Lab Section:
TA Name: Student Name:
Links to the (youtube) instructional videos are at the bottom of the web page:

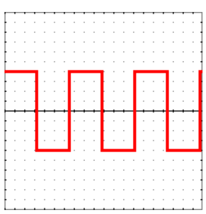
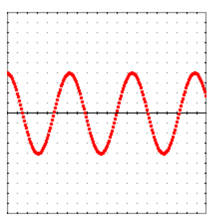
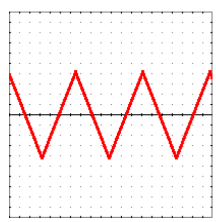
Part 1:

Step 1: Watch Video 9-1

Below is program 9-1.py introduced in that video:

```
clear()
k, m = 1.0, 100.0
t, dt = 0,1.0
v, pos = 0, 40
while t < 200:
  dot(t, pos, red)
  a = -pos * k/m
  v = v + a * dt
  pos = pos + v * dt
  t = t + dt
```

Step 2: Predict the position graph plotted by program 9-1.py and explain what aspect of each graph influenced your choice.

Step 3: Validate & correct your conclusions by running program 9-1.py. Indicate any misconceptions below.

Part 2:

Step 1: Watch Video 9-2

Step 2: Examining the relationship between initial position (with velocity equal to zero) and amplitude and period for harmonic motion.

To examine this relationship, modify program 9-1.py to correspond to the initial conditions from the table below and read the plot to determine (approximate) amplitude and period. be sure to indicate units for each result.

Initial position	Initial velocity	Amplitude (from plot)	Period (from plot)
40 m	0 m/s		
-40 m	0 m/s		
80 m	0 m/s		

Conclusions: What does the table above indicate is the relationship between…

- initial position and amplitude?

    - Musical notes correspond to particular frequencies and loudness corresponds to amplitude. A guitar string is effectively a spring with mass that is used to play a particular note. Given the phenomena you observed, would you expect a guitar's string's note to change depending on how hard it is plucked (and why)?

- initial position and period?

Step 3: The "resonant frequency" of a harmonic motion is the number of complete cycles that occur within a second. The units are called "Hertz", and abbreviated Hz. For example, if a sinusoid has a period of 0.2s, its frequency is 5Hz because 5 cycles * 0.2s = 1s. Compute the "resonant frequency" for the system we are examining.

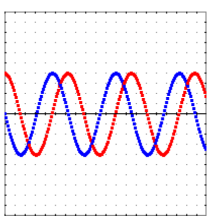
Part 3:

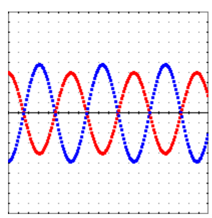
Step 1: Watch video 9-3

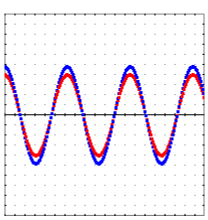
Below is the contents of program 9_2.py which plots both position and velocity

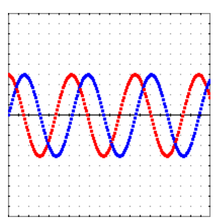
```
clear()
k, m = 1.0, 100.0
t, dt = 0,1.0
v, pos = 0, 40
while t < 200:
  dot(t, pos, red)
  dot(t, v*10, blue)
  a = -pos * k/m
  v = v + a * dt
  pos = pos + v * dt
  t = t + dt
```

Step 2: The relationship between velocity and position
Analyze the following plots and predict which is the correct depiction of position and velocity generated by program 9_2.py. Circle your selection and indicate for each of the 4 plots why you selected (or did not select) it.









Step 3: Validate your prediction from Step 2 by running program 9_2.py. If you predicted incorrectly, please indicate your likely misconception below.

Step 4: Analyze the (correct) plot:

- What is the amplitude and period (include units) for the velocity plot.

- When position is a minimum:
  - What is the velocity?
  - Is it increasing or decreasing?
  - Why?

