# 2.2 Forces

## Mark Schemes

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| Course | DP IB Physics |
| Section | 2. Mechanics |
| Topic | 2.2 Forces |
| Difficulty | Medium |



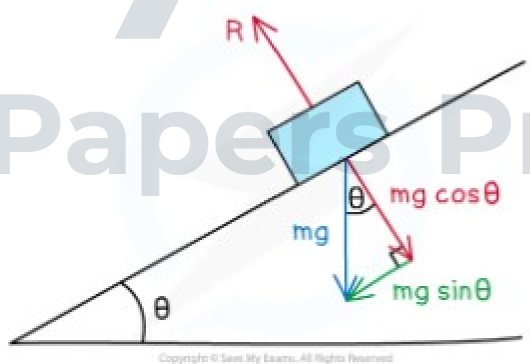
To be used by all students preparing for DP IB Physics HL
Students of other boards may also find this useful

1

The correct answer is **A** because:

- Newton's first law states that an object remains at rest, or moves with constant velocity, unless acted on by a resultant force
- This means that since the block has a constant velocity, it has **no** resultant force
    - This eliminates options **B** and **D**
- The force sliding the block down the plane is its weight component $W \sin \theta$
- The force resisting its motion up the plane is the friction force $F$
- For the resultant force to be 0, these two must be equal
    - Therefore, $F = W \sin \theta$

Sin $\theta$ and cos $\theta$ are mixed up a lot for the components of the weight. The weight ($W$ or $mg$) can be split into a component perpendicular to the slope ($W \cos \theta$) and parallel to the slope ($W \sin \theta$). To remember the one that is 'cos', think of 'the cos sandwich' i.e. the 'cos' component that 'sandwiches' the angle $\theta$ between the vector and the original $W$ vector.






2

The correct answer is **B** because:

- Newton's third law states that whenever two bodies interact, the forces they exert on each other are equal and opposite and of the same type
    - In other words, if object A exerts a force on object B, then object B exerts an **equal** but **opposite** force on object A

- Therefore, the forces must:
  - The same **type**
  - **Opposite** in direction
  - **Equal** in magnitude
- The only force pair that satisfies all three conditions in option **B**

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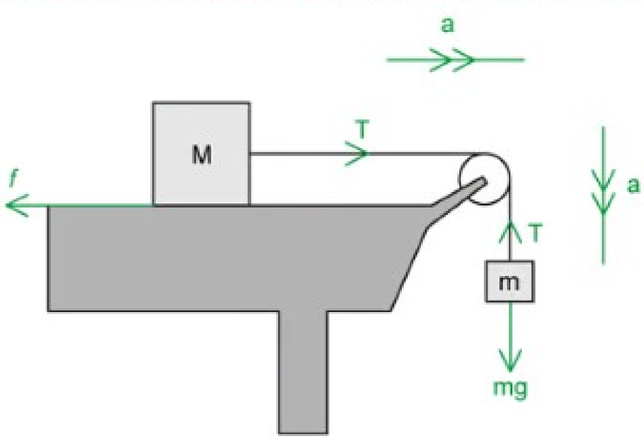
| **A** is incorrect as | the weight of the book is the gravitational force from the earth on the book, and the force of the book on the table is a **contact** force. They are in the same direction, and have the same magnitude, so they are not a Newton's third law pair |
| **C** is incorrect as | weight and normal reaction are two **different types** of forces (weight is gravitational and reaction force is a contact force), and they also act on the **same body** (the book). Therefore, they cannot be a Newton's third law force pair. This is the most common misconception of this law |
| **D** is incorrect as | these are three objects in this scenario (book, Earth and table), instead of two which is required for the Newton's third law force pair |



3

The correct answer is **C** because:

- Consider Newton's second law for both masses separately
  - Resultant force = mass x acceleration ($F = ma$)
  - Both masses have the **same** acceleration, $a$ and tension $T$



- For mass $m$:
  - $mg - T = ma$ (Equation 1)
- For mass $M$:
  - $T - f = Ma$ (Equation 2) where $f$ is the frictional force from the surface
- Rearranging for tension $T$ in equation 2 gives:
  - $T = Ma + f$
- Substituting this equation for $T$ into equation 1:
  - $mg - (Ma + f) = ma$
  - $mg - Ma - f = ma$
- Rearranging for acceleration, $a$:
  - $mg - f = ma + Ma = a(m + M)$
  - $a = \frac{mg - f}{(m + M)}$

Once you have learnt this technique for solving simultaneous equations by substitution masses on a pulley, you will notice exam questions require a similar approach each time. This is a **very** common exam question. Take great care with your algebra, watch out for minus signs outside brackets – remember to multiply **all** variables in the brackets by the minus sign, otherwise, you will get an answer that looks like distractor option **B**!



