Physics 2204
Unit 2: Dynamics
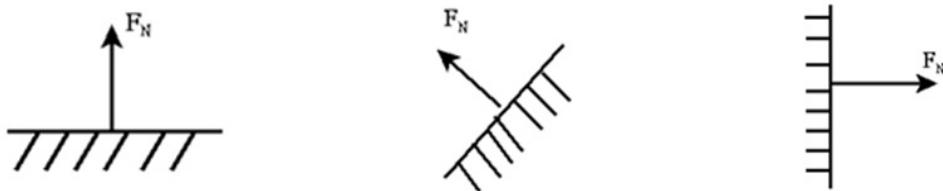## Worksheet 9: Frictional Force
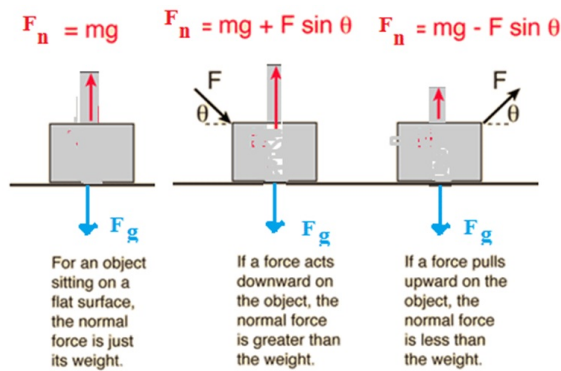
Student Name:_____

The Normal force (F_N): the reaction force of surface pushing back when the body receiving the action force is a surface.

Note that the Normal force is always perpendicular to the surface

Three different ways to calculate normal force"

$$F_n = mg \qquad F_n = mg + F \sin \theta \qquad F_n = mg - F \sin \theta$$

For an object sitting on a flat surface, the normal force is just its weight.

If a force acts downward on the object, the normal force is greater than the weight.

If a force pulls upward on the object, the normal force is less than the weight.

Example 1:

What is the normal force for a 10 kg Book resting on a table?

Example 2:

A 2.3 kg box is sitting on a desk. A string is pulling the box straight up with a force of 8.5 Find the normal force.

Example 3:

A 4.5 kg box is being pulled to the right by a 30 N force at 25 degrees above the horizontal. What is the normal force

Example 4:

What is the normal force acting on a 2.0 kg mass which is being pushed by a force of 41 N along a rigid handle that makes an angle of 36º to the horizontal?

Friction (F$_{fr}$) is the force that results when one object moves against another. Friction ALWAYS opposes motion.

There are two factors that may affect friction:

1) **Normal force (F$_n$):** the force that presses two surfaces together. In most cases, the normal force will be the weight of an object that is resting on the surface.

2) **Coefficient of friction (μ):** Smoothness of the surface.

The formula for Force of friction is:

Force of Friction = (normal force) x (coefficient of friction)

Or

$$F_f = F_n \mu$$

There are two types of coefficients of friction:

μ$_k$ = coefficient for kinetic friction

μ$_s$ = coefficient for static friction

Static friction > Kinetic friction: Therefore, it takes more force to start moving an object

Example 5:

A force of 42 N is needed to start a box sliding across the floor. The weight of the box is 55 N.

A)   Draw a FBD for the box.

B)   How large is the force of friction?

C)   Is the frictional force static or kinetic?

D)   What is the coefficient of friction

Example 6:

The coefficient of kinetic friction and the crate is 0.4000. The crate has a mass of 75 kg.

A)   What is the force of kinetic friction?

B)   What force is needed to keep the object moving at a constant velocity?

Example 7:

A hockey puck has a mass of 1.0 kg. The coefficient of kinetic friction between the puck and ice is 0.15. A force of 2.6 N is applied horizontally to the puck to push it to the right.

A)   Draw a FBD for the box.

B)   What is the normal force acting on the puck?

C)   What is the force of kinetic friction?

D)   What is the net force acting horizontally on the puck?

E)   What is the acceleration of the puck?

Example 8:

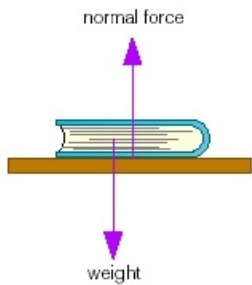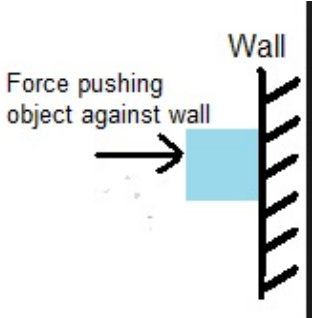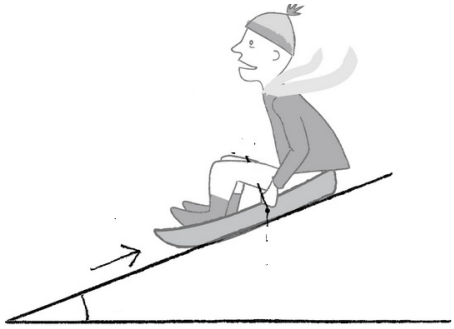A force of 185 N at an angle of 30o is needed to drag a 2200 N sleigh at a fixed speed.

