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Module 2: Dynamics — Topic 2.2: Force Analysis

Foundation

1. Describe the difference between static friction and kinetic friction, and state the formulae used to calculate each type of friction.

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2. (a) Calculate the normal force acting on a 4 kg mass that is at rest on a horizontal surface.

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   (b) Calculate the maximum static frictional force experienced by the mass if the coefficient of static friction between the block and surface is 0.74.

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   (c) Calculate the kinetic frictional force experienced by the mass if the coefficient of kinetic friction between the block and the surface is 0.56.

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   (d) A force of 30 N is now applied horizontally to the same 4 kg mass.

   Calculate the acceleration of the block when it is moving.

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★ 39.2 N, 29.01 N, 21.95 N, $2.01\ \mathrm{m\,s^{-2}}$ ★

Development

1. A 20 kg block of ice is pushed along a rough surface with a horizontal force of 60 N. The coefficient of kinetic friction between the ice and the surface is 0.25.

   What is the net horizontal force acting on the block of ice when it is moving?

   (a) 11 N

   (b) 146 N

   (c) 196 N

   (d) 246 N

2. A bicycle rider exerts a forwards force of 400 N through the pedals of the bike when riding on a horizontal surface. The total mass of the rider and the bike is 85 kg, and their acceleration is 2 $m\,s^{-2}$.

   From this information, it can be concluded that:

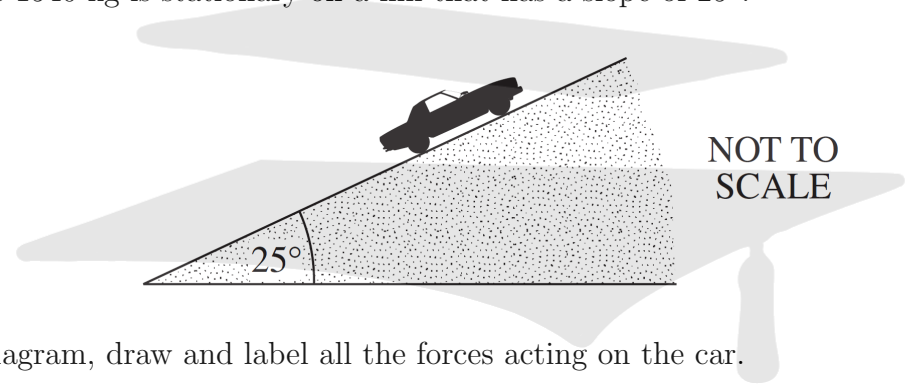
   (a) There is no frictional force acting on the bike at this time

   (b) Newton's 2nd law of motion is not applicable to this motion

   (c) The coefficient of static friction between the bike and the surface is 0.28

   (d) The coefficient of kinetic friction between the bike and the surface is 0.28

3. A car of mass 1540 kg is stationary on a hill that has a slope of 25°.



   (a) On the diagram, draw and label all the forces acting on the car. **2**

   (b) Calculate the force that is necessary to stop the car from moving down the slope. **2**

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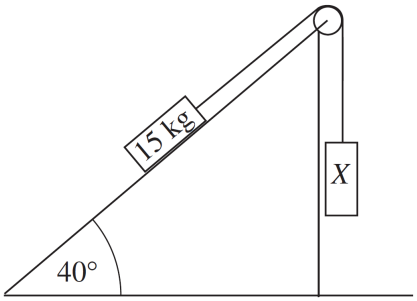
★ 6378.2 N ★

4. A 15 kg block is placed on a smooth inclined plane. It is attached by a light, inextensible string over a frictionless pulley to block X.



(a) The 15 kg mass accelerates down the slope at 0.50 $\mathrm{m\,s^{-2}}$.

i. Calculate the tension in the string. **2**

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ii. Calculate the mass of block X. **2**

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(b) The mass of block X is changed so that the resultant force acting on the 15 kg mass is zero. **2**

Calculate the new mass of block X.

