# Teacher notes
# Topic A

## 20 Conceptual questions in Mechanics

**1.** An object moves with negative acceleration along a straight line. What is correct about this motion?

**A** The speed of the object is decreasing

**B** The speed of the object is increasing

**C** The velocity is increasing

**D** The velocity is decreasing

**2.** An object moves with positive acceleration along a straight line. What is correct about the speed in this motion?

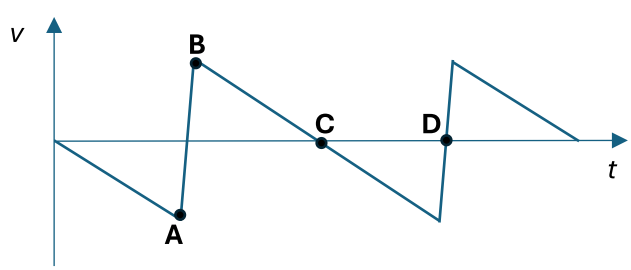
**A** It is always decreasing

**B** It is always increasing

**C** It is increasing if the velocity is positive

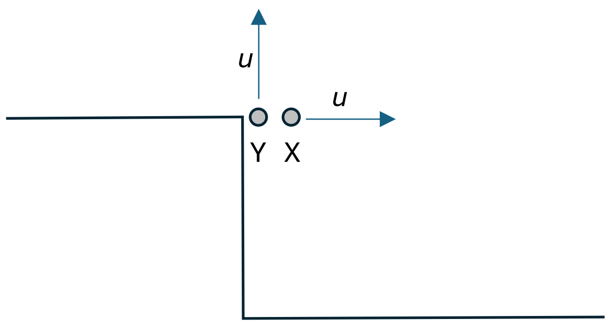
**D** It is increasing if the velocity is negative

**3.** A ball is dropped vertically from rest onto a horizontal surface. The ball bounces without loss of energy. The graph shows the variation with time of the velocity of the ball.




At which time is the ball at its maximum height?

**4.** X and Y are identical bodies. X is thrown horizontally from some height above ground and Y is thrown vertically upwards with the same speed as X and from the same height.




Which body lands with the greatest speed and which takes the longest time to land? Air resistance is negligible.

| | Lands with greatest speed | Takes the longest time to land |
|---|---|---|
| **A** | X | Y |
| **B** | Y | X |
| **C** | It is a tie | Y |
| **D** | It is a tie | X |

**5.** Two identical objects are dropped from rest from a large height in vacuum. One of the objects is dropped some time after the other. What is correct about the distance separating the two bodies when both are moving?

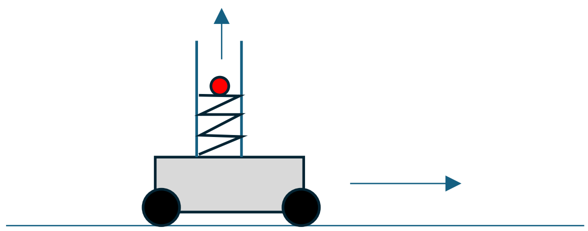
**A** It is constant

**B** It is increasing at a constant rate

**C** It is increasing at a rate proportional to time

**D** It is increasing at a rate proportional to time squared

**6.** A toy spring cannon is attached to a cart that moves with constant speed on a straight line. The canon launches a ball upwards. Where will the ball land? Air resistance is negligible.



