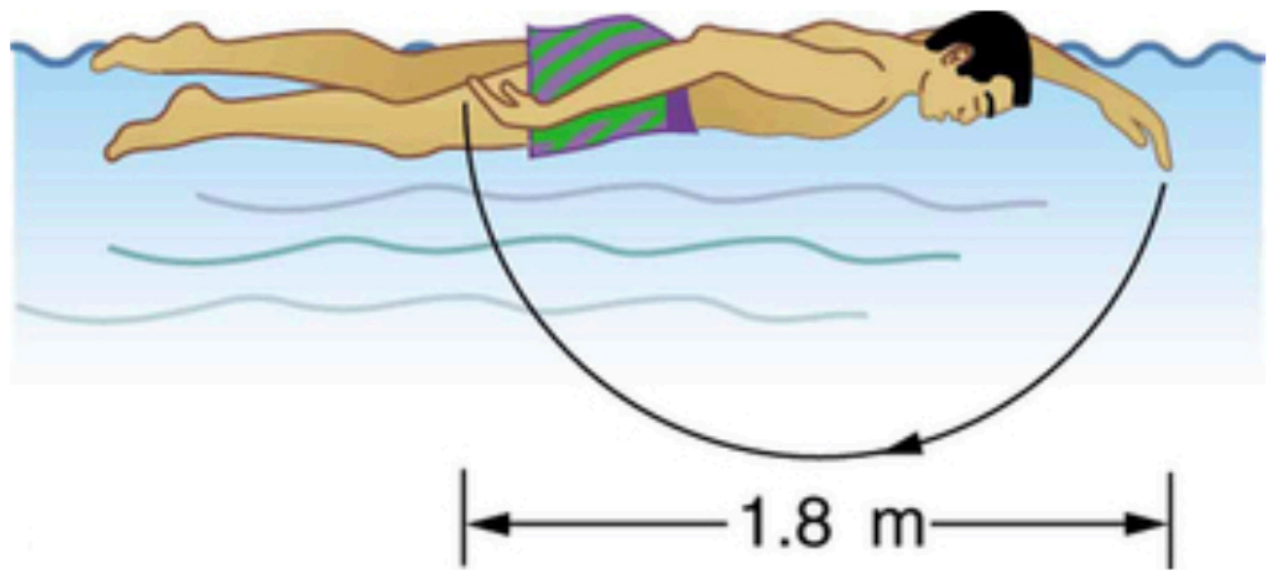
✓ d) $11\ \mathrm{s}$

**Detailed solution:** $P = \frac{W}{t} = \frac{\frac{mv^2}{2} - 0}{t};\ t = \frac{\frac{mv^2}{2}}{P} = \frac{mv^2}{2P} = \frac{(40.0)(3.2)^2}{2(18)} = 11\ \mathrm{s}$

A B C D E

# CQ.8.10

The swimmer shown in the figure exerts an average horizontal backward force of 80.0 N with his arm during each 1.80 m long stroke.




**What is his work output in each stroke?**

a) 144 J

b) 0.0 J

c) 44.4 J

d) 81.8 J

A B C D E

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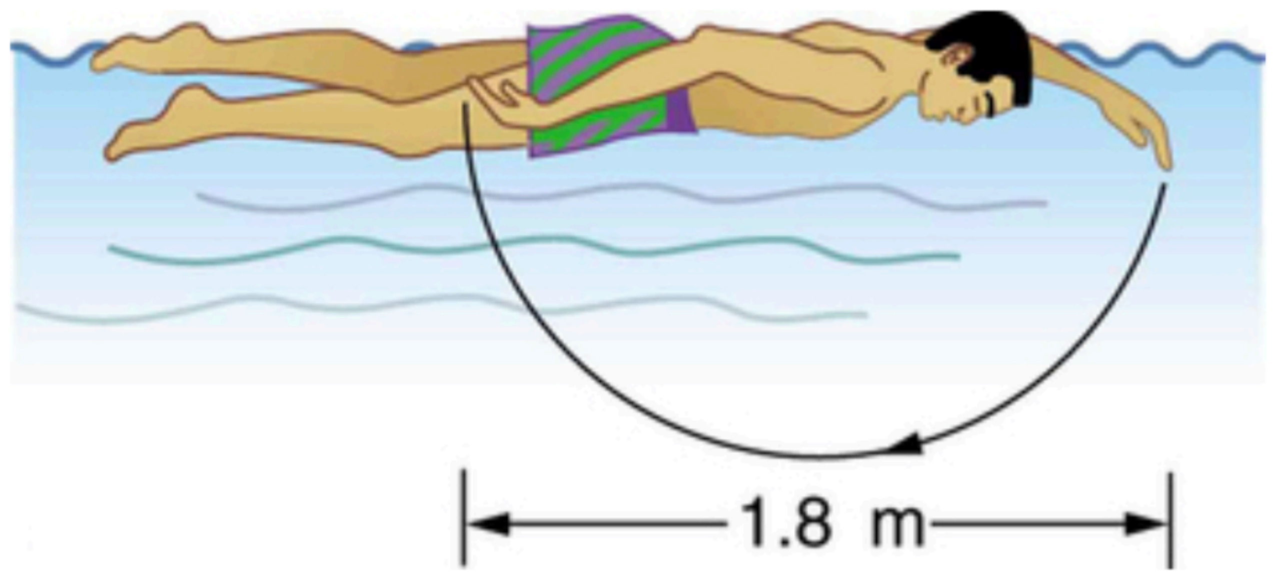


