A better solution to $\ddot{x} = -\omega^2 x$

is a more complete solution

(allows for different starting conditions)

- max. and min. values of sine are still …….
- the system oscillates from …….

The value of A in a real system is related to its energy….





**Phase angle ($\phi$)**

(measured in degrees / radians)

In this simple SHM analysis, it allows for ……
……

In other examples, it gives detail about the relative positions around the "……" of the SHM objects

(But it has much wider implications!)

Example 1);
take $\phi = 0$

This is our original solution; i.e at ……., the system starts from equilibrium at ……

So we can now more easily think of this as ……. ……., since sine is a “circular” / cyclical function.







Example 2);
take $\phi=\pi/2$

This corresponds to our normal start for a pendulum;

(i.e. we pull it away from x=0 to one side and then release).

So, using;

Which corresponds to;

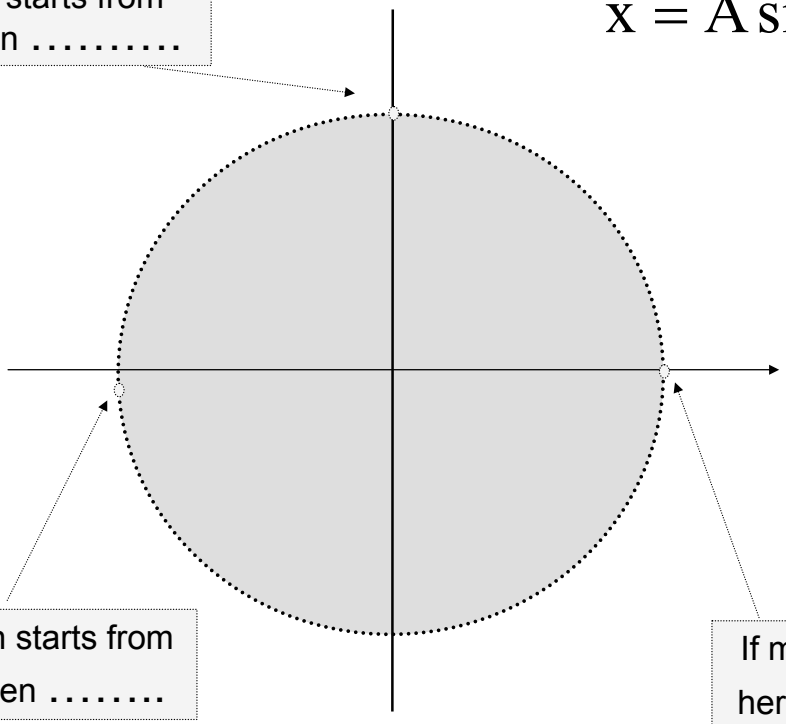
For $\phi=\pi/2$

So finally;

**We can look at the projection of the radius arm "A" onto one of the diameters (the Y=0 plane here).**

If motion starts from here, then .....

$$x = A\sin(\omega t + \phi)$$



If motion starts from here, then .....

If motion starts from here, then .....



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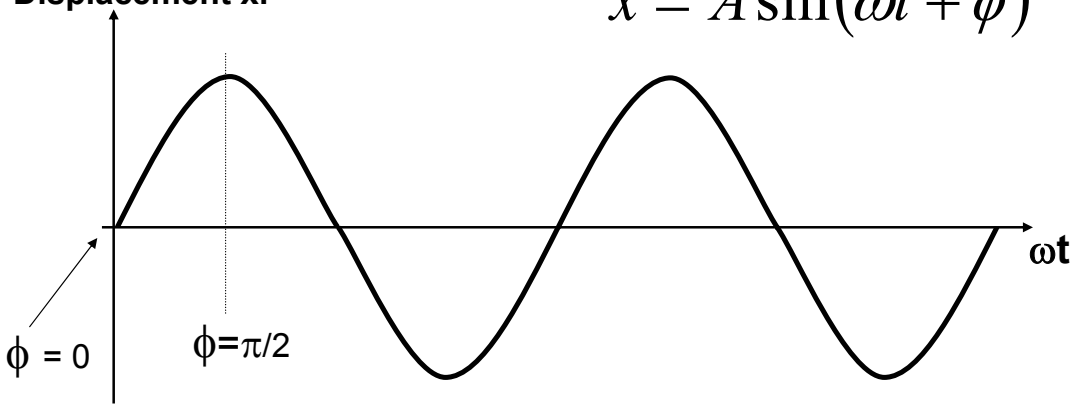
**The projection of the radius arm onto the diameter gives** .....