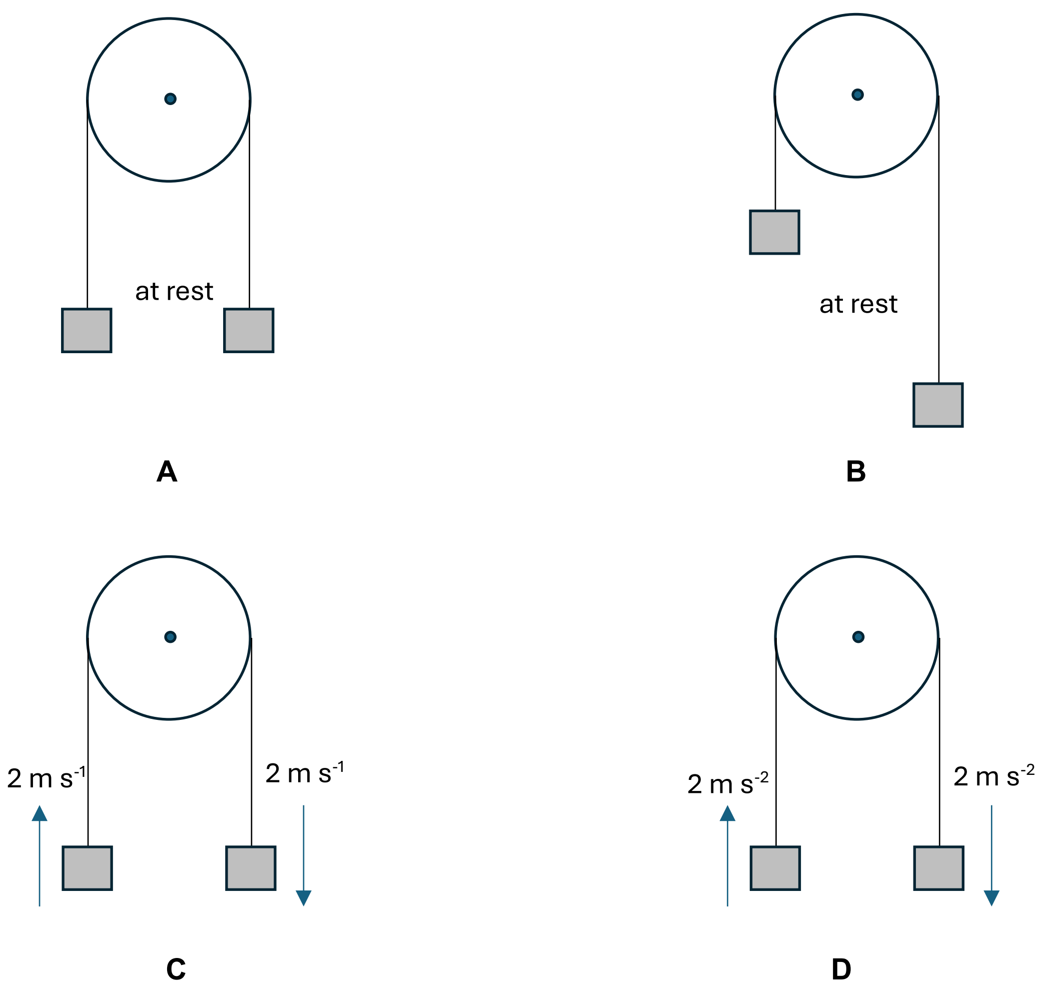
**A** Behind the cannon

**B** Inside the cannon

**C** In front of the cannon

**D** Any of the above depending on the speed of the cart

**7.** Two identical blocks are tied together with a string that goes over a frictionless pulley. Which diagram is **not** a possible state of the system?



**8.** A ball is launched vertically upwards by a toy spring gun. What is correct about the forces on the ball while it is in the air? Air resistance is negligible.

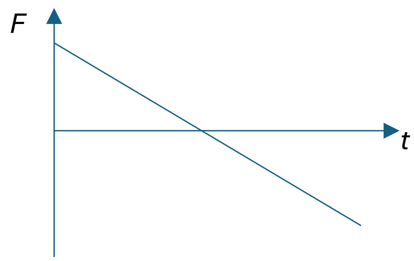
**A** On the way up the upward force is greater than the weight