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# CQ.8.11

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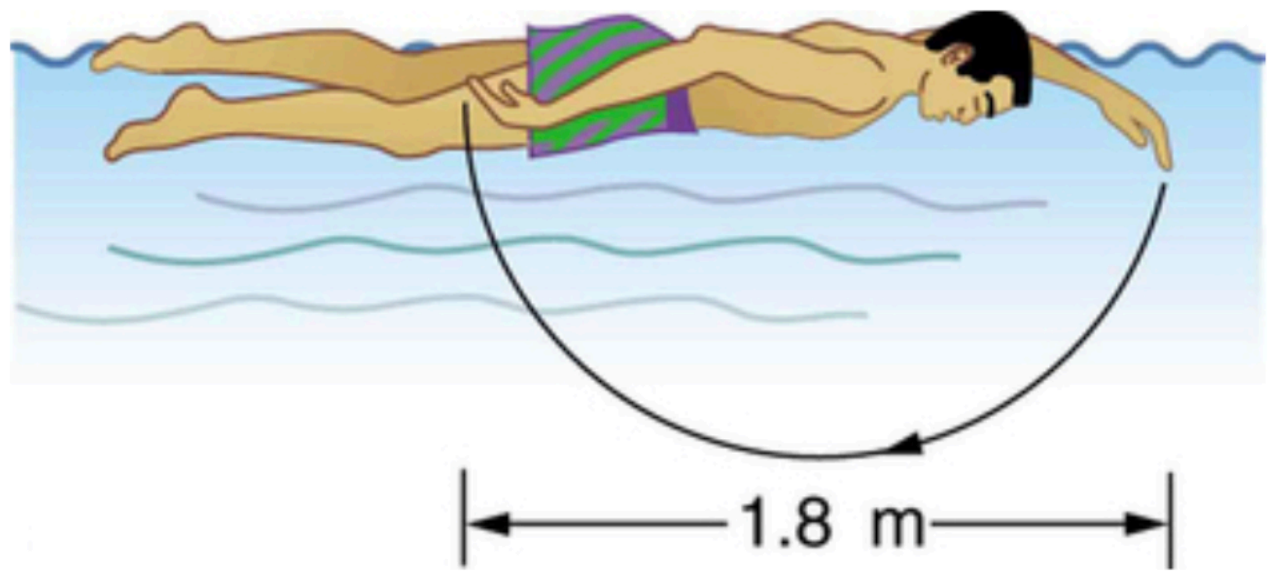


**What is his work output in each stroke?**

**Calculate the power output of his arms if he does 120 strokes per minute.**

a) 288 W

b) 17,300 W

c) 2.40 W

d) 4.80 W

A B C D E

# CQ.8.11

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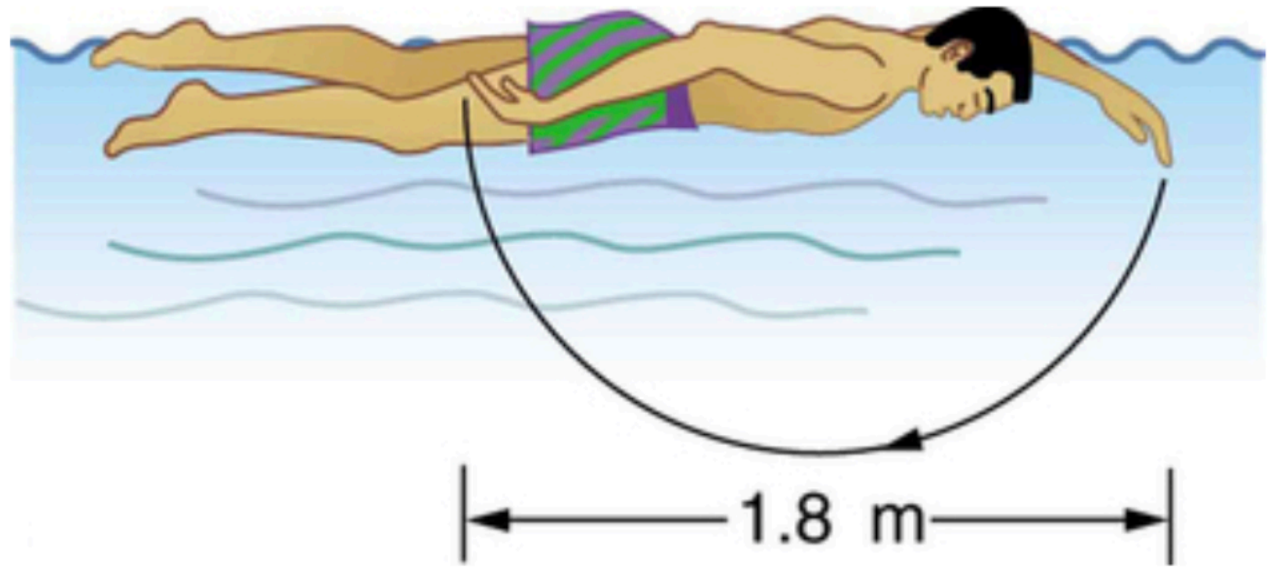


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A B C D E

# Activity:
# Worked Problems

**88** . Consider a particle on which a force acts that depends on the position of the particle. This force is given by $\vec{\mathbf{F}}_1 = (2y)\hat{\mathbf{i}} + (3x)\hat{\mathbf{j}}$. Find the work done by this force when the particle moves from the origin to a point 5 meters to the right on the *x*-axis.

# WP 7.4

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# WP 7.5

# See you next class!

# Attribution