Physics 1004: Summer 2012 Midterm Exam Solutions

Chapter 3

1

Two vectors **a** and **b** are added together to form a vector **c**. The relationship between the magnitudes of the vectors is given by $a + b = c$. Which **one** of the following statements concerning these vectors is true?

a) **a** and **b** must point in the same direction.

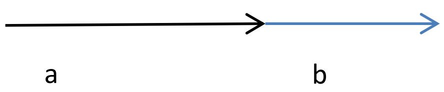
b) **a** and **b** must be displacements.

c) **a** and **b** must be at right angles to each other.

d) **a** and **b** must point in opposite directions.

e) **a** and **b** must have equal lengths.

Answer (a): They must point in the same direction.



2

What is the scalar Product **A.B,** if **A** = 1.1**i** +2.0**j** and **B** = 1.0**i** – 1.0**j**?

a) zero

b) –0.9

c) 0.5**i** -1.0**j**

d) 3.1

e) **0**.1**i** +1.0**j**

Answer (b)

A.B = $a_x b_x + a_y b_y + a_z b_z$ = (1.1*1.0+(2.0*-1.0) = -0.9

Answers (c) and (e) can be ruled out immediately, as they are vectors.

3

What is the vector product, **A×B** , if **A** = 2.2.**i** + 3.4**j** and **B** = 4.4**i** +2.0 **j**

a) zero

b) 6.6**i** -8.6**k**

c) 2.0**k**

d) -10.6**k**

e) 8.3

Answer (d) The formula is on the formula sheet!

$$\vec{c} = \vec{a} \times \vec{b} = (a_y b_z - b_y a_z)\mathbf{i} + (a_z b_x - b_z a_x)\mathbf{j} + (a_x b_y - b_x a_y)\mathbf{k}$$

As the two vectors have components only in the **i** and **j** directions, the answer must be in the k direction

Chapter 7

4

Ignoring friction effects, the amount of energy required to accelerate a car from rest to a speed *v* is *E*. The energy is delivered to the car by burning gasoline. What **additional** amount of energy is required to accelerate the car to a speed 2*v*?

a) 0.5*E*

b) *E*

c) 2*E*

d) 3*E*

e) 4*E*

Answer (d)

Use the work energy theorem. The work done is equal to the amount of energy needed

$$E = W = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = \frac{1}{2}mv^2$$

Now we change from speed v to speed 2v

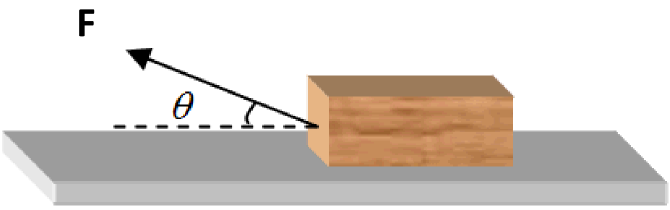
$$E_{additional} = K_f - K_i = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}m(2v)^2 - \frac{1}{2}mv^2$$

$$E_{additional} = \frac{1}{2}m(4v^2 - v^2) = \frac{1}{2}3mv^2 = 3E$$

The term "additional" probably confused people, so I dropped this question, as the average was very low (less than would be obtained by guessing!)

5

A block is in contact with a rough surface as shown in the drawing. The block has a rope attached to one side. Someone pulls the rope with a force F, which is represented by the vector in the drawing. The force F is directed at an angle θ with respect to the horizontal direction. The magnitude of F is equal to two times the magnitude of the frictional force, which is designated f. For what value of θ is the net work on the block equal to zero joules?



a) 0°

b) 30°

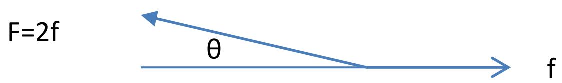
c) 45°

d) 60°

e) Net work will be done in the object for all values of θ.

Answer (d)

Free body diagram:



If the net work is to be zero, then the net force must be zero (W = F.d)

Take components of the force F in the x direction and assume the positive direction is to the right:

$$F_x = -F\cos\theta$$

$$F_{net} = f - F\cos\theta = f - 2f\cos\theta$$

If the net force is zero

$$0 = f - 2f\cos\theta$$
$$f = 2f\cos\theta$$
$$\cos\theta = \frac{1}{2}$$

and hence θ= 60°

6

Determine the amount of work done in firing a 2.0-kg projectile with an initial speed of 50 m/s. Neglect any effects due to air resistance.

a) 900 J

b) 1600 J

c) 2500 J

d) 4900 J

e) This cannot be determined without knowing the launch angle.