**B** On the way up the upward force is decreasing

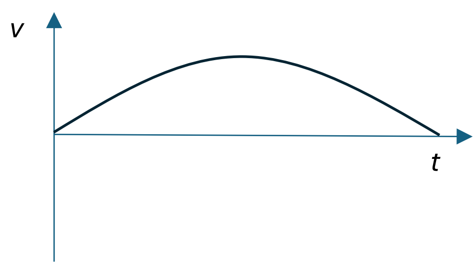
**C** At the highest point the net force is zero

**D** At the highest point the net force equals the weight

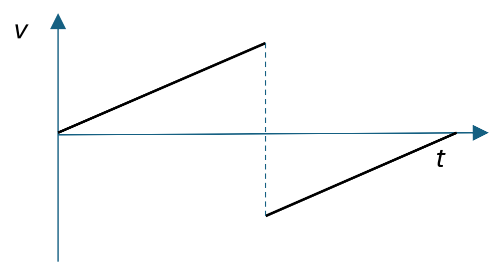
**9.** The diagram shows the variation with time of the net force acting on a body initially at rest.



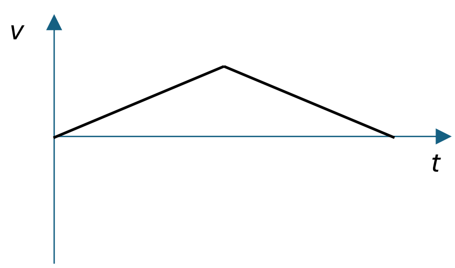

Which graph shows the variation with time of the velocity of the body?



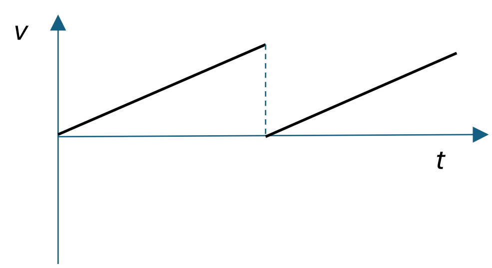

**A**




**B**

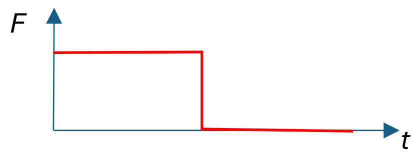



**C**

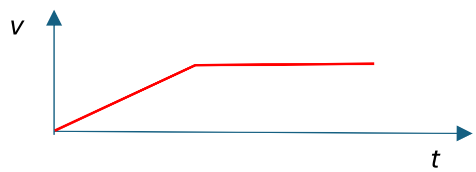



**D**

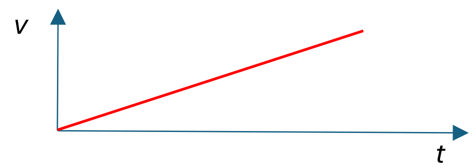
**10.** The diagram shows the variation with time of the net force acting on a body initially at rest.



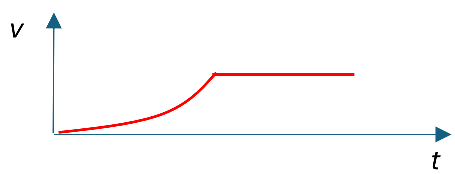

Which diagram shows the variation with time of the velocity of the body?



