EDEXCEL INTERNATIONAL A LEVEL · M1 MECHANICS 1

M1 Forces and Newton's Laws: exam questions

10 questions · 44 marks · full mark schemes

Name _____ Date _____ Score / 44

- Newton's three laws, resolving forces on inclines, connected particles (pulleys), friction with coefficient μ.
- Try every question before you look at the mark schemes. They start after the questions: M marks for method, A marks for accuracy, B marks for a correct result on its own.
- Online, with more practice: alevelmathrevision.com/alevel-frontend/units/m1/forces-newtons-laws-questions

1. **3 marks · warm-up**

A force of $50\ \text{N}$ acts horizontally on a block of mass $10\ \text{kg}$ on a smooth surface. Find the acceleration.

2. **3 marks · warm-up**

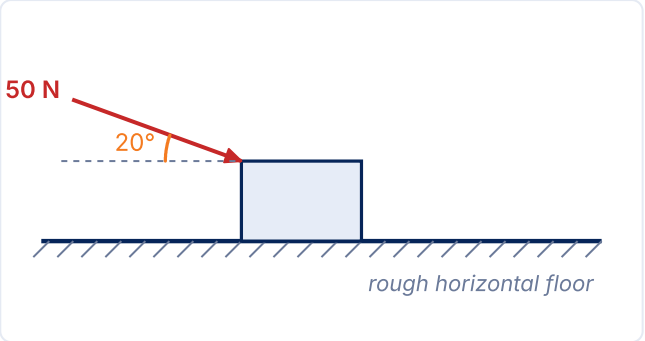
A box of mass $15\ \text{kg}$ is pushed along a rough horizontal floor by a constant horizontal force of $60\ \text{N}$. The box moves at a constant velocity. Find the coefficient of friction between the box and the floor.

3. **3 marks · standard**

A rough horizontal floor has a coefficient of friction of 0.35. A block of mass $m\ \text{kg}$ is pulled by a horizontal force of $75\ \text{N}$ and accelerates at $2\ \text{m s}^{-2}$. Find the value of m.

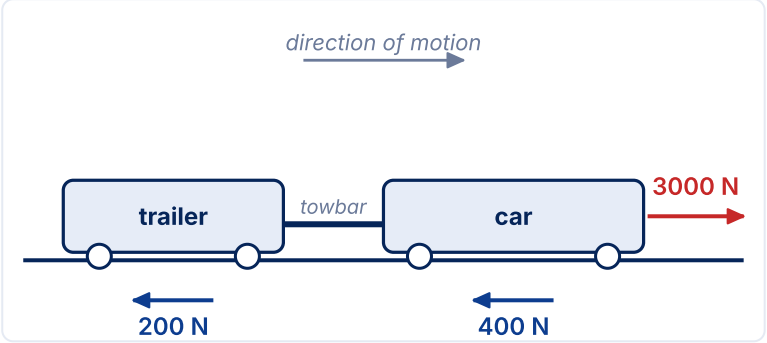
4. 4 marks · standard

A block of mass $8\ \text{kg}$ is pushed along a rough horizontal floor by a force of $50\ \text{N}$ acting at an angle of $20°$ below the horizontal. The coefficient of friction is 0.4. Find the acceleration of the block.



5. 5 marks · standard

A car of mass $1500\ \text{kg}$ tows a trailer of mass $500\ \text{kg}$ along a horizontal road. The tow-bar is horizontal and light. Total resistance to motion is $400\ \text{N}$ (on the car) plus $200\ \text{N}$ (on the trailer). The engine provides $3000\ \text{N}$. Find the acceleration of the car and the tension in the tow-bar.

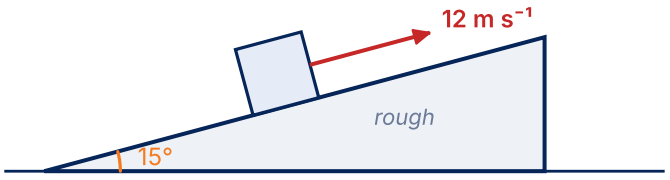


6. 5 marks · standard

A sled of mass $20\ \text{kg}$ starts from rest and slides down a rough hill inclined at $12°$. After 3 seconds, its velocity is $4.5\ \text{m s}^{-1}$. Find the coefficient of friction between the sled and the hill.