A)   Draw a FBD for the sled.

B)   What is the normal force acting on the puck?

C)   What is the force of kinetic friction?

D)   What is the coefficient of kinetic friction?
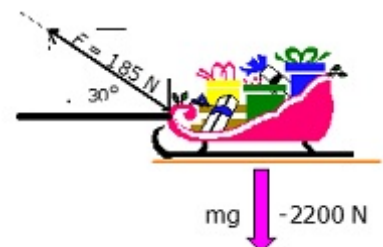
PART A: MULTIPLE CHOICE

Instructions: Shade the letter of the correct answer on the computer scorable answer sheet provided

1.   What is a normal force?

       (A)   The same as a frictional force.
       (B)   It is equivalent to the weight of an object.
       (C)   It is a force that acts perpendicular to the contact surface.
       (D)   It is equivalent to inertia

2.   Which of the following does not show a normal force?

(A)	(B)
(C)	(D)

3.   What is the normal force of a 1.5 kg physics textbook resting on a table?

       (A)   0.15 N
       (B)   1.5 N
       (C)   9.8 N
       (D)   15 N

4.   The free body diagram below represents an object sliding down a frictionless surface. Which vector represents the normal force?

       (A)   A
       (B)   B
       (C)   C
       (D)   D
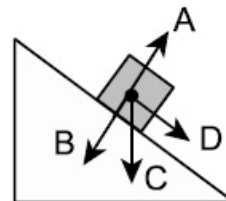
5.   The free body diagram below represents an object sliding down a rough incline. Which vector represents the normal force?

       (A) F_1
       (B) F_2
       (C) F_3
       (D) F_4

4
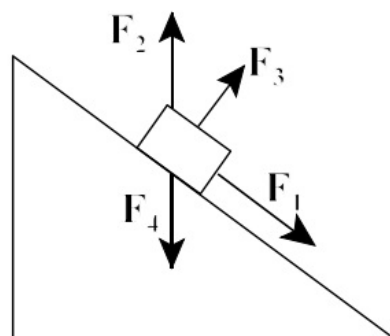
6. A box is pulled on a smooth horizontal floor at a constant velocity. If the mass of the box is 4.9 kg, what is the normal force?
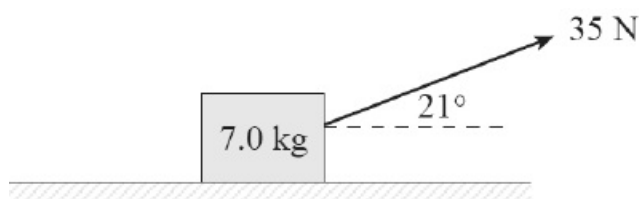
(A) 0.50 N
(B) 4.9 N
(C) 9.8 N
(D) 48 N

4.0 kg

7. A box is pulled on a smooth horizontal floor with a 1.00×10^2 N force, at 37.0° above the horizontal. If the mass of the box is 40.0 kg, what is the normal force?
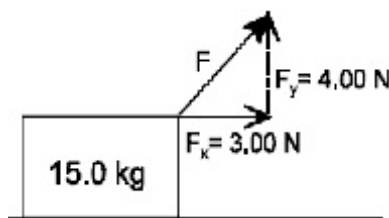
(A) 292 N
(B) 312 N
(C) 332 N
(D) 393 N

8. In the diagram below, what is the normal force acting on the box?

(A) 36 N
(B) 56 N
(C) 69 N
(D) 81 N

35 N

21°

7.0 kg

9. A 15.0 kg box is resting on a horizontal surface with an applied force, F, as shown. What is the magnitude of the normal force acting on the box?

(A) 11 N
(B) 15 N
(C) 143 N
(D) 147 N

F
$F_y = 4.00$ N
$F_x = 3.00$ N
15.0 kg

10. What normal force acts on the object shown, when it is pulled to the right on a frictionless surface by a force of 211 N at an angle of 25.0° to the horizontal?