**Displacement x.**

$$x = A\sin(\omega t + \phi)$$




- for $\phi = \pi/2$, motion would start at .....
- equivalent to:

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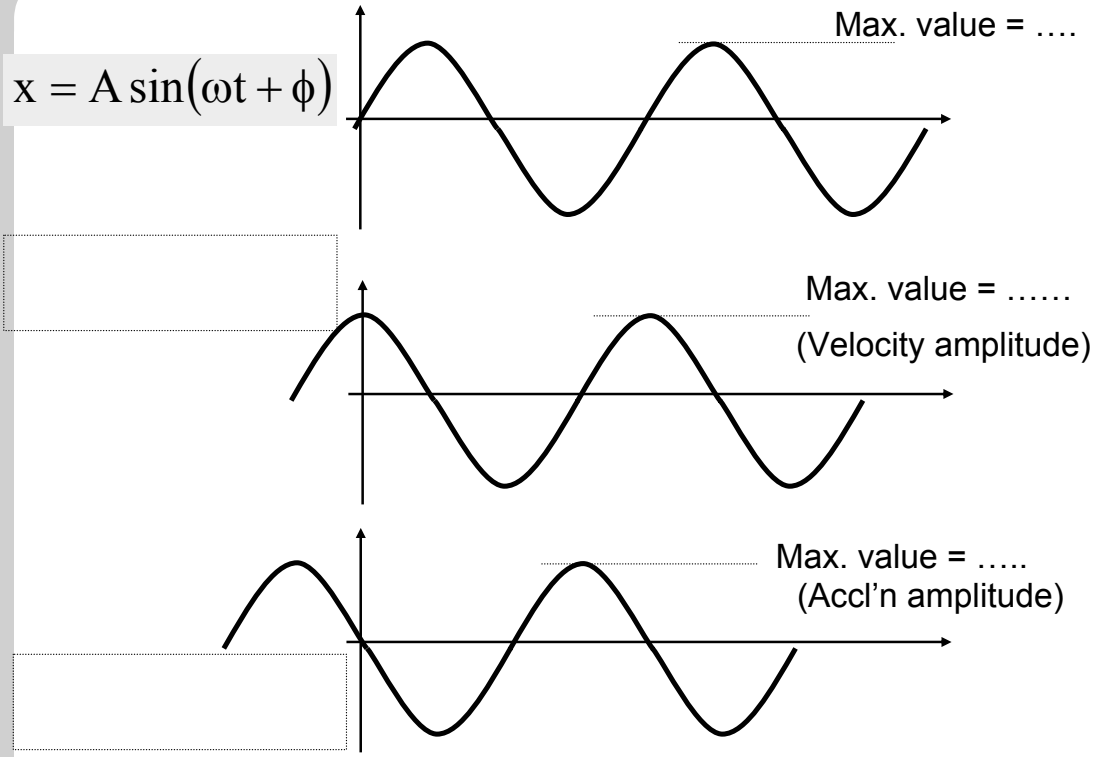
## Phase relation between; displacement, velocity, and acceleration.

$$x = A\sin(\omega t + \phi)$$





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## Note on phase relations.

1. ……. is out of phase with ……. by 90 degrees ($\pi$/2 radians)

   ……. leads the ……. by $\pi$/2 radians

   When …….. is maximum, ……. is zero (and vice versa)

2. ……. is *out of phase* with ……. by 180 degrees ($\pi$ radians).

   When ……. is maximum (positive), the ……. is maximum (negative)

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# I.3 Energy of Simple Harmonic Motion



(We continue with the spring / mass model of SHM)

Since the velocity at certain points becomes zero, there must ……

This transfer is only perfect if no energy is lost during the motion (…….. motion).

If it is lost we call it ……..

Kinetic Energy term for SHM:

But recall;

$\dot{x} =$





## Potential Energy term for SHM



As the spring moves a small distance *dx*, we calculate the work done…….

This is stored as (or produced from) the PE.

The force acting at displacement x, is;

Since this force changes as *x* changes,

• we must …… the work done for all dx increments.

Potential energy term for SHM

When displ. is max., x=A