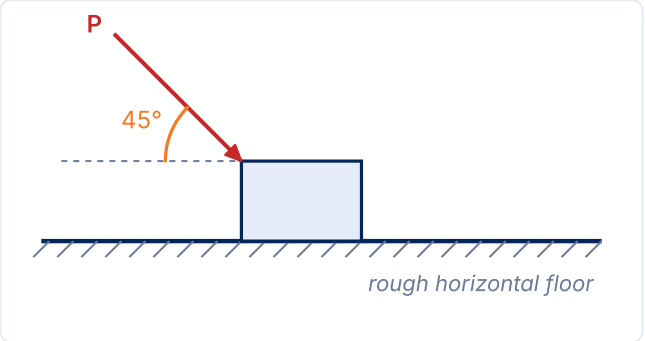
7. 5 marks · harder

A particle is projected **up** a line of greatest slope of a rough plane inclined at an angle of $15°$ to the horizontal. The initial speed is $12\ \text{m s}^{-1}$ and the coefficient of friction is 0.1. Find the distance the particle travels up the plane before coming to instantaneous rest.



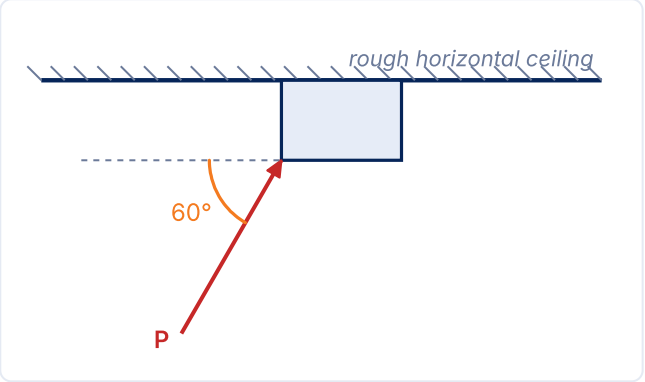
8. 5 marks · harder

A wooden crate of mass $10\ \text{kg}$ sits on a rough horizontal floor. A worker pushes the crate with a force P downwards at an angle of $45°$ to the horizontal. The coefficient of friction is 0.4. Find the maximum value of P that can be applied without the crate moving.



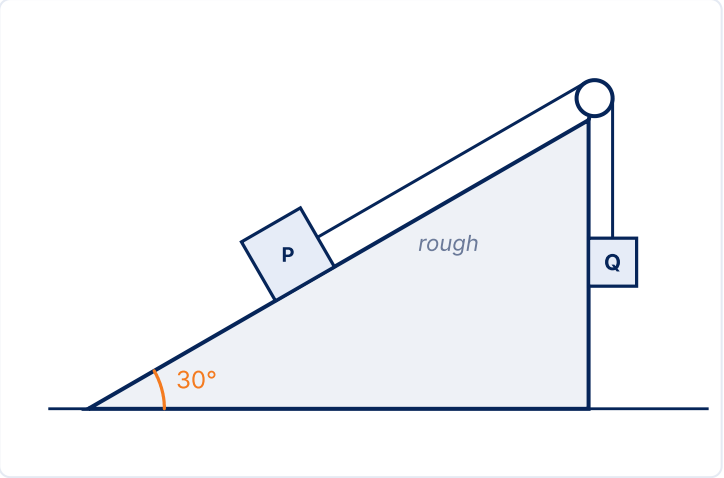
9. 5 marks · harder

A box of mass $12\ \text{kg}$ is pushed at a constant speed along a rough horizontal ceiling (the box is underneath the ceiling) by a force P acting upwards at an angle of $60°$ to the horizontal. The coefficient of friction between the box and the ceiling is 0.8. Find the magnitude of P.



10. 6 marks · harder

Particle P of mass $4\ \text{kg}$ lies on a rough plane inclined at $30°$ to the horizontal. It is connected by a light inextensible string passing over a smooth pulley at the top of the plane to a particle Q of mass $6\ \text{kg}$ which hangs freely. The coefficient of friction between P and the plane is 0.2. The system is released from rest. Find the acceleration of the system.



Answers and worked solutions

Question 1

3 marks

Answer: $a = 5\ \text{m s}^{-2}$

Newton II: $F = ma$ **M1**. $a = \frac{50}{10} = 5\ \text{m s}^{-2}$ **A1 A1**.

Question 2

3 marks

1. M1 for identifying that constant velocity implies zero acceleration, so the driving force equals the frictional force: $F = 60\ \text{N}$.
2. M1 for resolving vertically to find $R = 15g = 147\ \text{N}$.
3. A1 for applying $\mu = \frac{F}{R}$ to find $\mu = \frac{60}{147} \approx 0.408$ (to 3 s.f.).

Question 3

3 marks

1. M1 for formulating the friction: $F = 0.35 \times mg = 3.43m$.
2. M1 for setting up Newton's Second Law: $75 - 3.43m = 2m$.
3. A1 for solving for m: $75 = 5.43m \implies m = 13.8\ \text{kg}$ (to 3 s.f.).