(A) 201 N
(B) 303 N
(C) 392 N
(D) 481 N
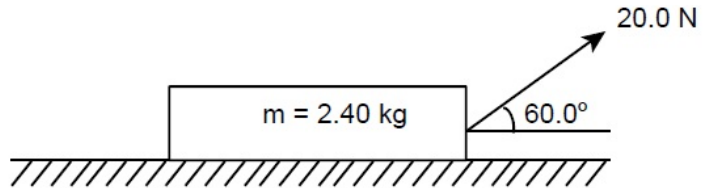
211 N
25.0°
40.0 kg
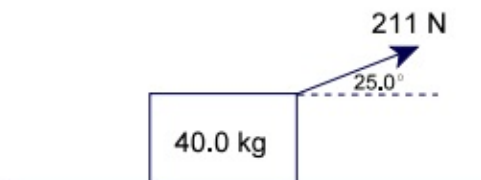
11. If a force of 45 N is applied at a 35° angle above the horizontal to pull a 21 kg crate forward, what is the normal force on the crate?

(A) 170 N
(B) 180 N
(C) 210 N
(D) 230 N

45 N
35°
m = 21 kg
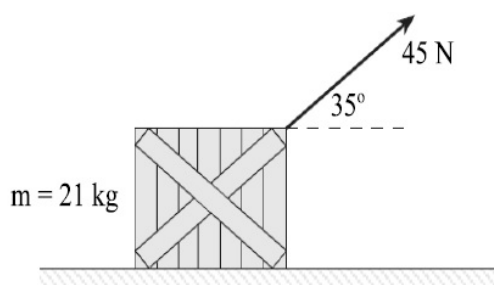
12. What is the normal force in the diagram below?

(A) 6.20 N
(B) 10.0 N
(C) 13.2 N
(D) 23.5 N

20.0 N

m = 2.40 kg   60.0°

13. A 25 kg chair is pushed across a frictionless horizontal floor with a force of 200 N, directed 20° below the horizontal. The magnitude of the normal force of the floor on the chair is:

(A) 25 N
(B) 180 N
(C) 250 N
(D) 310 N

14. What is a force that opposes motion between two surfaces that are in contact?

(A) Acceleration
(B) Friction
(C) Motion
(D) Velocity

15. Which one of the following is an advantage of friction?

(A) It holds your feet on the ground while you walk.
(B) It requires extra effort to push a box across a floor.
(C) Friction between an aircraft and the air causes extra fuel to be used.
(D) In a car, it wears out the brake pads.
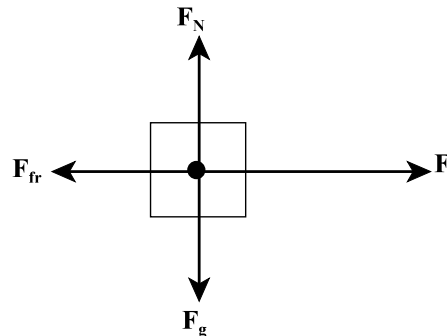
16. Which of these is opposed by kinetic friction?

(A) Book sitting on a table
(B) Box sliding on a floor
(C) Cat standing in a yard
(D) Child leaning on a building

17. What is the frictional force for a 24 kg object on a horizontal surface if $\mu_k = 0.25$?

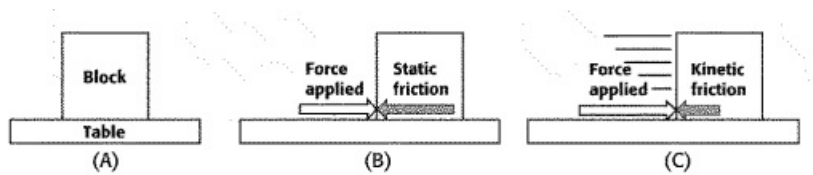(A) 6.0 N
(B) 24 N
(C) 59 N
(D) 96 N

18. Which represents the coefficient of kinetic friction for the diagram below?

(A) $\dfrac{F}{F_g}$

(B) $\dfrac{F_{fr}}{F}$

(C) $\dfrac{F_N}{F_g}$

(D) $\dfrac{F_{fr}}{F_N}$

F_N

F_{fr} F

F_g

Use the figures below to answer questions 19 to 21

(A)   (B)   (C)

19.   Look at Figure A. Why does the block not move?

(A)   Because of frictional force
(B)   Because no forces are applied
(C)   Because of kinetic friction
(D)   Because of surface friction

20.   Look at Figure C. The block is moving. What force acts against the movement of the block?

(A)   Gravity
(B)   Rolling kinetic friction
(C)   Sliding kinetic friction
(D)   Static friction

21.   Look at Figure B. What force keeps the block in place?

(A)   Kinetic friction
(B)   Force applied
(C)   Force greater than the force of static friction
(D)   Static friction

22.   What is the force of friction on a 10.0 kg object sliding at a constant speed along a horizontal surface if $\mu_k = 0.250$?

