M1 Ideas Test

No calculation is required – these questions are designed to test your understanding of key concepts and techniques required to succeed in Mechanics 1.
You must try to use appropriate terminology and explain as thoroughly and precisely as possible.

1. Name 5 different forces which act on a cyclist in motion.

2. Explain exactly why $6g$ represents the force pulling down on a $6kg$ object.

3. Under what circumstances could you use the formula $F_r = \mu R$?

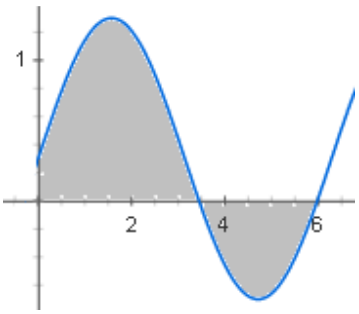
4. Under what circumstances could you use formula $speed = \frac{distance}{time}$?

5. Under what circumstances could you use the formula $s = ut + \frac{1}{2}at^2$?

6. When a person travels up in a lift, describe what happens to the normal reaction exerted on them by the floor of the lift.

7. If the momentum of a bullet is equal in size to the momentum of the gun it is fired from, why doesn't recoil kill people?

8. The following velocity-time graph is being studied:
One student calculates the total area between the curve and the horizontal axis.
Another student subtracts the area below the axis from the area above.
Each method is a valid way of calculating something.
What is the first student calculating, and what is the second student calculating?



9. How would you calculate the magnitude of a force given in i j form?

10. Which of the five variables used in the SUVAT equations could be written as vectors?

11. When a projectile is fired, assuming air resistance can be ignored, the horizontal speed remains constant throughout motion. Why is this?

12. There are two ways to increase the maximum frictional force acting on an object. One is to alter the contact surface between the two (generally by either altering the surface or the object). What is the other way?

13. If momentum is conserved, how is it that when two cars travelling towards each other at 40mph collide, they might both come to a complete stop?

14. What is the meaning of the word 'equilibrium' when applied to a particle?

15. If a particle is moving under the influence of a combination of forces, which formula would be used to describe the motion, and what do the terms represent? Be specific.

16. If two objects of different mass are connected by a string over a pulley, the tension in the string is identical on both sides. Their weights are different, so why do they accelerate at the same rate?

17. A bullet is fired vertically upwards. How would you determine whether or not the bullet reaches a particular altitude?

18. What is the key variable to consider which links horizontal and vertical motion in projectiles?

19. Why does a projectile fired at an angle of $35°$ to the horizontal have the same horizontal range as one fired at $55°$?

20. What is the effect of doubling the speed of a projectile on its horizontal range, and why? Consider both horizontal and vertical motion.

M1 Ideas Test - SOLUTIONS

1. Name 5 different forces which act on a cyclist in motion.

Weight, normal reaction, friction, air resistance and the motive force provided by the cyclist

2. Explain exactly why $6g$ represents the force pulling down on a $6kg$ object.

The force of gravity depends on mass, so since, for any force, $F = ma$, the acceleration due to gravity is constant for any object (on the Earth's surface). Since the acceleration due to gravity is usually written as g, representing the number $9.8ms^{-1}$, approximately, the force of gravity acting on a particular object (commonly known as its weight) is the mass (in kilograms) multiplied by g.

3. Under what circumstances could you use the formula $F_r = \mu R$?

When an object is either in motion or about to move ('limiting equilibrium'). Otherwise, $F_r \leq \mu R$ is the most we can say for sure.

4. Under what circumstances could you use the formula $speed = \frac{distance}{time}$?

When the object is moving at a constant speed (ie there is no acceleration).

5. Under what circumstances could you use the formula $s = ut + \frac{1}{2}at^2$?

When the object is moving with a constant acceleration.

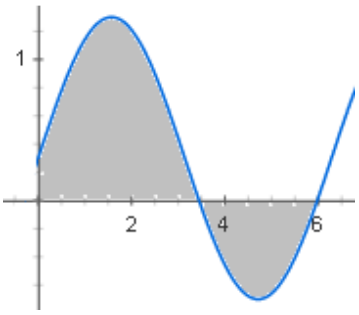
6. When a person travels up in a lift, describe what happens to the normal reaction exerted on them by the floor of the lift.

Initially the normal reaction will be equal to the weight of the person (when the lift is stationary), but will increase to more than the weight in order to provide a resultant upwards force (to accelerate them upwards). Once the lift reaches its maximum speed, the forces will be balanced again, so the normal reaction would again equal the weight. Once the lift begins to slow down, the resultant force must be downwards in order to cause downwards acceleration (or upwards deceleration). This means the normal reaction will be less than the weight, until the lift comes to rest once more.

7. If the momentum of a bullet is equal in size to the momentum of the gun it is fired from, why doesn't recoil kill people?

Momentum is the product of mass and velocity. The bullet has the same amount of momentum as the gun, but has much less mass, therefore a much greater velocity. Being both smaller and faster, it can pierce the body and do a lot of harm, but a gun, being both much bulkier (designed to rest against a shoulder, not pierce it) and much slower, will be much less deadly.

