

School of Physics

**DIAGNOSTIC-REMEDIAL TEST**

PRELUDE TO SIMPLE HARMONIC MOTION

This set of questions is intended to test knowledge of Mechanics and experiences with the behaviour of springs. Although it was intended for use preparatory to a formal study of Simple Harmonic Motion, the test may be used as a diagnostic or remedial instrument at an appropriate point in Introductory Mechanics. If the students have no experience of spring behaviour they should be encouraged to handle a coil spring (or even a rubber band) prior to undertaking this test.

This test is one of a series available on the website of the School of Physics, Monash University, Australia ([www.physics.monash.edu.au/community](http://www.physics.monash.edu.au/community)).

This test is NOT for the purposes of assessment. It is to assist you in locating misconceptions and misunderstandings and generally to assist you in your study of Physics.

Questions are on the left hand (even-numbered) pages. While reading or working on these, **keep the right hand (odd-numbered) answer page covered. DO NOT PEEK AT THE ANSWERS ON THE RIGHT HAND PAGE !**

The test was authored by Emeritus Professor Bill Rachinger who would appreciate any comments or suggestions for improvement. Please contact him at [bill.rachinger@sci.monash.edu.au](mailto:bill.rachinger@sci.monash.edu.au) or

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###### Assumptions about springs

In all cases we consider a coil spring which:

* is assumed massless
* is open-wound (i.e., capable of being extended or compressed
* obeys Hooke’s Law (extension or compression proportional to the applied force)

**QUESTIONS PRELUDE TO S.H.M.**



The spring hangs vertically and a mass m is attached to it when it is unextended (Position O).

The mass is released from rest and it falls in the (uniform) gravitational field of the earth and reaches the lowest point L.

H marks the half-way point between O and L

The following questions relate to the happenings during the journey from O to L

1. The speed of mass m will

A have its maximum value at O and decrease continuously until m comes to rest at L

B increase continually with acceleration g until m comes to a sudden stop at L

C increase at first and then decrease, becoming zero at L

D remain constant until m comes to a sudden stop at L

1. The gravitational force exerted on m during its passage from O to L will

A be zero because m is in free fall and therefore weightless

B be greater at O than at L because the gravitational PE will be greater at O

C remain constant since g is assumed constant

D become zero at L since m comes to rest here

1. The **magnitude** of the acceleration of m will

A be zero at O and increase continually as m falls towards L

B be large at O and at first decrease and then increase again

C remain constant during the whole journey from O to L

D be zero at O, increase to a maximum value and fall to zero at L

1. The force exerted by the spring on m will be

A always directed upwards with its magnitude continuously increasing as m moves from O to L

B directed upwards until m reaches H after which it will be directed downwards

C zero at O and L and having its maximum value at H

D vary in a sinusoidal fashion having its maximum values at O and L.

There are two potential energies associated with this system: the gravitational potential energy PE (grav) usually denoted by the familiar mgh and the potential energy PE (spring) associated with the energy stored in the spring.

5 Choose the correct statement from the following

A PE (grav) and PE (spring) both have their maximum values at O and L

B PE (grav) is a maximum at O and PE (spring) is a maximum at L

C PE (grav) remains constant since the field is uniform and PE (spring) increases as m moves from O to L

D PE (grav) and PE (spring) vary so that their sum remains constant so that the Law of Conservation of Energy is obeyed

1. The Kinetic energy of mass m will

A be a maximum at O and decrease continuously until m comes to rest at O

B increase continually and fall suddenly to zero when m suddenly stops at O

C increase at first and then decrease, becoming zero at L

D remain constant until m comes to a sudden stop at O

1. The total energy of the mass-spring system will

A remain constant as m moves from O to L

B be zero at O, increase to a maximum value and fall to zero at L

C be a maximum at O and decrease continuously until m comes to rest at O

D increase continually and then suddenly fall to zero at L

1. After reaching L the mass m will

A remain there at rest

B move to the equilibrium position H and remain there at rest

C move back to O and again fall back towards L

D move back towards O and overshoot this position to reach a point which is as far above O as L is below it