- When position is a maximum::
  - What is the velocity?
  - Is it increasing or decreasing?
  - Why?

- When velocity is a minimum:
  - What is the position?
  - Is it increasing or decreasing?
  - Why?

- When velocity is a maximum::
  - What is the position?
  - Is it increasing or decreasing?
  - Why?

Step 5: Determining the effect of increasing mass or spring constant.

Modify program 9_2.py to qualitatively determine the result of doubling mass, spring constant, or both upon the relative amplitude of the velocity to position, period, and frequency.

Init Pos	Init V	Mass	K	Pos amplitude	V amplitude	Period	Freq.
40 m	0 m/s	100 kg	1 N/m				
40 m	0 m/s	200 kg	1 N/m				
40 m	0 m/s	100 kg	2 N/m				
40 m	0 m/s	200 kg	2 N/m				

.

Circle the correct answer and conjecture why:

When only mass is doubled:

- V amplitude increases / stays the same / decreases
- Period increases / stays the same / decreases
- Frequency increases / stays the same / decreases
- Why? ____

When only K is doubled:

- V amplitude increases / stays the same / decreases
- Period increases / stays the same / decreases
- Frequency increases / stays the same / decreases
- Why? ____

When both mass and K are doubled:

- V amplitude increases / stays the same / decreases
- Period increases / stays the same / decreases
- Frequency increases / stays the same / decreases
- Why? ____

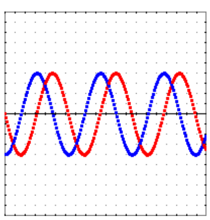
Part 4: Phase

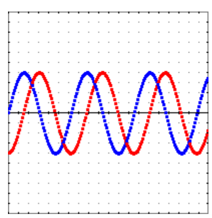
Step 1: Watch video 9-4

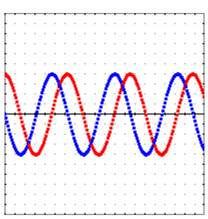
Below is program 9-3.py from that video.

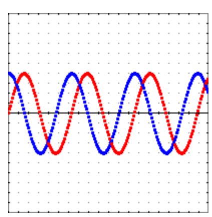
```
clear()
k, m = 1.0, 100.0
t, dt = 0,1.0
v, pos = 4, 0
while t < 200:
  dot(t, pos, red)
  dot(t, v*10, blue)
  a = -pos * k/m
  v = v + a * dt
  pos = pos + v * dt
  t = t + dt
```

Step 2: Predict which of the these plots corresponds with the output of program 9-3. Circle your selection and indicate for each of the 4 plots why you selected (or did not select) it.









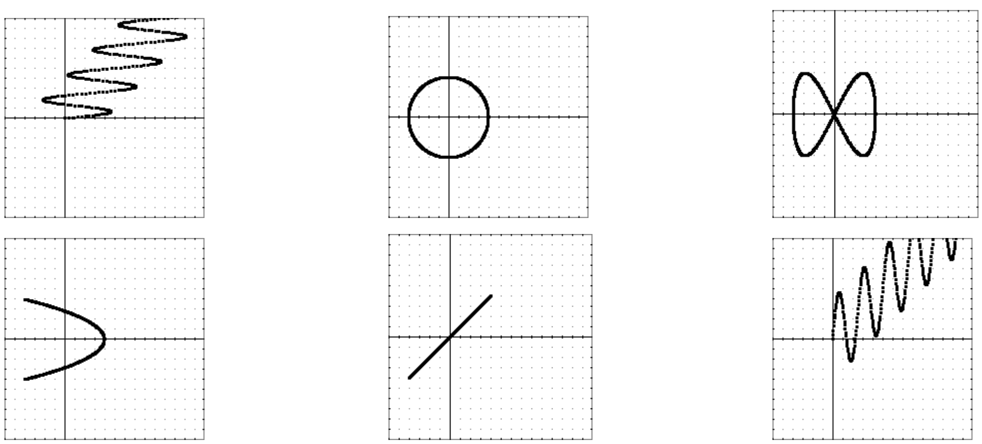
Step 3: Validate your prediction by running program 9-3.py and indicate any misconceptions that led to an error in Step 2.

