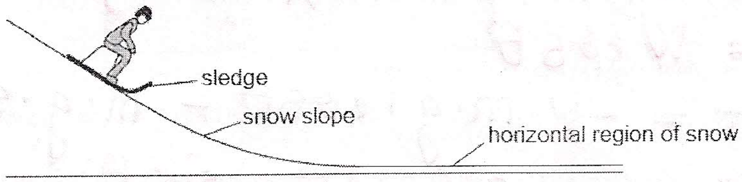
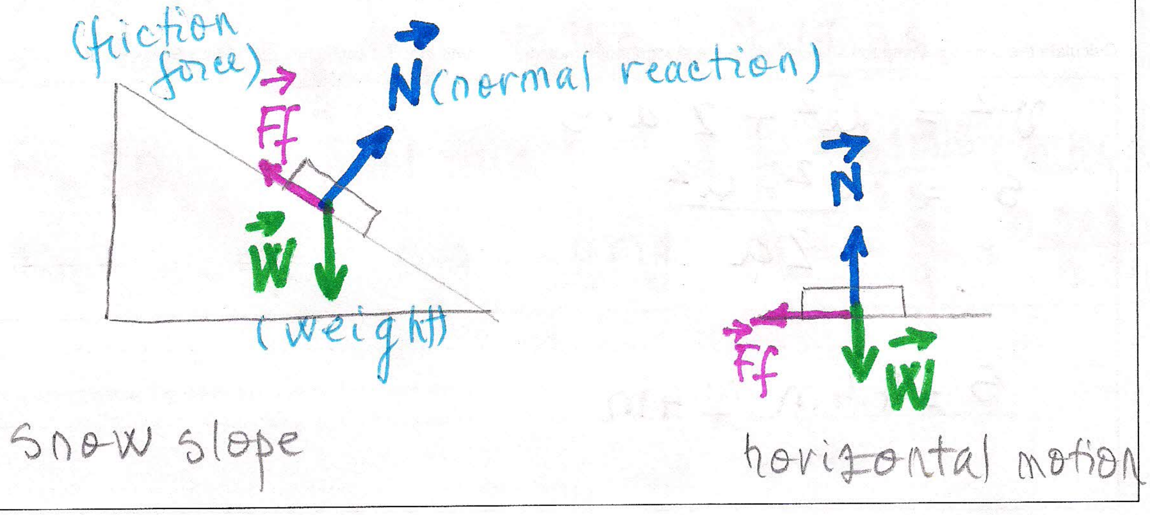
IB practice

Friction and forces practice *[23 marks]*

A girl on a sledge is moving down a snow slope at a uniform speed.



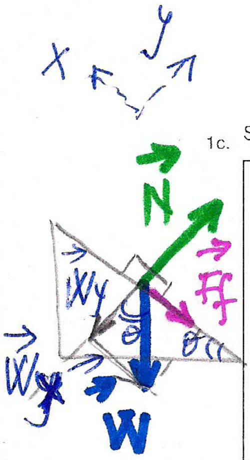
1a. Draw the free-body diagram for the sledge at the position shown on the snow slope. *[2 marks]*



1b. After leaving the snow slope, the girl on the sledge moves over a horizontal region of snow. Explain, with reference to the physical origin of the forces, why the vertical forces on the girl must be in equilibrium as she moves over the horizontal region. *[3 marks]*

The girl's acceleration on vertical direction is zero (no vertical motion)
The weight is acting vertically downward
The normal force (reaction force from the snow) is acting vertically upward.
The weight and normal force have the same magnitude (horizontal section of the motion)

The sledge, without the girl on it, now travels up a snow slope that makes an angle of 6.5˚ to the horizontal. At the start of the slope, the speed of the sledge is 4.2 m s^{-1}. The coefficient of dynamic friction of the sledge on the snow is 0.11.



