M1 Statics of a Particle: exam questions

10 questions · 36 marks · full mark schemes

Name _____ Date _____ Score / 36

- Resolving forces; equilibrium of a particle; friction and limiting equilibrium (F ≤ μR).
- 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/statics-particle-questions

1. **2 marks · warm-up**

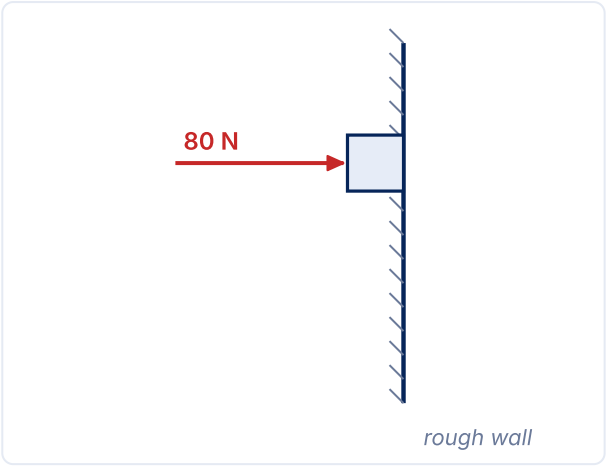
A block of mass $5\ \text{kg}$ rests in limiting equilibrium on a rough horizontal surface under the action of a horizontal pull of $15\ \text{N}$. Find the coefficient of friction, μ, between the block and the surface.

2. **2 marks · warm-up**

A particle rests in limiting equilibrium on a rough plane inclined at an angle θ to the horizontal. No other forces act on the particle. Show that the coefficient of friction $\mu = \tan\theta$.

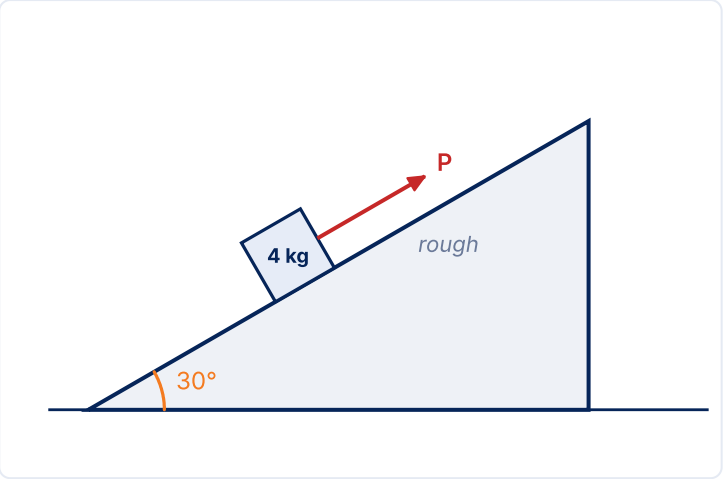
3. 3 marks · standard

A particle of mass $3\ \text{kg}$ is held stationary against a rough vertical wall by a horizontal force of $80\ \text{N}$. Find the minimum coefficient of friction required between the particle and the wall to prevent sliding.



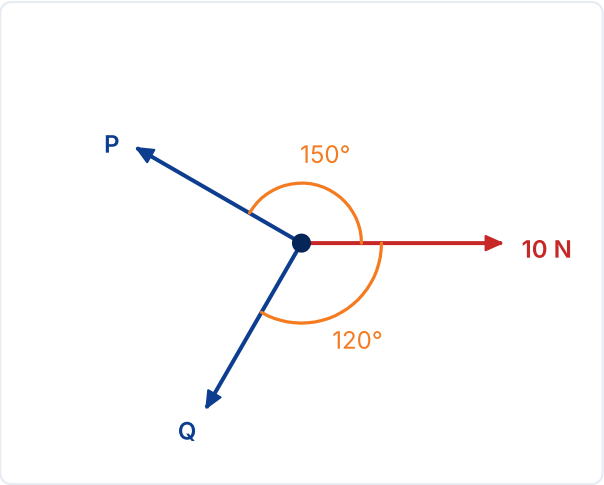
4. **4 marks · standard**

A particle of mass $4\ \text{kg}$ rests on a rough plane inclined at $30°$ to the horizontal. The coefficient of friction is 0.2. A force P acts parallel to the plane, directed **up** the plane, to prevent the particle from sliding down. Find the minimum value of P.