**answers**

1. C is correct. On release the mass has zero speed (A is incorrect) and will be INSTANTANEOUSLY at rest when it reaches L. It does not stop here (A, B and D are incorrect) but it turns around and starts to move upwards. In the first part of its journey (O to H) it increases its speed --- It accelerates downwards being subjected to the downward gravitational force mg and the (increasing) upward force exerted by the spring At H these forces balance and below H the force exerted by the spring is greater than mg so that now the acceleration is upwards, this having the effect of reducing the speed which becomes zero at L. B is also incorrect since the acceleration is continuously changing as the spring force changes and D is also incorrect since it implies zero acceleration.
2. C is correct. The gravitational field was stated to be uniform (which is normally assumed for any “earth-bound” experiment) and therefore the gravitational force is the same at O and L. B is therefore incorrect. The mass is subject to the gravitational force whether it is at rest (D is incorrect) or in free fall (A is incorrect).
3. B is correct. The magnitude of the resultant force on m, and the associated acceleration, changes continually (C is incorrect) and is greatest at O (A and D are incorrect). As the spring extends the magnitude of the force and the acceleration falls to zero at H after which the upward force (and acceleration) increase in magnitude as the spring extends further.
4. A is correct. The force exerted by the spring is always upwards (B is incorrect) being smallest at O (D is incorrect) and increasing to its maximum value at L (C is incorrect)
5. B is correct. PE (grav) has its minimum value at L and its maximum at O while PE (spring) has its minimum value at O and its maximum at L. (A and C are incorrect). D is incorrect since the Kinetic energy associated with the moving mass must also be taken into account in using the Law of Conservation of Energy.
6. C is correct. Since KE = ½mv, this answer is consistent with the answer to Question 1

7 A is correct. Since no external forces act on this system (earth, mass, spring), no work is done on it and the total energy remains constant. Answer B relates to the Kinetic Energy of the mass and C relates to the gravitational PE. Answer D is a nonsense.

8 C is correct. At L the mass is INSTANTANEOUSLY at rest with KE zero and Total PE (grav & spring) is a maximum. It is subject to a resultant upwards force which causes it to move upwards (A is incorrect). At H, total PE (grav & spring) is a minimum and KE and speed are a maximum (B is incorrect). The mass continues to move upwards with increasing total PE and decreasing KE until it reaches O where KE is zero and it moves downwards again (D is incorrect)

**QUESTIONS**

Recall again the properties of the spring

* It is assumed massless
* is open-wound (ie capable of being extended or compressed)
* and obeys Hooke’s Law (extension or compression proportional to the applied force)



This spring with the mass m attached now lies as shown on a horizontal frictionless table.

The spring is extended by moving the mass 4 cm to the right where it is held at rest and then released

1. The magnitude of the force exerted by the spring on the mass m at the 2cm mark will be

A greater than the force exerted on it at the 4 cm mark

B non-zero and less than the force exerted on it at the 4 cm mark

C the same as the force exerted on it at the 4 cm mark

D zero

1. The **magnitude** of the force exerted by the spring on the mass m at the 0cm mark will be

A greater than the force exerted on it at the 4 cm mark

B non-zero and less than the force exerted on it at the 4 cm mark

C the same as the force exerted on it at the 4 cm mark

D zero

1. The speed of m at the 2cm mark will be

A greater than its speed on reaching the 0 cm mark

B less than its speed on reaching the 0 cm mark

C the same as its speed on reaching the 0 cm mark

1. The **magnitude** of the acceleration of m at the 4 cm mark will be

A greater than its acceleration at the 2 cm mark

B non-zero and less than its acceleration at the 2 cm mark

C the same as its acceleration at the 2 cm mark

D zero

1. The **magnitude** of the acceleration of m on reaching the 0 cm mark will be

A greater than its acceleration at the 2 cm mark

B non-zero and less than its acceleration at the 2 cm mark

C the same as its acceleration at the 2 cm mark

D zero

Consider now the energetics associated with the spring.

Let the work done in extending the spring by 4.00 cm be denoted by W

1. The energy stored in the extended spring is

A W B 2W C ½ W D 0

1. The additional work required to extend the spring by a further 4.00 cm is

A W B 2W C 3W D 4W

16 If a force of 9.80N is required to extend the spring by 4.00 cm the value of W is

A 0.784J B 0.392J C 0.196J D None of these

17 If the spring hangs vertically what mass must be hung on it to extend it by 8.00 cm

A 19.6kg B 9.8kg C 1.00kg D 2.00kg

**ANSWERS**

1. B is correct. The force exerted by the spring is proportional to its extension, being zero at the 0 cm mark and increasing linearly to its maximum value at the 4 cm mark.
2. D is correct. Here the spring is unextended.
3. B is correct. m is accelerated to the left after release from rest at the 4 cm mark, its speed increasing continuously from zero to reach a maximum at the 0 cm mark.

1. A is correct. The acceleration will vary in the same way as the spring force (F=ma) and will have its maximum value at the 4 cm mark.
2. D is correct. At the 0 cm mark the spring is unextended and so the spring force and the acceleration are zero.
3. A is correct. All of the work done is stored as (potential) energy in the spring.
4. C is correct. Remember that the work required to extend the spring by a small amount Δx is F. Δx and F becomes larger as the spring extends (F=kx) so that the total work done varies as the square of x (½) The total work done in extending the spring from the 0 to 8 cm is  4W so that the work done in the further extension from 4.00cm to 8.00cm is 3W.
5. C is correct. The spring constant k = 9.8/4.00 Newton per cm = 245 Nm

W = ½= ½(245)(.0400)= 0.196 J.