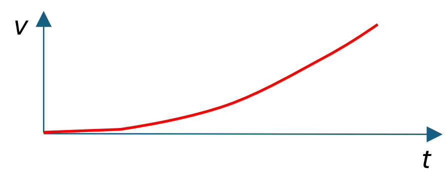

**A**




**B**

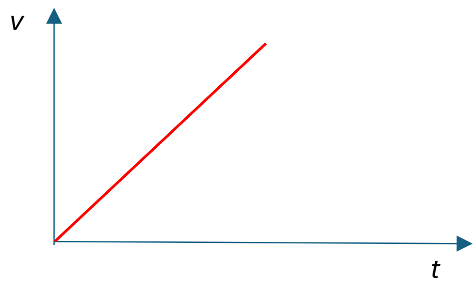



**C**

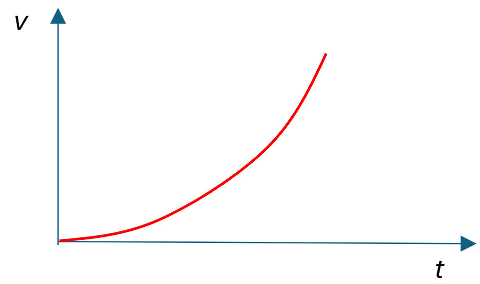



**D**

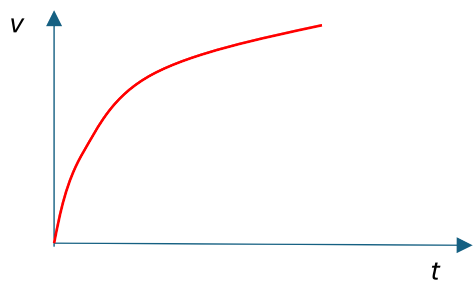
**11.** A body is initially at rest. The body is pulled by a force that delivers a constant power. Which graph shows the variation with time of the speed of the body?



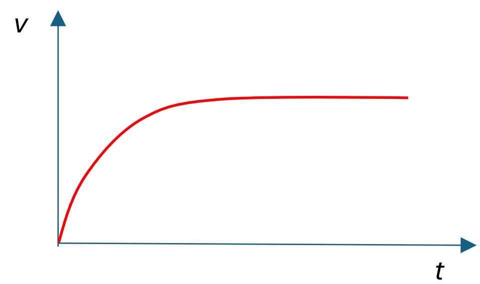

**A**




**B**

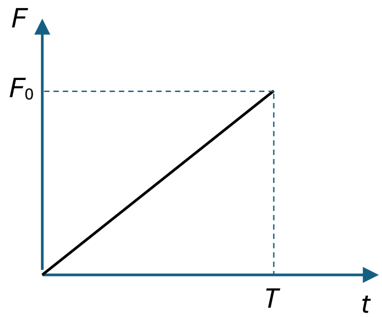



**C**

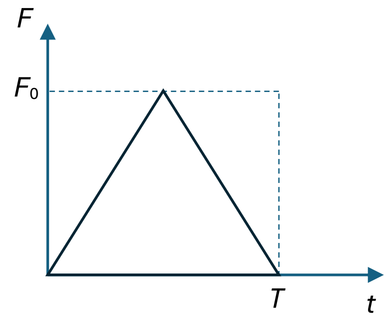



**D**

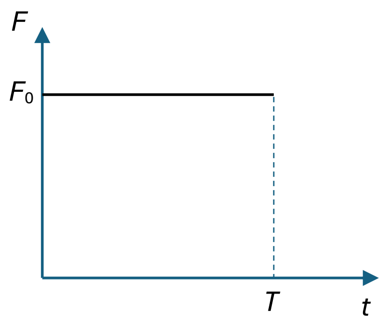
**12.** The graphs show the variation with time of the net force of a body initially at rest. In which case will the final speed of the body be the greatest?



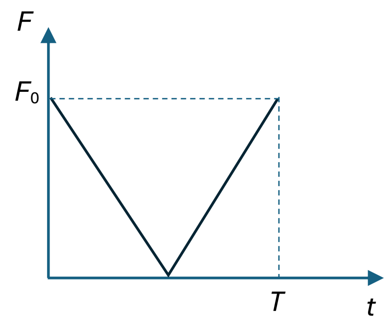

**A**




**B**

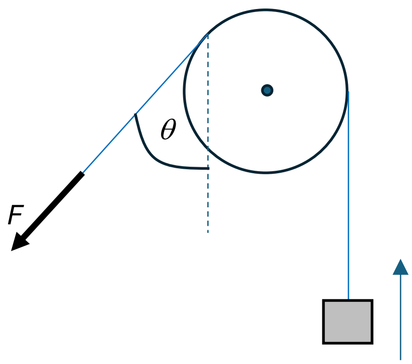



**C**




**D**

**13.** A block of mass $m$ is connected to a string that goes over a pulley. The other end of the string makes an angle of $\theta$ with the vertical. A person pulls on this end with a force $F$ raising the mass vertically at constant speed by a distance $d$.