8. The following velocity-time graph is being studied:



One student calculates the total area between the curve and the horizontal axis.

Another student subtracts the area below the axis from the area above.

Each method is a valid way of calculating something. What is the first student calculating, and what is the second student calculating?

The total area combined will give the overall distance travelled, but since while velocity is negative the object is moving backwards, counting the area below the axis as negative would give overall displacement.

9. How would you calculate the magnitude of a force given in i j form?

Use Pythagoras' theorem – square the i and j components, add the results and square root.

10. Which of the five variables used in the SUVAT equations could be written as vectors?

Displacement (s), Initial and Final Velocity (u and v) and Acceleration (a). Time is the only scalar.

11. When a projectile is fired, assuming air resistance can be ignored, the horizontal speed remains constant throughout motion. Why is this?

The only force acting is weight, which is directed vertically downwards, at right angles to the horizontal. It can neither increase nor decrease the speed since it isn't acting even partially with or against the horizontal motion.

12. There are two ways to increase the maximum frictional force acting on an object. One is to alter the contact surface between the two (generally by either altering the surface or the object). What is the other way?

Increase the normal reaction. This could be done by increasing the weight (although this may be impractical – for a car it would also increase the force required to slow it down, negating the advantage), or by using some other force to act downwards (eg down-thrust on formula 1 cars).

13. If momentum is conserved, how is it that when two cars travelling towards each other at 40mph collide, they might both come to a complete stop?

Momentum is a vector, with both direction and magnitude. Two cars travelling towards each other would have velocities in opposite directions, and therefore their combined momentum even before the collision could be 0.

14. What is the meaning of the word 'equilibrium' when applied to a particle?

All forces are balanced. That is, the resultant force acting on the object is zero.

15. If a particle is moving under the influence of a combination of forces, which formula would be used to describe the motion, and what do the terms represent? Be specific.

$\boldsymbol{F = ma}$ where $\boldsymbol{F}$ is the resultant force acting on the particle, $\boldsymbol{m}$ is its mass in kilograms and $\boldsymbol{a}$ is the resulting acceleration of the particle. Both $\boldsymbol{F}$ and $\boldsymbol{a}$ can be vectors.

16. If two objects of different mass are connected by a string over a pulley, the tension in the string is identical on both sides. Their weights are different, so why do they accelerate at the same rate?

The force acting on each one is different (a combination of the tension and the weight), but since their masses are also different, using $\boldsymbol{F = ma}$ yields the same acceleration. The particles are connected by a taut string, so it stands to reason that when in motion they would move at the same rate at all times.

17. A bullet is fired vertically upwards. How would you determine whether or not the bullet reaches a particular altitude?

Use the SUVAT equation $\boldsymbol{s = ut + \frac{1}{2}at^2}$. If the quadratic has no solutions for $\boldsymbol{t}$, the bullet never reaches this height, if two solutions, it passes it twice, and if one solution this is its maximum height.

18. What is the key variable to consider which links horizontal and vertical motion in projectiles?

Time. Using SUVAT equations vertically links vertical speeds, vertical displacement and vertical acceleration, and time (not limited to the vertical). Using $\boldsymbol{speed = \frac{distance}{time}}$ horizontally will link horizontal speed, horizontal displacement (range) and time (not limited to the horizontal). Your information will enable you to find the time either by using the horizontal or the vertical situation, but then you will need to use the time to investigate motion in the other direction.

19. Why does a projectile fired at an angle of $35°$ to the horizontal have the same horizontal range as one fired at $55°$?

Horizontal range is determined by both the time in flight and the horizontal component of velocity. The lower the angle, the greater the horizontal speed, but the shorter the time. The greater the angle, the lower the horizontal speed but the longer the time. Range is proportional to $\boldsymbol{\sin\theta}$ and $\boldsymbol{\cos\theta}$, and $\boldsymbol{\sin 35 = \cos 55}$ and vice versa.

20. What is the effect of doubling the speed of a projectile on its horizontal range, and why? Consider both horizontal and vertical motion.

Four times the range. Doubling the speed means doubling the initial vertical speed, and therefore doubling the time in the air. But it also means doubling the horizontal speed (which is constant), thereby doubling the total distance travelled horizontally each second. Twice the time and twice the horizontal speed means four times the range. As it turns out, for an optimal angle of $\boldsymbol{45°}$, the horizontal range of a projectile fired at a speed $\boldsymbol{v}$ is given by $\boldsymbol{x = \frac{v^2}{g}}$. Increasing gravity would, naturally, reduce the range, but it is also clear that, for a fixed acceleration due to gravity, $\boldsymbol{x}$ is directly proportional to $\boldsymbol{v^2}$. If the speed were increased to $\boldsymbol{10v}$, for example, $\boldsymbol{x = \frac{(10v)^2}{g} = 100\frac{v^2}{g}}$, or 100 times the previous range.