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★ 87 N, 8.4 kg, 9.6 kg ★

5. A girl of mass 40.0 kg slides at a constant speed down a dip inclined at 22° to the horizontal.

(a) Calculate the frictional force acting on the girl and the coefficient of kinetic friction between the girl and the surface of the dip. **3**

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(b) Suppose the girl accelerated down the incline at 1.84 $m\,s^{-2}$ instead of moving at constant speed because of a decrease in friction. **2**

Calculate the magnitude of the change in the frictional force.

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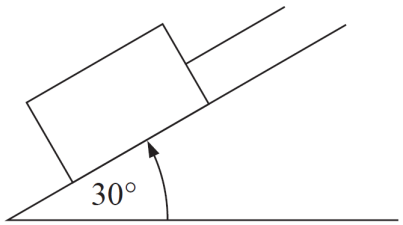
★ 146.85 N, 0.40, 73.6 N ★

6. A 3.7 kg box is initially held stationary on a smooth slope at 30° by a lightweight inextensible string. Ignore the effects of friction.



(a) Calculate the tension in the string when the box accelerates up the slope with a magnitude of 1.7 $m\,s^{-2}$. **2**

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(b) Describe the motion of the box when the tension in the string is 16 N. Include relevant calculations to support your answer. **2**

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The tension in the string and the angle of the slope can be changed in order to observe the motion of the box under different conditions.

(c) The box accelerates up the slope when the tension in the string is 35 N and the slope is at 30°. **2**

If the slope is changed to 50°, should the tension in the string be smaller or larger to keep the same acceleration? Explain your answer.

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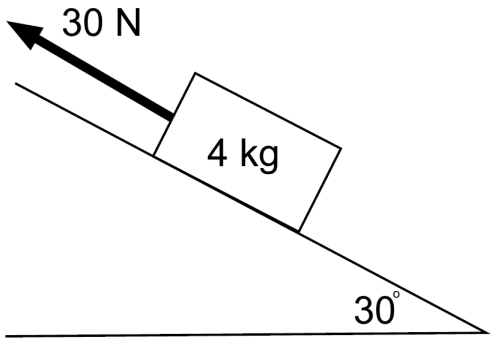
★ 24.42 N ★

7. A 4 kg block is pulled up an inclined plane at a constant velocity with a force of 30 N as shown in the diagram below.



(a) Calculate the kinetic frictional force and the coefficient of kinetic friction between the block and the inclined plane. **3**

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(b) If the coefficient of static friction is two times that of the coefficient of kinetic friction, calculate the minimum pulling force required to move the block if it is initially stationary. **2**

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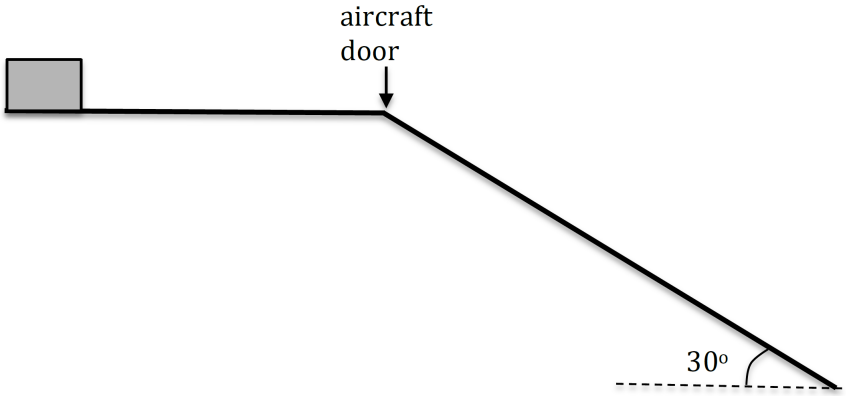
★ 10.4 N, 0.31, 40.4 N ★

8. A rectangular crate of mass 35 kg is being unloaded from an aeroplane. Inside the aeroplane, it is pushed across a rough horizontal floor to the door of the aircraft at a constant speed of $1\ \text{m}\,\text{s}^{-1}$. The coefficient of kinetic friction between the crate and the floor of the aircraft is 0.45.



