I. An airplane is heading due east and is moving at a speed of 370 km/h relative to the air. The wind is blowing 45.0 degrees north of west at a speed of 93.0 km/h.

a) Represent the airplane’s and wind’s velocities by:
   i. Making a sketch of the airplane and include the velocity vectors and coordinate axes.
   ii. Writing an expression for the velocities using \( \mathbf{i} \) and \( \mathbf{j} \) notation.

\[
\vec{V}_a = \text{______________________________} \\
\vec{V}_w = \text{______________________________} \\
\]

b) Find the speed (in km/h) of the airplane relative to the ground.

c) If the airplane is at the origin at the time \( t=0 \), what will the coordinates of the plane be at the time \( t=10 \) mins?
II. In each case below, an arrow has been shot at a speed of 8 m/s from the top of a building either up at a 45° angle, straight out horizontally, or down at a 45° angle. All arrows are identical and are shot at the same speed, and the heights of the buildings and the direction the arrows are shot are given. Ignore air resistance.

a) In which case(s) does the arrow have the greatest speed just before hitting the ground? Explain your reasoning algebraically.

b) In which case(s) is the arrow in the air for the longest amount of time before hitting the ground? Explain your reasoning.

c) Determine the speed of the arrows just before hitting the ground for the case(s) you selected in parts a) and b).
III. In each case below a block has been pushed against a spring on a frictionless horizontal surface, compressing the spring. The blocks were then released from rest, and at the instant shown they are just about to lose contact with the end of the spring that had been compressed. The mass of the blocks, the force constant of the springs, and the amount the springs were initially compressed are given for each system.

![Diagram of spring systems](image)

a) In which case(s) does the block have the greatest kinetic energy in the positions shown?

b) Determine the speed of the block(s) for the case(s) in part a).

c) If the fastest block(s) from part b) goes over a rough patch where the coefficient of kinetic friction between the block and the surface is 0.2, how far will the block(s) slide before coming to a stop?
4. The graph at the right describes the motion of two children, Ariel and Byron, who are moving along a straight hallway. The vertical axis is position. Which of the following statements are TRUE?

I. Ariel and Byron have the same acceleration for at least one instant during their motion.

II. Ariel and Byron have the same velocity simultaneously at one (and only one) instant.

III. Ariel and Byron are at the same position at the same time more than once.

a) I
b) II
c) III
d) I & II
e) I & III
f) II & III
g) I, II, & III

5. The motion of a particle is described by

\[ x(t) = (4 - 12t + t^3) \text{ meters} \]

Which one of the following statements is TRUE?

a) There is a constant net force acting in the positive direction.
b) The particle starts from rest.
c) The acceleration of the particle at t=1s is 6 m/s².
d) The particle always moves in the negative direction.
e) Between t=0s and t=1s the particle speeds up.

6. The horizontal surface on which the blocks slide (shown below) is frictionless. If \( F = 6.0 \text{ N} \) and \( M = 1.0 \text{ kg} \), which is closest to the tension in the string connecting the two blocks?

a) 5 N
b) 16 N
c) 12 N
d) 10 N
e) 7.5 N
7. A 1.6-kg block is sliding down the 30 degree ramp at a constant speed of 3.5 m/s. Which is closest to the value of the frictional force?

   a) 8 N
   b) 18 N
   c) 5.6 N
   d) 10 N
   e) You need to know coefficient of static friction in order to solve this.

8. Moon A orbits planet A and Moon B orbits planet B, as shown. The radiuses of the orbits are the same, and equal to $d$. It takes Moon A three times as long to orbit its planet as it takes Moon B to orbit Planet B. How do the masses of the planets compare?

   a) $M_A = M_B$
   b) $M_A = 3M_B$
   c) $M_A = \frac{1}{3}M_B$
   d) $M_A = 9M_B$
   e) $M_A = \frac{1}{9}M_B$

9. Two boxes are tied together by a string and are sitting at rest in the middle of a large frictionless surface. Between the two boxes is a massless compressed spring. The string tying the two boxes together is cut suddenly and the spring expands explosively, pushing the boxes apart. The box on the left has four times the mass of the box on the right. Express the speed of the box on the left in terms of the speed of the box on the right at the instant (after the string is cut) that the boxes lose contact with the spring.

   a) $v_{\text{left}} = v_{\text{right}}$
   b) $v_{\text{left}} = 2v_{\text{right}}$
   c) $v_{\text{left}} = 4v_{\text{right}}$
   d) $v_{\text{left}} = \frac{1}{2}v_{\text{right}}$
   e) $v_{\text{left}} = \frac{1}{4}v_{\text{right}}$
10. In Case A shown below, a metal bullet penetrates a wooden block. In Case B, a rubber bullet with the same initial speed and mass bounces off of an identical wooden block. Which of the following statements best describes the speed of the wooden block after the collision?
   
a) The block will move faster in case A.
   b) The block will move faster in case B.
   c) The block will move at the same speed in both cases because the bullet’s initial momentum is the same in both cases.
   d) It is impossible to compare without knowing the relative mass of the bullet and block.
   e) It is impossible to compare without knowing the initial speed of the bullet.

11. Two identical blocks are released from rest of the same height. Block A slides down a steeper and shorter ramp than Block B. The coefficient of friction between the block and the ramp is the same for both ramps. The blocks reach the same final height indicated by the lower dashed line. In which case is the amount of negative work done by the frictional force greater, for Block A or for Block B? Pick the BEST answer and explanation from below.
   a) Block A because although the distance is less the angle of incline is larger.
   b) Block A because it moves faster so it heats up more.
   c) Block B because the distance is greater.
   d) Block B because the distance is greater and the angle of incline is smaller.
   e) The amount of work done by friction is the same for both blocks because the change in height is the same.

12. A circus performer on a skateboard is launched by a spring initially compressed a distance $\Delta x$ as shown below. His speed on the horizontal portion of the ramp is $v$, and he rises to a height $H$ after he leaves the ramp. He then conducts a second launch with the spring initially compressed distance $2.5*\Delta x$. In this case how high will he go up?
   
a) $2.5H$
   b) $(2.5)^2H$
   c) $\sqrt{2.5}H$
   d) $\frac{1}{2}(2.5)^2H$
   e) $\frac{1}{2}\sqrt{2.5}H$
13. Two blocks are placed on separate frictionless ramps that make an angle of 30 degrees with the horizontal. The blocks are held against a spring that is compressed one-half meter. (The mass of the blocks and force constant of the springs are given for each system.) The blocks are then released from rest, and the compressed spring causes the blocks to accelerate up the ramp while in contact with the blocks. At the instant shown, the blocks are just about to lose contact with the end of the spring.

Which of the following values is closest to the farthest up the ramp either block will travel before stopping momentarily?

a) 3.1 m  

b) 6.3 m  

c) 1.2 m  

d) 1.6 m  

e) 8.2 m

14. A 1.6 kg block is launched horizontally on a frictionless surface by a spring of force constant \( k = 10^4 \) N/m which was compressed a distance of 10 cm. After it is launched the block collides with a 40 g bullet traveling in the opposite direction. The bullet remains in the block and causes the block to come to rest. What was the speed of the bullet just before it hit the block?

a) 160 m/s  

b) 250 m/s  

c) 50 m/s  

d) 320 m/s  

e) 80 m/s