What is the work done by $F$?

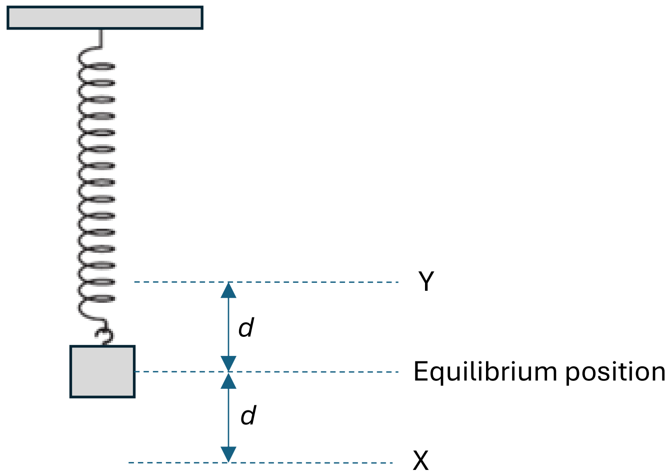
**A** $mgd$

**B** $mgd\cos\theta$

**C** $mgd\sin\theta$

**D** $mgd\tan\theta$

**14.** A block of mass $m$ oscillates in simple harmonic motion at the end of vertical spring of spring constant $k$. The extreme positions of the block during the oscillations are X and Y.




What is the work done by the **net** force on the body as the body moves from X to Y?

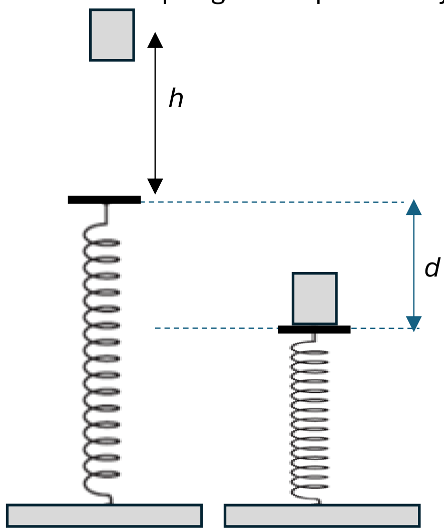
**A** Zero

**B** $mgd$

**C** $2mgd$

**D** $kd^2$

**15.** A block of mass $m$ falls from a height $h$ above an unstretched vertical spring of spring constant $k$. The spring is compressed by a maximum distance $d$.




What is the work done by the spring tension force?

**A** Zero

**B** $-mgd$

**C** $-mgh$

**D** $-mg(h+d)$

**16.** A block of mass $M$ and kinetic energy $K$ collides with and sticks to an identical block initially at rest. What is the magnitude of the change in momentum of the system and what is the change in the kinetic energy of the system?

| | **Change in momentum** | **Change in kinetic energy** |
|---|---|---|
| **A** | 0 | $-\frac{K}{4}$ |
| **B** | 0 | $-\frac{K}{2}$ |
| **C** | $\sqrt{2MK}$ | $-\frac{K}{4}$ |
| **D** | $\sqrt{2MK}$ | $-\frac{K}{2}$ |

**17.** Hailstones of mass *m* are falling vertically on a horizontal surface at a rate of *N* per second. The speed of the hailstones is *v* and the raindrops bounce off the surface without change of speed.
What is the force exerted on the surface?