4

The correct answer is **C** because:

- The two strings have a tension force that acts up towards where the strings are fixed
- In a free-body diagram, all the vectors are represented by arrows, with the arrow head in the direction of that vector
- Since the tension $T$ is equal in both strings, the tension vector arrows must be the same length
- The diagram that satisfies all three conditions is option **C**

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| **A** is incorrect as | the arrows for the tension forces are the wrong way around |
| **B** is incorrect as | the arrow is missing for the *W* force |
| **D** is incorrect as | the strings have equal tension *T*, so both arrows for tension need to be the same size. The second one here is shorter than the first, indicating it has a smaller tension |

5

The correct answer is **B** because:

- The maximum coefficient value of static friction $\mu_s$ is **higher** than the coefficient of dynamic friction $\mu_d$
  - Dynamic friction acts when the object is moving
- The coefficient of friction has to be a value between 0 and 1
- The pair of values that satisfies these conditions is option **B**



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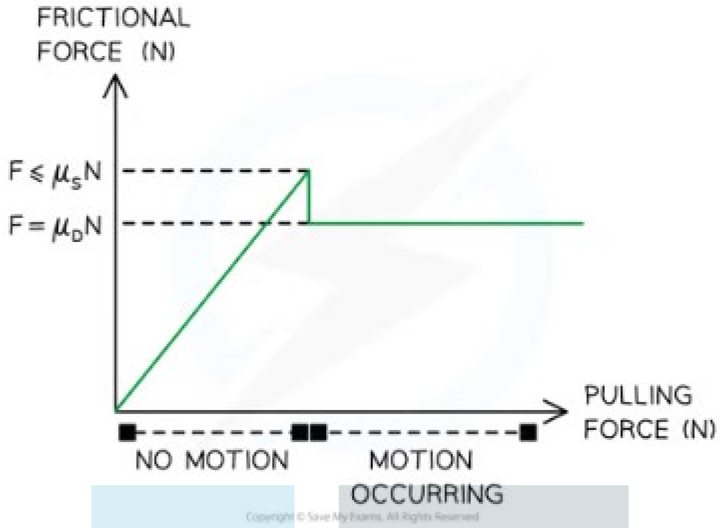
| **A** is incorrect as | $\mu_d > \mu_s$ which is never the case |
| **B** is incorrect as | $\mu_s > 1$ which cannot be the case, it can only be between 0 and 1 |
| **C** is incorrect as | $\mu_d < 1$ which cannot be the case, it can only be between 0 and 1 |

These values can be seen on a coefficient of friction graph:




6

The correct answer is **C** because:

- Since the top of the ladder is in contact with the wall, there is a normal reaction force from the wall on the ladder
  - The normal reaction force is always perpendicular to the surface
  - Therefore, this is an arrow horizontally to the left at the point of contact between the ladder and wall
- Since the ladder is uniform, its weight acts vertically downward from its centre of mass
- Since the bottom of the ladder is in contact with the ground, there is a normal reaction force from the ground to the ladder
- Since the ground is rough, this means there is a frictional force on the bottom of the ladder
  - If the ladder slipped, the bottom of it would move to the left as it falls into the wall
  - This means the frictional force is in the opposite direction i.e. to the right
- The diagram that satisfies all these conditions is option **C**

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| **A** is incorrect as | there should only be the arrow to the right on the bottom of the ladder showing the frictional force, there is no arrow to the left |
| **B** is incorrect as | the normal force from the wall on the ladder is perpendicular to the wall, there is no force going down the wall |
| **D** is incorrect as | the normal force from the wall on the ladder is perpendicular to the wall, there is no force going along the ladder **AND** there should only be the arrow to the right on the bottom of the ladder showing the frictional force, there is no arrow to the left |

Always check that the friction force is in the **opposite** direction to which the object will move in.

7

The correct answer is **D** because:



- The equation for dynamic friction, $f$ is:
  - $f = \mu R$
- Since the friction force acts between the block and the trolley, the reaction force $R$ upwards on $m$ is equal to the weight of $m$
  - $R = mg$
- Therefore the frictional force is:
  - $f = \mu mg$
- The question asks for the acceleration of the **trolley**. Newton's second law states:
  - $F = ma$, where $F$ is the resultant force on an object, $m$ is the mass of the object and $a$ is its acceleration
- The only force that is on the trolley is the frictional force, therefore, this is the resultant force on the trolley
- The acceleration, $a$ on the trolley is:
  - $a = \frac{f}{M} = \frac{\mu mg}{M}$

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| **A** is incorrect as | the force *F* is not a force that is on the trolley. It is only on mass *m* so does not affect its acceleration |
| **B** is incorrect as | the question asks about the acceleration of the trolley, so it is mass *M* of the trolley that should be in Newton's second law equation |
| **C** is incorrect as | the force *F* does is not a force that is on the trolley, only on mass *m* so does not affect its acceleration and the *m* and *M* are the wrong way around in the fraction |

The force *F* here is a big red herring. The important part of this question is to check which object it asks the acceleration for. This would be a very different question had it asked about the acceleration of the block of mass *m* instead, so remember to read the question carefully!