Part 5: Phase plots

Step 1: Watch video 9-5
Below is program 9-4.py from that video.

```
clear()
k, m = 1.0, 100.0
t, dt = 0,1.0
v, pos = 4, 0
while t < 200:
  dot(60+v*10, pos)   # (v*10,p) translated to the right by 60
  a = -pos * k/m
  v = v + a * dt
  pos = pos + v * dt
  t = t + dt
```

Step 2: Predict which of the these plots corresponds with the output of program 9-4.py. For reference, we added a vertical line at column 60. Circle your selection, and indicate for each of the plots why you selected (or did not select) it.



Step 3: Validate your prediction by running program 9-4.py and indicate any misconceptions that led to an error in Step 2.

Part 6: Analysis

Step 1: watch video 9-6

- Students in the non-calculus physics course may skip the last section "With Calculus This Makes Sense" starting at time 5:51.

Step 2: Using the mathematical analysis from the videos, analytically determine frequency, and period for the following and compare with simulated results from Part 3.

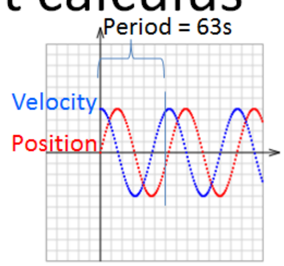
Init Pos	Init V	Mass	K	Period	Frequency
40 m	0 m/s	100 kg	1 N/m		
40 m	0 m/s	200 kg	1 N/m		
40 m	0 m/s	100 kg	2 N/m		
40 m	0 m/s	200 kg	2 N/m		

For reference, two key slides from video 9-4 are duplicated below.:

Solving for period without calculus

- Assertion:
  - $P(t) = B \sin \omega t$
  - $V(t) = C \cos \omega t$
- Omega (frequency multiplier)
  - Recall that frequency
    - Should increase if k increases
    - Should decrease if m increases
  - Actually..
    - $\omega^2 = \frac{k}{m}$
  - Therefore
    - $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{1}{100}} = \frac{1}{10}$
- Solving for period

$$\frac{2\pi}{\omega} = \frac{2\pi}{\frac{1}{10}} = 20\pi = 63\text{s}$$




```
clear()

k, m = 1.0, 100.0
t, dt = 0,1.0
v, pos = 4, 0
while t < 200:
  dot(t, pos, red)
  dot(t, v*10, blue)
  a = -pos * k/m
  v = v + a * dt
  pos = pos + v * dt
  t = t + dt
```

With calculus, this makes sense

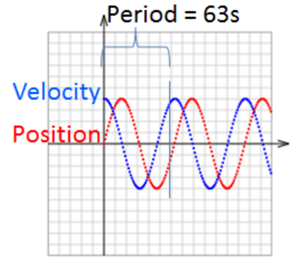
- Assertion:
  - $Pos(t) = B \sin \omega t$

$V(t) =$ $Pos'(t) = B\omega \cos \omega t$

$A(t) =$ $Pos''(t) = -B\omega^2 \sin \omega t = -\omega^2 Pos(t)$

- Recall
  - $A(t) = -\frac{k}{m} Pos(t)$
- Therefore
  - $\omega^2 = \frac{k}{m}$
  - $\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{1}{100}} = \frac{1}{10}$
  - $V(t) = \frac{1}{10} \cos \frac{t}{10}$
- Period

  $\frac{2\pi}{\omega} = \frac{2\pi}{\frac{1}{10}} = 20\pi = 63s$




```
clear()

k, m = 1.0, 100.0
t, dt = 0,1.0
v, pos = 4, 0
while t < 150:
  dot(t, pos, red)
  dot(t, v*10, blue)
  a = -pos * k/m
  v = v + a * dt
  pos = pos + v * dt
  t = t + dt
```