Answer (c)

Use the Work energy theorem.

Calculate the final kinetic energy. The initial kinetic energy is zero

$$W = K_f - K_i = \frac{1}{2}mv_f^2 - 0 = \frac{1}{2}mv^2 = \frac{1}{2}\times(2.0\text{ kg})\times(50\text{ m/s})^2 = 2500J$$

Chapter 8

7

A mountain climber pulls a supply pack up the side of a mountain at constant speed. Which one of the following statements concerning this situation is false?

a) The net work done by all the forces acting on the pack is zero joules.

b) The work done on the pack by the normal force of the mountain is zero joules.

c) The work done on the pack by gravity is zero joules.

d) The gravitational potential energy of the pack is increasing.

e) The climber does "positive" work in pulling the pack up the mountain

Answer (c)

a) The net work done by all the forces acting on the pack is zero joules. **True, moving at constant speed, so no acceleration and hence no net force.**

b) The work done on the pack by the normal force of the mountain is zero joules. **True, the normal force is perpendicular to the displacement, and so does no work.**

c) The work done on the pack by gravity is zero joules. **Work is done by gravity, as the climber moves upwards in the Earth's gravitational field. False**

d) The gravitational potential energy of the pack is increasing. **True, the pack gets higher, so the GPE increases.**

e) The climber does "positive" work in pulling the pack up the mountain. **True, the force and the displacement are in the same direction.**

8

After an ice storm, ice falls from one of the top floors of a 65-story building. The ice falls freely under the influence of gravity. Which one of the following statements concerning this situation is **true**? Ignore any effects due to non-conservative forces.

a) The kinetic energy of the ice increases by equal amounts for equal distances.

TRUE; use the work-energy theorem again $W = F.d = \Delta K$ **The change in kinetc energy is proportional to distance d**

b) The kinetic energy of the ice increases by equal amounts for equal times.

Can't be true since $d = -\frac{1}{2}gt^2$

c) The potential energy of the ices decreases by equal amounts for equal times.

If (b) isn't true then neither is (c) because as KE increases, PE decreases by the same amount

d) The total energy of the block increases by equal amounts over equal distances.

The total energy remains constant, ignoring friction etc.

e) As the block falls, the net work done by all of the forces acting on the ice is zero joules.

Net work must be done, as the block is accelerating

9

A dam blocks the passage of a river and generates electricity. Approximately 57 000 kg of water fall each second, through a height of 19 m. If one half of the gravitational potential energy of the water were converted to electrical energy, how much power would be generated?

a) 2.7×10^6 W

b) 5.3×10^6 W

c) 1.1×10^7 W

d) 1.3×10^8 W

e) 2.7×10^8 W

Answer (b)

Consider the change in potential energy in 1 second (as power is energy/sec)

$$\Delta U = mg\Delta y = 57000\,\mathrm{kg} \times 9.8\,\mathrm{m/s}^2 \times 19m = 1.1 \times 10^7\ \mathrm{J}$$

There is only 50% efficiency

$$\frac{\Delta U}{1s} = 0.5 \times \frac{1.1 \times 10^7\ \mathrm{J}}{1s} = 5.3 \times 10^6\ \mathrm{W}$$

Chapter 15

10

15.2.2. A steel ball is hung from a vertical ideal spring where it oscillates in simple harmonic motion with an amplitude of 0.157 m and an angular frequency of π rad/s. Which one of the following expressions represents the acceleration, in m/s^2, of the ball as a function of time?

a) $a = -1.55 \cos(\pi t)$

b) $a = -1.55 \cos^2(\pi t)$

c) $a = -0.157 \cos(\pi t)$

d) $a = -0.493 \cos^2(\pi t)$

e) $a = -0.493 \cos(\pi t)$

Answer (A)

Position of the ball would be given by $y = y_m \cos(\omega t) = (0.157\text{ m})\cos(\pi t)$