8

The correct answer is **A** because:

- The maximum static frictional force between the sled and surface just before it moves is:
  - $F_{static} = \mu_s R$ where *R* is the normal reaction force and $\mu_s$ is the coefficient of static friction
- Since the sled is not moving vertically up or down, *R* is equal to the combined weight of the child and sled
  - $R = W = 400$ N
- Therefore, the maximum static frictional force is:
  - $F_{static} = 0.50 \times 400 = 200$ N
- Once the sled is in motion, the dynamic frictional force between the sled and surface whilst its moving is:
  - $F_{dynamic} = \mu_d R$
- Substituting in the values gives:
  - $F_{dynamic} = 0.30 \times 400 = 120$ N
- Therefore, the minimum resultant force on the sled and child is:
  - 200 – 120 = 80 N

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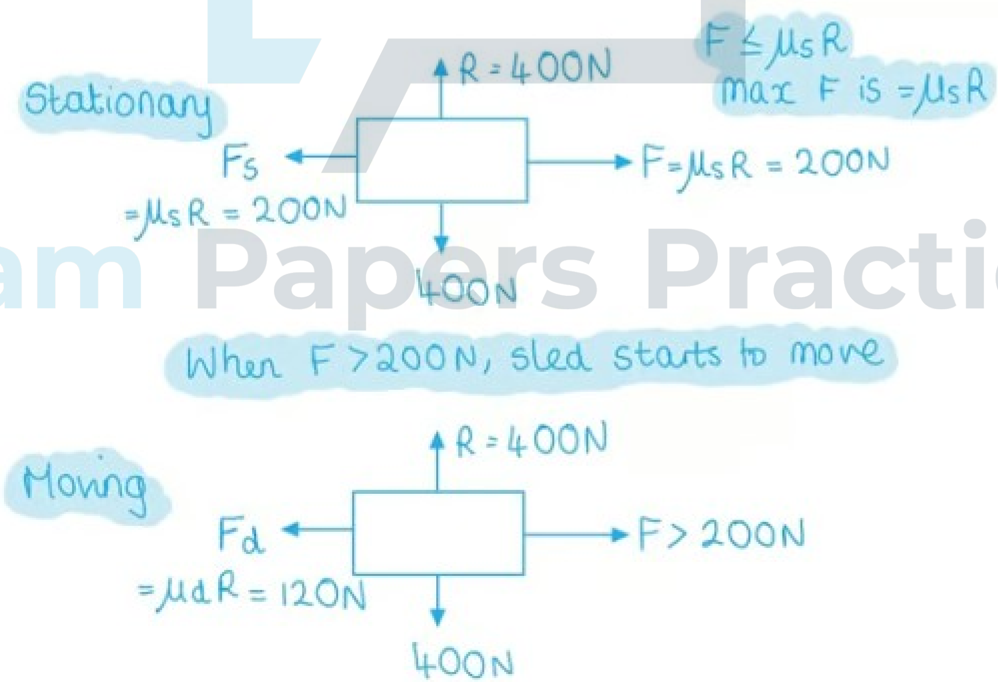
| **B** is incorrect as | the calculation is incorrectly 120 – 200 and ignored the minus sign |
| **C** is incorrect as | the net force has been calculated as the sum of the forces instead of the force when stationary minus the force when moving |
| **D** is incorrect as | since the sled moves from rest it must have accelerated to do so, since the question does not mention it travelling at constant speed there is therefore a resultant force on the sled (and it is not 0) |

This scenario should be treated as whilst the sled is stationary, then when the sled is moving separately. This is because the dynamic and static friction are different values.