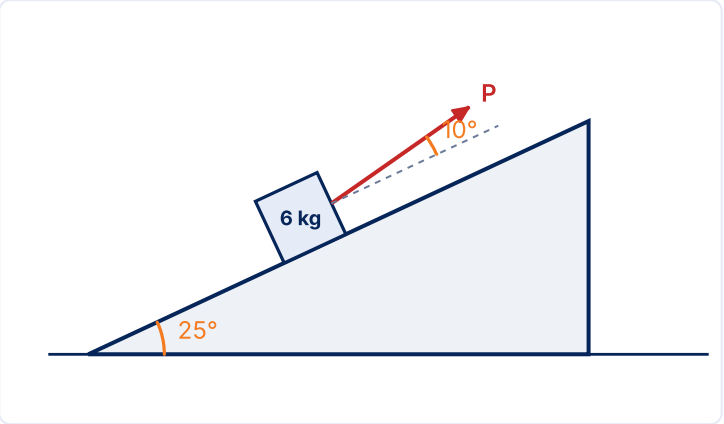
5. 4 marks · standard

Three coplanar forces P, Q, and $10\ \text{N}$ act at a point and are in equilibrium. The angle between P and the $10\ \text{N}$ force is $150°$, and the angle between Q and the $10\ \text{N}$ force is $120°$. Find the magnitudes of P and Q.



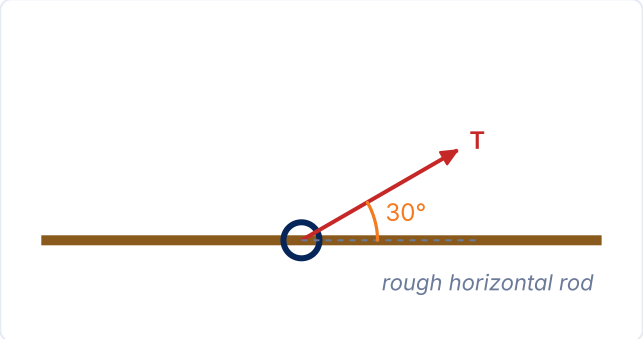
6. 4 marks · standard

A particle of mass $6\ \text{kg}$ is kept in equilibrium on a smooth plane inclined at $25°$ to the horizontal by a force P acting at an angle of $10°$ **above** the line of greatest slope of the plane. Find the magnitude of P.



7. 4 marks · harder

A small ring of mass $0.2\ \text{kg}$ is threaded on a rough horizontal rod. The coefficient of friction is 0.5. A light string is attached to the ring and pulled with a force T at an angle of $30°$ above the rod. Find the maximum value of T for which the ring remains in equilibrium.

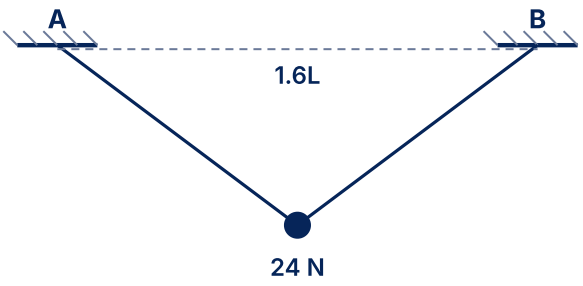


8. 4 marks · harder

Two forces of magnitudes $10\ \text{N}$ and $F\ \text{N}$ act on a particle in equilibrium with a third force $R\ \text{N}$. The angle between the $10\ \text{N}$ force and the $F\ \text{N}$ force is $120°$. Given that F can vary, find the minimum possible magnitude of R.

9. 4 marks · harder

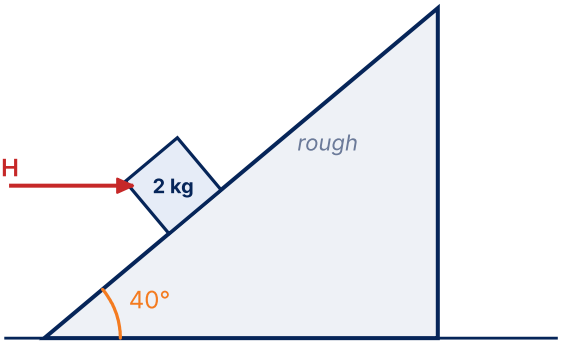
A light inextensible string of length $2L$ has its ends attached to two fixed points A and B on the same horizontal level, distance $1.6L$ apart. A weight of $24\ \text{N}$ is attached to the midpoint of the string. Find the tension in the string.



string length 2L, weight at its midpoint

10. 5 marks · harder

A particle of mass $2\ \text{kg}$ is held in limiting equilibrium on a rough plane inclined at $40°$ to the horizontal by a **horizontal** force H. The particle is on the point of sliding **down** the plane. The coefficient of friction is 0.3. Taking $g = 9.8\ \text{m s}^{-2}$, find the value of H.



Answers and worked solutions

Question 1

2 marks

1. M1 for identifying $R = 5g$ and using $F = \mu R$ with $F = 15$ N: $15 = \mu(5 \times 9.8)$.
2. A1 for finding $\mu = \frac{15}{49} \approx 0.306$.