Acceleration is given by differentiating the position function twice with respect to time:

$$a = \frac{d^2 y}{dt^2} = -\pi^2 (0.157\text{ m})\cos(\pi t) = -1.55\text{ m/s}^2 \cos(\pi t)$$

11

15.3.5. An ideal spring is hung vertically from a device that displays the force exerted on it. A heavy object is then hung from the spring and the display on the device reads *W*, the weight of the spring plus the weight of the object, as both sit at rest. The object is then pulled downward a small distance and released. The object then moves in simple harmonic motion. What is the behavior of the display on the device as the object moves?

a) The force remains constant while the object oscillates.

b) The force varies between –*W* and +*W* while the object oscillates.

c) The force varies between a value near zero newtons and *W* while the object oscillates.

d) The force varies between a value near zero newtons and 2*W* while the object oscillates.

e) The force varies between *W* and 2*W* while the object oscillates.

$$F = -m\omega^2 x_m \cos(\omega t) = -m\frac{k}{m} x_m \cos(\omega t) = -kx_m \cos(\omega t) = -W\cos(\omega t)$$

At the extreme values for cos, F = ±W=0

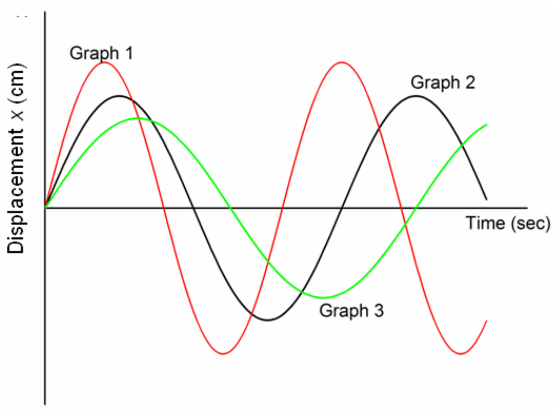
The force only varies between +W and –W, it never reaches a value of 2W.

The display registers values between 0 and W (we do not know what the behavior of the display is when W is negative!)

Answer (c)

12

The graph represents the oscillatory motion of three different springs with identical masses attached to each. Which of these springs has the smallest spring constant?



a) Graph 1

b) Graph 2

c) Graph 3

d) Both 2 and 3 are smallest and equal

e) All three have the same spring constant.

Answer (C)

The periods are different for each of the springs. Oscillation 1 has the shortest period (highest frequency) , and Oscillation 3 has the longest period (lowest frequency). Since

$$\omega = 2\pi f = \sqrt{\frac{k}{m}}$$

Higher frequency means higher k if the mass remains constant

13

A block is attached to the end of a horizontal ideal spring and rests on a frictionless surface. The other end of the spring is attached to a wall. The block is pulled away from the spring's unstrained position by a distance x_0 and given an initial speed of v_0 as it is released. Which one of the following parameters must be known in addition to x_0 and v_0 to determine the amplitude of the subsequent simple harmonic motion?

a) period

b) spring constant

c) mass of the block

d) the direction of the initial velocity of the block

e) the direction of the initial displacement of the block

Answer (A)

The motion of the particle is given by:

$$x = x_m \cos(\omega t + \phi)$$
$$v = -v_m \sin(\omega t + \phi)$$

At t= 0

$$x_0 = x_m \cos(\phi)$$
$$v_0 = -x_m \omega \sin(\phi)$$

We can't get a solution without knowing a value for ω

Chapter 16

14

A transverse wave is traveling along a Slinky. The drawing below represents a section of the Slinky at one instant in time. The direction the wave is travelling is from left to right. Two segments are labeled on the Slinky. At the instant shown, which of the following statements correctly describes the motion of the particles that compose the Slinky in segments A and B?

a) In segment A the particles are moving downward and in segment B the particles are moving upward.

b) In segment A the particles are moving upward and in segment B the particles are moving upward.

c) In segment A the particles are moving downward and in segment B the particles are moving downward.

d) In segment A the particles are moving upward and in segment B the particles are moving downward.

e) In segment A the particles are moving toward the left and in segment B the particles are moving toward the right.

Remember that in this wave (a transverse wave) the particles oscillate vertically, so (e) must be incorrect. The particles in the positive sections of the wave must be moving in opposite directions to the ones in the negative sections, which cuts out (b) and (c).