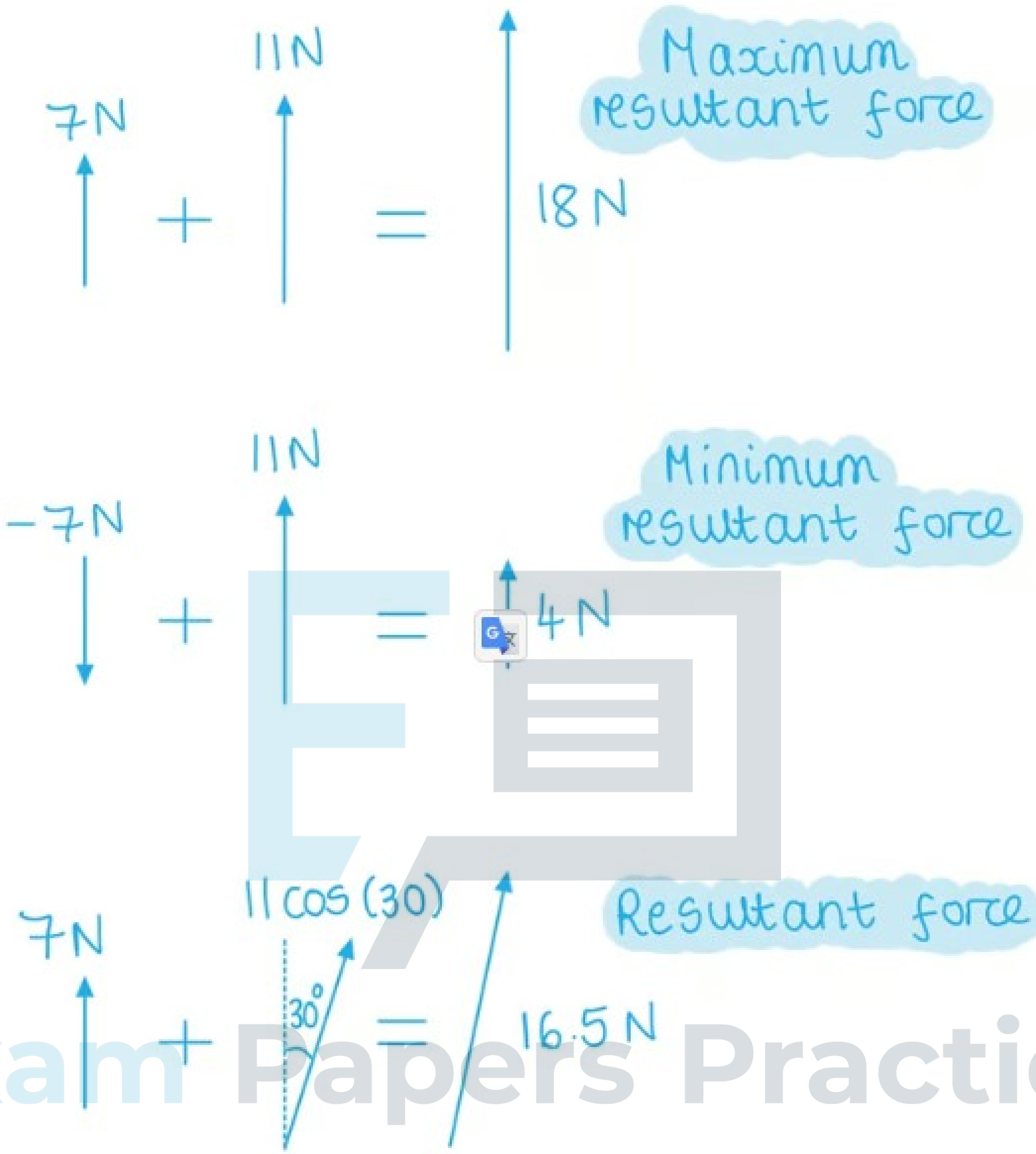


9

The correct answer is **B** because:

- Force is a **vector**, so this is treated like vector addition
- Given two coplanar forces:
  - The maximum resultant force is the **sum** of the forces
  - The minimum resultant force is the **difference** between the forces
- For the two forces 11 N and 7 N therefore:
  - Max resultant force: 11 + 7 = 18 N
  - Min resultant force: 11 – 7 = 4 N
- Therefore:
  - 4 N ≤ Resultant force ≤ 18 N
- Since option **B** of 1 N is < 4 N, it is therefore not a possible resultant of these two vectors

The values in between the maximum and minimum resultant force come from the fact that the forces could be at an angle to each other.




For the resultant force at angle, the vector addition is done from addition a **component** of the vector instead that is in the same direction as the other vector it is being added too. The last example gives a magnitude of: $7 + 11\cos(30) = 16.5$ N. The vertical component has been taken because this is the same direction as the 7 N force. The direction of the resultant force will be somewhere in the middle of both of the individual vectors.

10

The correct answer is **D** because:

- The boxes are moving at a constant speed
- Since acceleration is the rate of change of velocity, at constant speed this means they have 0 acceleration
- Newton's first law says that a body will move at a constant velocity unless a resultant force acts on it
    - Therefore, since the box is moving at a constant speed in a straight line, the resultant force on it must be zero

At first glance, the answer to this question looks like it will be **C**. This is why it's very important to make sure to read the question properly. Often, seemingly complicated questions are simplified by a very straightforward application of Newton's laws!