1c. Show that the acceleration of the sledge is about −2 m s^{-2}. *[3 marks]*

$F_{net} = m \cdot a$

$F_{net} = -F_f - W_x = -\mu N - W \cdot \sin\theta$

$N = W \cos\theta$

$F_{net} = -\mu \cdot m \cdot g \cdot \cos\theta - m \cdot g \cdot \sin\theta$

$m \cdot a = -\mu g (\cos\theta + \sin\theta) \cdot m$

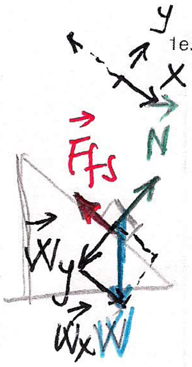
$a = -\mu g (\cos\theta + \sin\theta)$

1d. Calculate the distance along the slope at which the sledge stops moving. Assume that the coefficient of dynamic friction is constant. *[2 marks]*

$v^2 = u^2 + 2 a \cdot s$

$s = \dfrac{v^2 - u^2}{2a}$

$s = 4.4 m \simeq 4 m$



1e. The coefficient of static friction between the sledge and the snow is 0.14. Outline, with a calculation, the subsequent motion of the sledge. *[2 marks]*

Maximum of static friction force

$F_{fs} = \mu_s \cdot N = \mu_s \cdot m \cdot g \cdot \cos\theta$

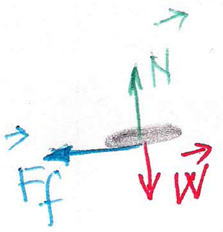
$W_x = mg \cdot \sin\theta$

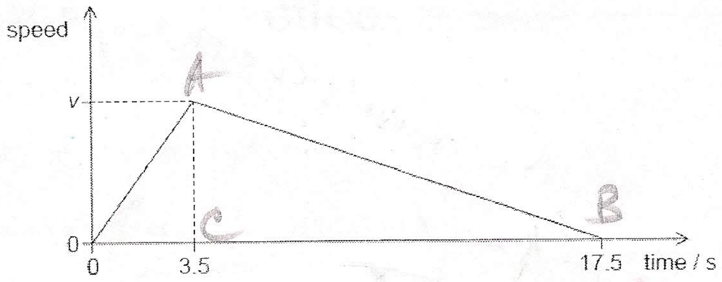
Which force is bigger?

$\dfrac{F_{fs}}{W_x} = \dfrac{\mu_s \cdot m \cdot g \cdot \cos\theta}{mg\sin\theta} = \dfrac{\mu_s \cdot \cos\theta}{\sin\theta} > 1$

The sledge will not move as the maximum static friction is bigger than the component of the weight down on the slope

Curling is a game played on a horizontal ice surface. A player pushes a large smooth stone across the ice for several seconds and then releases it. The stone moves until friction brings it to rest. The graph shows the variation of speed of the stone with time.





The total distance travelled by the stone in 17.5 s is 29.8 m.

2a. Determine the coefficient of dynamic friction between the stone and the ice during the last 14.0 s of the stone's motion. *[3 marks]*

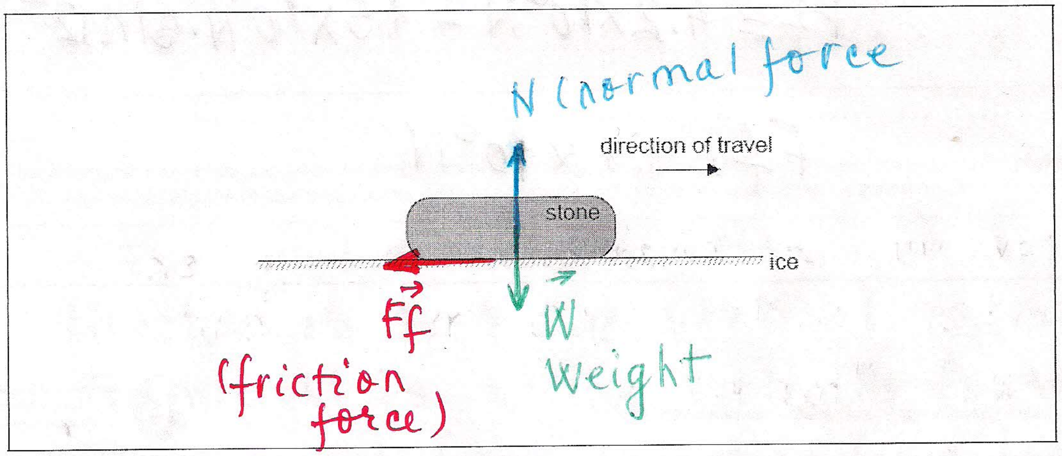
The displacement is equal with the area under the graph.