**A** $Nmv$

**B** $2Nmv$

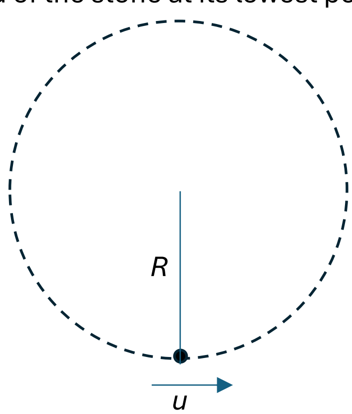
**C** $\frac{mv}{N}$

**D** $\frac{2mv}{N}$

**18.** A person walks to the right along a plank that is placed on a horizontal frictionless surface. What happens to the plank while the person is walking and what happens when the person stops at the right-hand end of the plank?

| | **While walking** | **After stopping** |
|---|---|---|
| **A** | Stays at rest | Stays at rest |
| **B** | Stays at rest | Moves to the left |
| **C** | Moves to the left | Stays at rest |
| **D** | Moves to the left | Moves to the left |

**19.** A stone is attached to a string and is made to move on a vertical circle of radius *R*. The speed of the stone at its lowest point is *u*.




What is the minimum value of *u* such that the string does not slack?

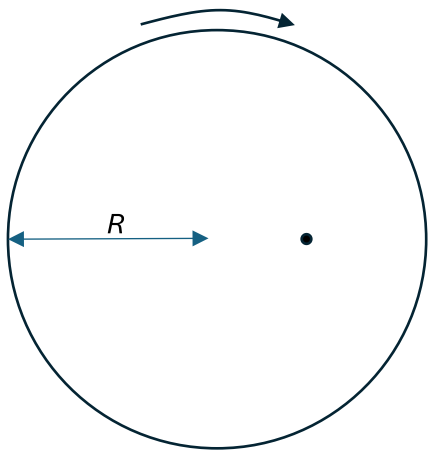
**A** $\sqrt{gR}$

**B** $\sqrt{3gR}$

**C** $\sqrt{5gR}$

**D** $\sqrt{7gR}$

**20.** A stone is placed on a horizontal rotating circular platform of radius $R$ at a distance $\frac{R}{2}$ from the center.




The static friction coefficient between the stone and the platform is $\mu_s$ and the dynamic coefficient is $\mu_d$.
What is the maximum angular velocity of the platform such that the stone does not move relative to the platform?

**A** $\sqrt{\dfrac{\mu_s g}{R}}$

**B** $\sqrt{\dfrac{2\mu_s g}{R}}$

**C** $\sqrt{\dfrac{\mu_d g}{R}}$

**D** $\sqrt{\dfrac{2\mu_d g}{R}}$

## Answers

1. Acceleration is defined in terms of velocity so we ignore A and B. Negative acceleration means the velocity is decreasing. Hence **D**.
2. Positive acceleration means the velocity is increasing. If the velocity is positive and is increasing the speed is increasing. If the velocity is negative and is increasing the magnitude of velocity is decreasing. Hence **C**.
3. At the maximum height the velocity is zero so this eliminates A and B. The gradient at the point we seek must be negative (acceleration of free fall). Hence **C**.