Now look at the wave equation:

$$y(x,t) = y_m \sin(kx - \omega t);$$

Differentiate it to with respect to x (not t!)

$$\frac{dy}{dx} = k y_m \cos(kx - \omega t);$$

The slope between points A and B is negative, so

$$\cos(kx - \omega t) < 0$$

Now differentiate again to find the speed of the particles:

$$\frac{\partial y(x,t)}{\partial t} = -\omega y_m \cos(kx - \omega t);$$

Now we know that the cosine term has to be negative, so the velocity of the particles must be positive, and so the particles are moving upwards. This means option (d) is correct.

Answer (D)

That's a very difficult question!

15

A radio station broadcasts its radio signal at a frequency of 101.5 MHz. The signals travel radially outward from a tower at the speed of light. Which one of the following equations represents this wave if *t* is expressed in seconds and *x* is expressed in meters?

a) *y* = 150 sin[(6.377 × 108)*t* – (2.123)*x*]

b) *y* = 150 sin[(637.7)*t* – (2.961)*x*]

c) *y* = 150 sin[(6.283 × 106)*t* – (2.961 × 103)*x*]

d) *y* = 150 sin[(101.5 × 106)*t* – (2.961)*x*]

e) *y* = 150 sin[(101.5 × 106)*t* – (2.123)*x*]

Answer (A)

This one was messed up because the superscripts did not print correctly!

I will not mark it.

a) $y = 150 \sin[(6.377 \times 10^8)t - (2.123)x]$

b) $y = 150 \sin[(637.7)t - (2.961)x]$

c) $y = 150 \sin[(6.283 \times 10^6)t - (2.961 \times 10^3)x]$

d) $y = 150 \sin[(101.5 \times 10^6)t - (2.961)x]$

e) $y = 150 \sin[(101.5 \times 10^6)t - (2.123)x]$

$$y = y_m \sin(kx - \omega t)$$

k is the wavenumber.

$$k = \frac{2\pi}{\lambda}$$

$$v = f\lambda = c$$

$$\lambda = \frac{c}{f} = \frac{3\times 10^{8}\ \text{m/s}}{101.5\times 10^{6}\ \text{Hz}} = 2.955m$$

$$k = \frac{2\pi}{\lambda} = 2.12\ \text{m}^{-1}$$

This eliminates everything except (a) and (e)

$$\omega = 2\pi f = 2\pi \times 101.5\times 10^{6}\, Hz = 6.47\times 10^{10}\, s^{-1}$$

(a) was the closest, but still not correct!

16

The tension of a guitar string is increased by a factor of 4. How does the speed of a wave on the string increase, if at all?

a) The speed of a wave is reduced to one-fourth the value it had before the increase in tension.

b) The speed of a wave is reduced to one-half the value it had before the increase in tension.

c) The speed of a wave remains the same as before the increase in tension.

d) The speed of a wave is increased to two times the value it had before the increase in tension.

e) The speed of a wave is increased to four times the value it had before the increase in tension.

Answer (D)

Use the formula

$$v = \sqrt{\frac{\tau}{\mu}};$$

Create two instances of the speed

$$v_1 = \sqrt{\frac{\tau_1}{\mu}}$$

$$v_2 = \sqrt{\frac{4\tau_1}{\mu}}$$

Take the ratio

$$\frac{v_2}{v_1} = \frac{\sqrt{\frac{4\tau_1}{\mu}}}{\sqrt{\frac{\tau_1}{\mu}}} = \frac{\sqrt{4\tau_1}}{\sqrt{\tau_1}} = \sqrt{4} = 2$$

After increasing the tension by a factor of 4, the speed increases by a factor of 2: answer (D)

17

16.8.1. A wave is described by the equation *y* = 0.020 sin (3.0*x* – 6.0*t*), where the distances are in meters and time is measured in seconds. Using the wave equation, determine the speed of this wave?

a) 0.50 m/s

b) 0.75 m/s

c) 1.0 m/s

d) 2.0 m/s

e) 4.0 m/s

Answer (D)

The speed of the wave is given by

$$v = f\lambda = \frac{\lambda}{T} = \frac{\omega}{k};$$

The wave function is of form

$$y(x,t) = y_m \sin(kx - \omega t)$$

So in the given equation, k = 3.0 m^{-1}, and ω = 6.0 s^{-1}

Hence:

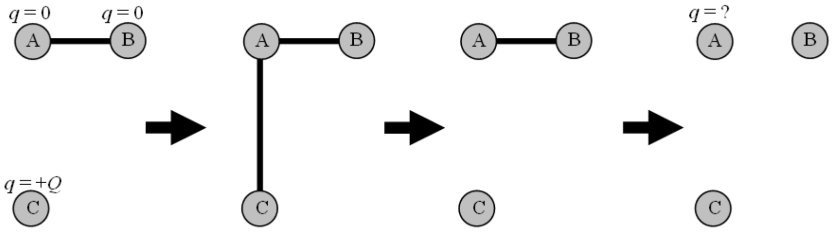
$$v = \frac{\omega}{k} = \frac{6.0s^{=1}}{3.0m^{-1}} = 2.0\text{m/s}$$

Answer (D)

Chapter 21

18

21.3.6. Consider the conducting spheres labeled A, B, and C shown in the drawing. The spheres are initially charged as shown on the left, then wires are connected and disconnected in a sequence shown moving toward the right. What is the final charge on sphere A at the end of the sequence?



a) $+Q$

b) $+Q/2$

c) $+Q/3$

d) $+Q/4$

e) $+Q/8$

Answer (D)

In the first step, q/2 is transferred to sphere B, and none to sphere A. In the next step, the charge on B is shared between A and B, so q/4 ends up on sphere A. Answer (D)

19

21.4.12. What is the magnitude of the electrostatic force that two electrons separated by 1.0 nm exert on each other?

a) 1.3×10^{-16} N

b) 2.3×10^{-10} N

c) 4.6×10^{-14} N

d) 5.2×10^{-6} N

e) 7.8×10^{-4} N

Answer (B)

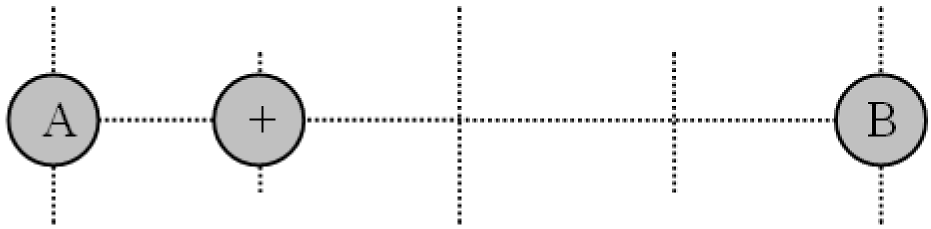
From the formula sheet:

$$\vec{F} = k\frac{q_1q_2}{r^2}\hat{r};$$

$$F = \frac{q_1q_2}{4\pi\varepsilon_0 r^2} = \frac{(1.6\times10^{-19}C)^2}{4\pi\varepsilon_0(1.0\times10^{-9}m)^2} = 2.3\times10^{-10}N$$

Answer (B)

As shown in the drawing, a positively charged particle remains stationary between particles A and B. The positively charged particle is one-quarter of the distance between the two other particles, as shown.



What can be concluded from the situation?

a) The charge on A must be four times as large as the charge on B.

b) The charge on A must be sixteen times as large as the charge on B.

c) The charge on A must be one-half as large as the charge on B.

d) The charge on A must be one-fourth as large as the charge on B.

e) The charge on A must be one-sixteenth as large as the charge on B.

I took this question directly from a question collection (and should have checked that it was correct!)

Given answer from the question bank is (e)

Force on the charge q due to A is

$$F_A = k\frac{q_Aq}{r_a^2}\mathbf{i}$$

Force on the charge q due to B is

$F_B = -k\frac{q_Bq}{r_b^2}\mathbf{i}$ **(in the opposite direction to the force from A)**

If the particle is stationary, then the net force must be zero.

$$F_A + F_B = k\frac{q_A q}{r_a^2} - k\frac{q_B q}{r_b^2} = 0$$

$$\frac{q_A}{r_a^2} = \frac{q_B}{r_b^2}$$

This is where the given solution goes wrong

$$\frac{q_A}{r_a^2} = \frac{q_B}{9r_a^2}$$

$$9 = \frac{q_B}{q_A}$$

Q_B is 9 times bigger than Q_A

Obviously this question will not be marked either.