Question 4

4 marks

1. M1 for resolving vertically: $R = 8g + 50\sin 20°$.
2. M1 for calculating $R = 78.4 + 17.10 = 95.5\ \text{N}$ and hence $F = 0.4 \times 95.5 = 38.2\ \text{N}$.
3. M1 for resolving horizontally and applying $F_{net} = ma$: $50\cos 20° - 38.2 = 8a$.
4. A1 for calculating $a = \frac{46.98 - 38.2}{8} = 1.10\ \text{m s}^{-2}$ (to 3 s.f.).

Question 5

5 marks

Answer: $a = 1.2\ \text{m s}^{-2}$; $T = 800\ \text{N}$

Whole system: net force $= 3000 - 400 - 200 = 2400\ \text{N}$; total mass $= 2000\ \text{kg}$; $a = 1.2\ \text{m s}^{-2}$ **M1 A1**. Trailer alone (Newton II): $T - 200 = 500 \times 1.2 = 600 \Rightarrow T = 800\ \text{N}$ **M1 A1 A1**.

Question 6

5 marks

1. M1 for finding the acceleration using SUVAT: $v = u + at \implies 4.5 = 0 + 3a \implies a = 1.5\ \text{m s}^{-2}$.
2. M1 for setting up Newton's Second Law parallel to the plane: $20g\sin 12° - F = 20(1.5)$.
3. A1 for calculating $F = 20(9.8)\sin 12° - 30 = 40.75 - 30 = 10.75\ \text{N}$.
4. M1 for resolving perpendicularly to find $R = 20g\cos 12° = 191.7\ \text{N}$.
5. A1 for finding $\mu = \frac{F}{R} = \frac{10.75}{191.7} = 0.0561$ (to 3 s.f.).

Question 7

5 marks

1. M1 for determining the forces acting down the plane while moving up: weight component and friction.
2. M1 for calculating acceleration a: $ma = -(mg\sin 15° + \mu mg\cos 15°) \implies a = -g(\sin 15° + 0.1\cos 15°)$.
3. A1 for evaluating $a = -9.8(0.2588 + 0.0966) = -3.483\ \text{m s}^{-2}$.
4. M1 for applying SUVAT $v^2 = u^2 + 2as$ with $v = 0$: $0 = 12^2 + 2(-3.483)s$.
5. A1 for calculating distance $s = \frac{144}{6.966} = 20.7\ \text{m}$ (to 3 s.f.).

Question 8

5 marks

1. M1 for resolving vertically to find the normal reaction: $R = 10g + P\sin 45°$.
2. M1 for setting up the limiting friction condition: $F = \mu R = 0.4(98 + P\frac{\sqrt{2}}{2})$.
3. M1 for resolving horizontally in limiting equilibrium: $P\cos 45° = F$.
4. M1 for substituting and gathering terms in P: $P\frac{\sqrt{2}}{2} = 0.4(98) + 0.4P\frac{\sqrt{2}}{2} \implies P\frac{\sqrt{2}}{2} - 0.4P\frac{\sqrt{2}}{2} = 39.2 \implies 0.6P\frac{\sqrt{2}}{2} = 39.2$.
5. A1 for calculating $P = \frac{39.2}{0.3\sqrt{2}} = \frac{39.2}{0.424} = 92.4\ \text{N}$ (to 3 s.f.).

Question 9

5 marks

Answer: $P = 488\ N$

resolving vertically, the ceiling pushes down on the box:

$R + 12g = P\sin 60°$ **M1**

$R = P\frac{\sqrt{3}}{2} - 117.6$ **A1**

resolving horizontally at constant speed, with $F = \mu R$:

$P\cos 60° = 0.8R$ **M1**

$0.5P = 0.8\left(\frac{\sqrt{3}}{2}P - 117.6\right)$ **A1**

$P = 488\ N$ (3 s.f.) **A1**

Answer: $P = 488\ N$

Question 10

6 marks

1. M1 for resolving perpendicular to the plane for P to find R: $R = 4g\cos 30° \approx 33.95\ \text{N}$.
2. M1 for calculating friction: $F = 0.2 \times 33.95 = 6.79\ \text{N}$.
3. M1 for setting up the equation of motion for Q: $6g - T = 6a$.
4. M1 for setting up the equation of motion for P (assuming it moves up the plane): $T - 4g\sin 30° - F = 4a$.
5. M1 for adding equations to eliminate T: $6g - 4g\sin 30° - 6.79 = 10a \implies 58.8 - 19.6 - 6.79 = 10a$.
6. A1 for finding $a = \frac{32.41}{10} = 3.24\ \text{m s}^{-2}$ (to 3 s.f.).

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