   At A the ball makes first contact with the surface. At B the ball loses contact with the surface. At C the ball is at its maximum height. At D the ball is at rest instantaneously on the surface and at maximum compression.
4. The landing speed will be the same by energy conservation: $mgH+\frac{1}{2}mu^2=\frac{1}{2}mv^2$, so this is a tie. X will land after a time given by $H=\frac{1}{2}gt^2 \quad \Rightarrow \quad t=\sqrt{\frac{2H}{g}}$. Y will land after a time given by $-H=ut-\frac{1}{2}gt^2 \quad \Rightarrow \quad t=\frac{u}{g}+\sqrt{\left(\frac{u}{g}\right)^2+\frac{2H}{g}}$ which is always greater than the time for X, no matter the height. Hence **C**.
5. The distance separating the objects is $\frac{1}{2}gt^2-\frac{1}{2}g(t-\tau)^2=gt\tau-\frac{1}{2}g\tau^2$ where $\tau$ is the delay in dropping the second object. Hence the distance is increasing at a constant **rate** equal to $g\tau$. Hence **B**.
6. If you are moving along with the cart, you see the ball going straight up and then straight down. So, it will fall inside the cannon. Hence **B**.
7. The masses are equal, so we have equilibrium. The blocks can be at rest or move at constant velocity. They cannot have acceleration. Hence **D**.
8. While the ball is in the air the only force acting on it is its weight. Hence **D**.
9. The acceleration is not constant so answer is A or B (graph cannot be straight). The gradient must start positive, become zero and then negative. Hence **A**.
10. The acceleration is positive and constant at the beginning and so we need a straight line graph with positive gradient. Afterwards the force is zer so the velocity stays constant. Hence **A**.
11. The energy provided after time $t$ is $Pt$ hence $Pt=\frac{1}{2}mv^2 \quad \Rightarrow \quad v=\sqrt{\frac{2Pt}{m}}$. Hence **C**.
12. We need the graph with the largest area under the curve. Hence **C**.
13. The tension in the string is $mg$ and that equals $F$. Hence the work done is $mgd$. Hence **A**. Equivalently, the force $F$ is an external force and $W_{ext}=\Delta E_T$ and $\Delta E_T=mgd$.
14. The work done by the net force is the change in kinetic energy and this is zero from X to Y. Hence **A**.
15. The net force on the block is the tension $T$ of the spring upwards and the weight $mg$ downwards. The work done by the net force is the change in kinetic energy (from when the block first meets the spring until it stops moving) i.e. $0-\frac{1}{2}mv^2$. By energy conservation:

$\frac{1}{2}mv^2 = mgh$. Thus, $W_T + W_{mg} = -mgh \Rightarrow W_T = -mgh - W_{mg} = -mgh - mgd = -mg(h+d)$. Hence **D**.

Equivalently, the work done by the tension force is the negative change in the elastic energy of the spring. This is $-\left(\frac{1}{2}kd^2 - 0\right)$. Apply conservation of energy from when the block is released until it stops moving: $mg(h+d) = \frac{1}{2}kd^2 \Rightarrow W_T = -mg(h+d)$.

**16.** Momentum conservation says that the momentum stays the same and hence the change in momentum is zero. The blocks will move with a common speed found from: $Mu = 2mv \Rightarrow v = \frac{u}{2}$. Hence the final kinetic energy is $\frac{1}{2}(2M)\left(\frac{u}{2}\right)^2 = \frac{1}{2}\frac{Mu^2}{2} = \frac{K}{2}$. Hence the change is $-\frac{K}{2}$. Hence **B**.

**17.** The change in momentum of one hailstone is $2mv$ and the rate of change of all of them per second, i.e. the force, is $2Nmv$. Hence **B**.

**18.** The total momentum was zero to begin with and so if the person walks to the right the plank moves to the left to keep momentum zero. When the person stops walking the plank must stop moving to keep momentum zero. Hence **C**.

**19.** The critical point is the highest point in the path. There, the net force is $mg + T$ and so $mg + T = m\frac{v^2}{R}$. The string goes slack when $T \to 0$ and so $g = \frac{v^2}{R}$ where $v$ is the speed at the top. Energy conservation gives $\frac{1}{2}mu^2 = \frac{1}{2}mv^2 + 2mgR$ i.e. $v^2 = u^2 - 4gR$. Hence $v^2 = u^2 - 4gR = gR \Rightarrow u^2 = 5gR$. Hence **C**.

**20.** The stone is not supposed to move so we must use the static coefficient. The net force on the stone is a horizontal force directed towards the center of the platform of magnitude $\mu_s mg$ and so $\mu_s mg = m\omega^2\frac{R}{2}$ leading to $\omega = \sqrt{\frac{2\mu_s g}{R}}$. Hence **B**.