21

21.4.6. A charged particle is located at the center of a uniformly charged hollow sphere. What is the net electrostatic force on the charged particle?

a) The net electrostatic force on the particle will be zero newtons because all of the charges on the sphere are either repelled or attracted to the particle, so they exert no force on it.

b) The net electrostatic force on the particle will be zero newtons because the vector sum of all of the forces on it due to the charges on the sphere is zero, so they exert no force on it.

c) The net electrostatic force on the particle will be the least at the center, but its magnitude will be greater than zero newtons.

d) The net electrostatic force on the particle will be positive if the particle and sphere have opposite signs and negative if they have the same sign.

e) The net electrostatic force on the particle will be negative if the particle and sphere have opposite signs and positive if they have the same sign.

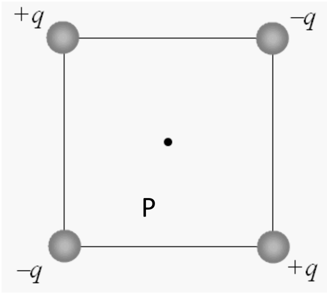
Answer (B)

All the forces sum to zero by symmetry.

Chapter 22

22

Four charges are located on the corners of a square as shown in the drawing. What is the direction of the net electric field at the point labeled P?



a) Towards the upper left corner of the square

b) Towards the middle of the right side of the square

c) Towards the middle of the bottom side of the square

d) Towards the lower right corner of the square

e) There is no direction. The electric field at P is zero N/C.

Answer (E)

The electric field sums to zero. The fields from the two +q charges on one diagonal cancel each other out. The fields from the two _q charges on the other diagonal also cancel out.

23

A negatively-charged object is released from rest in a region containing a uniform electric field. Which one of the following statements concerning the subsequent motion of the object is correct?

a) The object will remain motionless.
b) The object will experience a constant acceleration and move in the direction of the electric field.
c) The object will experience a constant acceleration and move in the direction opposite that of the electric field.
d) The object will accelerate to some constant speed and move in the direction of the electric field.
e) The object will accelerate to some constant speed and move in the direction opposite that of the electric field.

Answer (C)

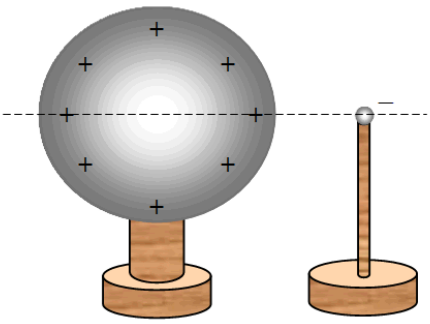
The uniform electric field exerts a constant force on a charged particle. From the definition

$$\mathbf{F} = q\mathbf{E}$$

the force on a negatively charged particle must be in the opposite direction to the field

24

The drawing shows a hollow conducting sphere with a net positive charge uniformly distributed over its surface. A small negatively-charged object is then brought near the sphere as shown. What is the direction of the electric field at the centre of the sphere?



a) There is no electric field at the centre of the sphere.

b) to the left

c) to the right

d) upward

e) downward

The external negative charge will tend to attract the positive charge towards it. The uniform charge distribution on the sphere will change to having more charge on the side nearer to the negative charge. Hence there will be a net electric field inside the sphere pointing away from the region of higher positive charge.

Answer B

25

If a proton is accelerated in a 2.0×10^{4} N/C electric field, what is the magnitude of the acceleration? The mass of a proton is 1.6726×10^{-27} kg and the charge on the proton (+e) is $+1.602\times10\text{-}^{19}$ C.

a) 1.2×10^{-2} m/s
b) 2.8×10^{2} m/s
c) 5.3×10^{7} m/s
d) 8.4×10^{10} m/s
e) 1.9×10^{12} m/s

Answer (e)

The acceleration can be related to the force on the proton by Newton's Second Law.

$$F = ma$$

The force on a charged particle in an electric field is given by

$$F = qE$$

So, putting these equations together

$$m_p a = +eE$$

$$a = \frac{+eE}{m_p} = \frac{(1.602\times10^{-19}C)(2.0\times10^{4}\,N/C)}{1.6726\times10^{-27}\,\mathrm{kg}} = 1.9\times10^{12}\,\mathrm{m/s\ to\ 2\ s.f.}$$

Answer (E)