(a) Draw a free body diagram showing all the forces acting on the crate while it moves across the horizontal floor. **1**

(b) What is the acceleration of the crate while the crate is being pushed across the horizontal floor of the aircraft? **1**

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(c) Calculate the horizontal force that is pushing the crate across the floor of the aircraft. **2**

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(d) The crate is pushed out of the aircraft door and allowed to slide down a rough ramp that makes an angle of 30° to the horizontal. The coefficient of kinetic friction between the crate and the ramp is 0.40.

i. Draw a free body diagram showing all the forces acting on the crate while it is on the ramp. **1**

ii. Calculate the magnitude of the acceleration of the crate while it is sliding down the ramp. **3**

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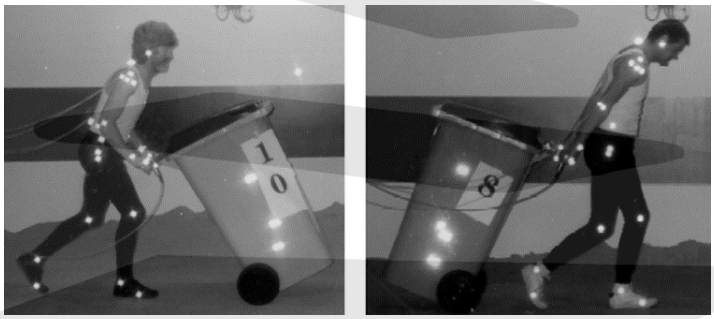
★ 154.35 N, 1.5 $\mathrm{m\,s^{-2}}$ ★

9. A bin is to be wheeled across a yard. This can be done by either pushing the bin from behind or pulling the bin from in front as shown in the photos below. **4**



By analysing the normal and frictional forces involved in each case, explain whether it is more efficient to push or pull the bin. Include relevant free body diagrams in your answer.

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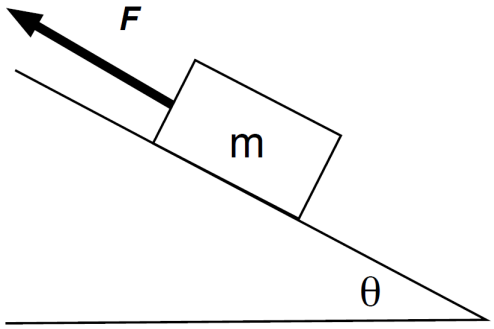
10. A block with mass m lies on a plane inclined at an angle of θ. The coefficient of kinetic friction between the mass and the plane is μ_k. A force of magnitude F acting up the plane causes the mass to accelerate up the plane at a constant acceleration of a. The acceleration due to gravity is g. **4**



Show that $F = m(a + g(\sin\theta + \mu_k \cos\theta))$.

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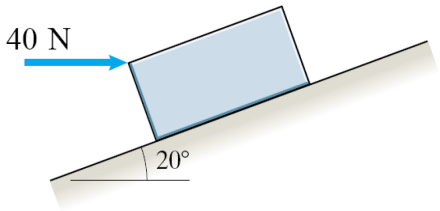
11. A 8 kg block is initially at rest on a plane inclined at 20° to the horizontal. The block is then pushed up the inclined plane with a horizontal force of 40 N. The coefficient of kinetic friction between the block and the surface is 0.1.



(a) Calculate the acceleration of the block when it is moving. **3**

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(b) Calculate the speed of the block and the distance it has moved after 3 seconds. **2**

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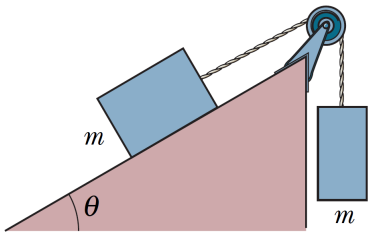
★ 0.25 $m\,s^{-2}$, 0.75 $m\,s^{-1}$, 1.13 m ★

12. Two blocks with equal mass (m) are connected via a light, inextensible string over a frictionless pulley. One of the masses slides on a plane inclined at an angle of θ to the horizontal. The coefficient of kinetic friction between this mass and the inclined plane is μ_k. When released, the mass on the right accelerates downwards with an acceleration of a. The acceleration due to gravity is g.



(a) Draw TWO free body diagrams showing all the forces acting on each of the blocks. **3**

(b) Show that $a = \frac{g}{2}(1 - \sin\theta - \mu_k \cos\theta)$. **4**

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