17 D is correct. To extend the spring by 8.00 cm requires a force of 19.6 N which is the gravitational force (mg) on a mass of 2.00 kg

**questions**



Two experiments are conducted side by side.

Experiment I is the same as that considered earlier, a spring with a mass m attached set up on a frictionless horizontal table.

Experiment II is the same except that the attached mass is 2m

As in the earlier experiments the springs are extended moving the masses 4 cm

to the right where they are held at rest and then released

1. At the 2 cm mark the acceleration of 2m at the 2 cm mark will be

A twice the acceleration of m at the 2 cm mark

B one-half of the acceleration of m at the 2 cm mark

C the same as the acceleration of m at the 2 cm mark

D None of these

1. When both the masses are at the 2 cm mark the total energy of system II will be

A twice the total energy of system I

B one-half of the total energy of system I

C the same as the total energy of system I

D None of these

1. At the 2 cm mark the speed of 2m at the 2 cm mark will be

A twice the speed of m at the 2 cm mark

B one-half of the speed of m at the 2 cm mark

C the same as the speed of m at the 2 cm mark

D None of these

1. At the 2 cm mark the Kinetic Energy of 2m at the 2 cm mark will be

A twice the Kinetic Energy of m at the 2 cm mark

B one-half of the Kinetic Energy of m at the 2 cm mark

C the same as the Kinetic Energy of m at the 2 cm mark

D None of these

**ANSWERS**

1. B is correct. Since the springs are identical the forces exerted by them at the 2 cm mark will be the same. The acceleration of the mass 2m will therefore be one half of that of mass m in accord with Newton’s Law F = ma
2. C is correct. The total energy of both systems will be the same (equal to the energy stored in the spring at the 4cm mark) and this total remains unchanged during the experiment
3. D is correct. At the 2 cm mark the total energy, the energy stored in the spring and hence the kinetic energy of the masses will be the same in each experiment. Since KE = ½mv, the speed of mass m =  (speed of 2m)
4. C is correct. As implied in the previous question this follows from the Law of Conservation of Energy

**QUESTIONS**



Now consider another pair of experiments. Experiment I is the same as before and in Experiment II the mass m is attached to a stiffer spring in fact one for which the force required to extend it by 4 cm is twice that required for the spring in Experiment I

Again the springs are extended moving the masses 4 cm to the right where they are held at rest and then released

22 At the 2 cm mark the acceleration of the mass m in Experiment I will be

A twice the acceleration of the mass m at the 2 cm mark in Experiment II

B one-half of the acceleration of the mass m at the 2 cm mark in Experiment II

C the same as the acceleration of m at the 2 cm mark in Experiment II

D none of these

23 When both the masses are at the 2 cm mark the total energy of system II will be

A twice the total energy of system I

B one-half of the total energy of system I

C the same as the total energy of system I

D None of these

24 At the 0 cm mark the speed of the mass m in Experiment I will be

A twice the speed of the mass m at the 0 cm mark in Experiment II

B one-half of the speed of the mass m at the 0 cm mark in Experiment II

C the same as the speed of m at the 0 cm mark in Experiment II

D none of these

25 At the 0 cm mark the Kinetic Energy of the mass m in Experiment I will be

A twice the Kinetic Energy of the mass m at the 0 cm mark in Experiment II

B one-half of the Kinetic Energy of m at the 0 cm mark in Experiment II

C the same as the Kinetic Energy of m at the 0 cm mark in Experiment II

D none of these



Consider the situation where the origin corresponds to the unstretched position and the downward direction is taken as positive

When the mass m is at position x the forces on it are

the gravitational force + mg

and the spring force –kx

giving a net force –kx + mg

Newton’s law is then F = ma = –kx + mg

1. A consequence of this relation is that

A the oscillations will be only approximately simple harmonic since SHM results from a situation where the restoring force F is proportional to the displacement

B the oscillations will be simple harmonic only for small amplitudes of oscillation

C the oscillations will not be symmetrical but will be “lopsided” (because of the uni-directional mg gravity term”)

D the oscillations will be truly simple harmonic as can be seen by change of origin and reformulating Newton’s Law to the standard form of F = ma = –ky

**ANSWERS**

22 A is correct. The force exerted by the stiffer spring will be twice that exerted by the weaker spring and so it will cause twice the acceleration of mass m

1. A is correct. The total energy of each of the systems is equal to the energy (½) stored in the spring extended to the 4 cm mark. The spring constant k for experiment II is twice that for experiment I so that the total energy for experiment II is at all times twice that for experiment I
2. D is correct . At the 0 cm mark, the energy stored in the springs is zero and so the K E of system II will be twice that of the system I. Since KE=½mv, the speed of mass m in experiment II will be equal to  (speed of mass m in experiment I)
3. B is correct. See explanation to previous question
4. D is correct. Newton’s Law can be written as 