Question 2

2 marks

1. M1 for resolving parallel ($F = mg\sin\theta$) and perpendicular ($R = mg\cos\theta$) and using $F = \mu R$.
2. A1 for substituting to get $mg\sin\theta = \mu mg\cos\theta \implies \mu = \frac{\sin\theta}{\cos\theta} = \tan\theta$.

Question 3

3 marks

1. M1 for identifying the normal reaction R is provided by the horizontal force: $R = 80$ N.
2. M1 for resolving vertically, where friction must balance weight: $F = 3g = 29.4$ N.
3. A1 for applying $F \le \mu R \implies 29.4 \le \mu(80) \implies \mu \ge 0.3675$, so minimum $\mu = 0.368$ (to 3 s.f.).

Question 4

4 marks

1. M1 for finding normal reaction $R = 4g\cos 30^\circ = 33.95$ N.
2. M1 for finding limiting friction $F = \mu R = 0.2 \times 33.95 = 6.79$ N acting **up** the plane.
3. M1 for resolving parallel to the plane: $P + F = 4g\sin 30^\circ$.
4. A1 for calculating $P = 19.6 - 6.79 = 12.8$ N.

Question 5

4 marks

1. M1 for finding the angle between P and Q: $360^\circ - 150^\circ - 120^\circ = 90^\circ$.
2. M1 for applying Lami's theorem or resolving: $\frac{P}{\sin 120^\circ} = \frac{Q}{\sin 150^\circ} = \frac{10}{\sin 90^\circ}$.
3. A1 for finding $P = 10\sin 120^\circ = 10 \times \frac{\sqrt{3}}{2} = 5\sqrt{3} \approx 8.66$ N.
4. A1 for finding $Q = 10\sin 150^\circ = 10 \times 0.5 = 5$ N.

Question 6

4 marks

1. M1 for identifying the component of weight down the plane: $6g\sin 25^\circ$.
2. M1 for identifying the component of P parallel to the plane: $P\cos 10^\circ$.
3. M1 for equating the parallel components (equilibrium): $P\cos 10^\circ = 6g\sin 25^\circ$.
4. A1 for calculating $P = \frac{6 \times 9.8 \times \sin 25^\circ}{\cos 10^\circ} = \frac{24.85}{0.985} = 25.2$ N (to 3 s.f.).

Question 7

4 marks

1. M1 for resolving vertically to find the normal reaction: $R + T\sin 30^\circ = 0.2g \implies R = 1.96 - 0.5T$.
2. M1 for resolving horizontally in limiting equilibrium: $T\cos 30^\circ = F$.
3. M1 for setting $F = \mu R$: $T\frac{\sqrt{3}}{2} = 0.5(1.96 - 0.5T) \implies 0.866T = 0.98 - 0.25T$.
4. A1 for solving for T: $1.116T = 0.98 \implies T = 0.878$ N (to 3 s.f.).

Question 8

4 marks

1. M1 for using the cosine rule (or components) for the resultant of the 10 N and F N forces, which is equal and opposite to R: $R^2 = 10^2 + F^2 + 2(10)(F)\cos 120^\circ$.
2. A1 for the correct quadratic $R^2 = F^2 - 10F + 100$.
3. M1 for completing the square or differentiating: $R^2 = (F-5)^2 + 75$, least when $F = 5$.
4. A1 for the minimum $R = \sqrt{75} = 5\sqrt{3} \approx 8.66$ N.

Question 9

4 marks

1. M1 for forming a right-angled triangle with hypotenuse L and horizontal side $0.8L$.
2. M1 for finding the angle θ to the horizontal: $\cos\theta = \frac{0.8L}{L} = 0.8$, so $\sin\theta = 0.6$.
3. M1 for resolving vertically: $2T\sin\theta = 24$.
4. A1 for calculating $T = \frac{24}{2 \times 0.6} = 20$ N.

Question 10

5 marks

1. M1 for resolving perpendicular to the plane: $R = 2g\cos 40^\circ + H\sin 40^\circ$.
2. M1 for resolving parallel to the plane (friction acts up): $H\cos 40^\circ + F = 2g\sin 40^\circ$.
3. M1 for substituting $F = 0.3R$: $H\cos 40^\circ + 0.3(2g\cos 40^\circ + H\sin 40^\circ) = 2g\sin 40^\circ$.
4. M1 for rearranging to isolate H: $H(\cos 40^\circ + 0.3\sin 40^\circ) = 2g\sin 40^\circ - 0.6g\cos 40^\circ$.
5. A1 for calculating $H = \frac{12.599 - 4.504}{0.7660 + 0.1928} = \frac{8.095}{0.9589} = 8.44$ N (to 3 s.f.).

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