$s = \frac{3.5\,s \cdot v}{2} + \frac{v \cdot 14\,s}{2} = \frac{v \cdot 17.5\,s}{2}$

$v = \frac{2s}{17.5\,s} = 3.41\ m \cdot s^{-1}$ $\quad a = \frac{3.41\,m/s}{14\,s} = 0.243\,m \cdot s^{-2}$

$F_{NET} = -F_f \quad m \cdot a = -\mu m g \quad \mu = -\frac{a}{g} = \frac{0.243\,m/s^2}{9.81\,m/s^2} = 0.025$

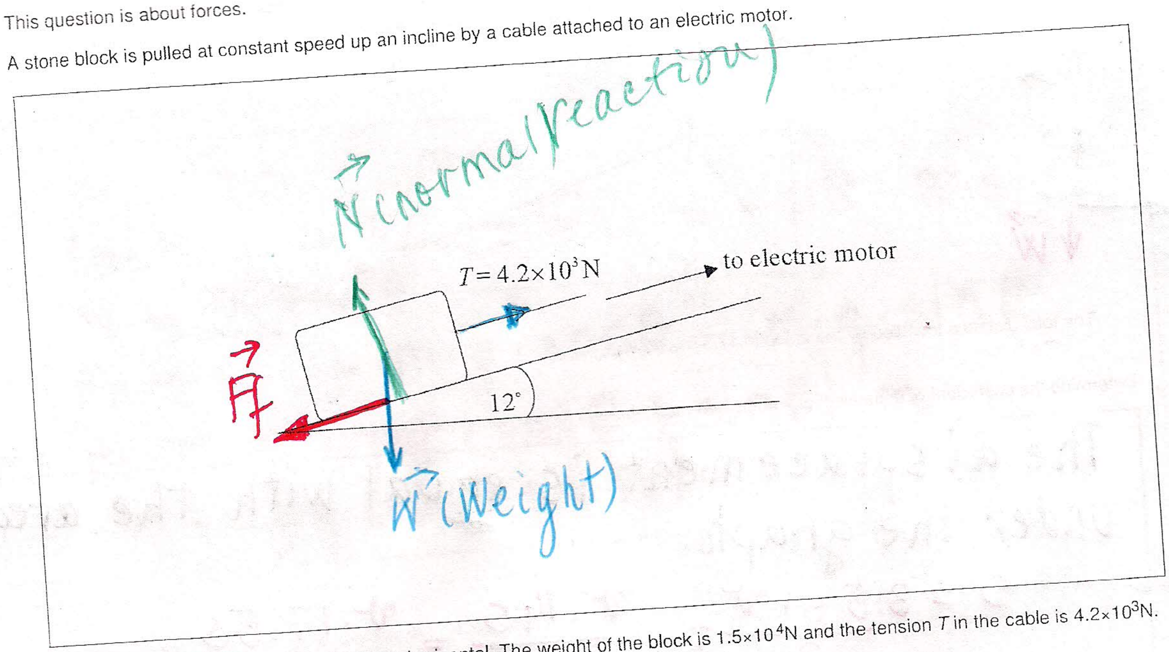
2b. The diagram shows the stone during its motion **after** release. *[3 marks]*



Label the diagram to show the forces acting on the stone. Your answer should include the name, the direction **and** point of application of each force.

This question is about forces.

A stone block is pulled at constant speed up an incline by a cable attached to an electric motor.



The incline makes an angle of 12° with the horizontal. The weight of the block is 1.5×10^{4} N and the tension T in the cable is 4.2×10^{3} N.

3a. On the diagram draw and label arrows that represent the forces acting on the block. [2 marks]

3b. Calculate the magnitude of the friction force acting on the block. [3 marks]

$$F_f = T - W\sin\theta$$

$$F_f = 4.2\times10^{3}\,N - 1.5\times10^{4}\,N \cdot \sin 12^{\circ}$$

$$F_f = 1.1\times10^{3}\,N$$