(A)   2.50 N
(B)   24.5 N
(C)   97.8 N
(D)   392 N

23.   Which force slows a puck gliding along rough ice?

(A)   Kinetic friction
(B)   Normal force
(C)   Static friction
(D)   Weight

24.   What is the force of static friction between a 100.0 kg box and a table if the coefficient of static friction is 0.010?

(A)   0.098 N
(B)   9.8 N
(C)   98 N
(D)   980 N

25.   An object at rest on a table experiences a normal force of 12 N (up). If the maximum static frictional force is 8.0 N, what is the coefficient of static friction between the object and the table?

(A)   0.67
(B)   0.96
(C)   8.0
(D)   96
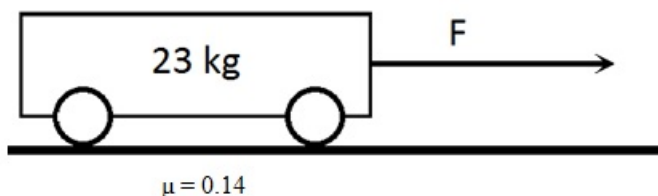
26. Force F_A causes an object to move with a constant speed over a rough surface as shown. How does the force of friction f_f compare to F_A?

    (A) $f_f = F_A$
    (B) $f_f > F_A$
    (C) $f_f < F_A$
    (D) $f_f = 0$

27. A 23 kg cart is being pulled by a horizontal force. The coefficient of kinetic friction between the cart and the surface is 0.14. What is the force of kinetic friction acting on the cart?

    (A)   3.2 N
    (B)   32 N
    (C)   160 N
    (D)   230 N

28. A tool cabinet experiences a normal force of 610 N and a frictional force of 150 N. What is the coefficient of friction?

    (A)   0.016
    (B)   0.25
    (C)   0.41
    (D)   2.4

29. A horizontal force of 7.104 N is applied to a block of wood with a mass of 1.2 kg. The coefficient of friction between the block and the surface on which it is resting is $\mu = 0.4$. What is the acceleration?

    (A) 0.592 m/s^2
    (B) 2 m/s^2
    (C) 2.5 m/s^2
    (D) 23 m/s^2

30. A block of wood on a horizontal surface accelerates at 0.2 m/s^2 when a force of 24.6 N is applied to it. If the object has a mass of 10 kg what must be the value of μ?

    (A)   0.081
    (B)   0.231
    (C)   0.492
    (D)   12.3

31. The driving force of a 45 kg jet ski is 657 N [right]. If the jet ski reaches 56 km/hr after 1.0 s, how much friction must there be?
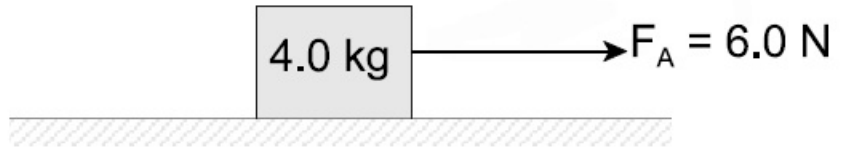
    (A)   78 N
    (B)   43 N
    (C)   15 N
    (D)   0 N

32. What is the force of friction on a 10.0 kg object sliding at a constant speed along a horizontal surface if $\mu_k = 0.250$?
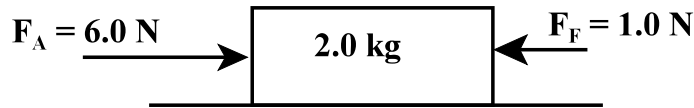
    (A)   2.50 N
    (B)   24.5 N
    (C)   97.8 N
    (D)   392 N

33.　What is the magnitude of the acceleration for the object below if $F_f = 1.0$ N?

(A)　0.80 m/s^2
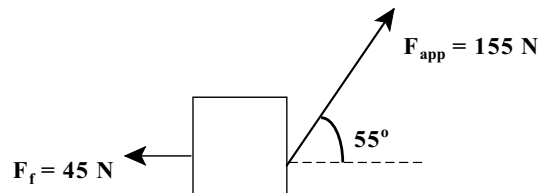(B)　1.3 m/s^2
(C)　1.5 m/s^2
(D)　1.8 m/s^2

4.0 kg ⟶ $F_A = 6.0$ N

34.　What is the magnitude of the acceleration for the object shown below?

$F_A = 6.0$ N ⟶ 2.0 kg ⟵ $F_F = 1.0$ N

(A)　2.5 m/s^2
(B)　3.0 m/s^2
(C)　9.8 m/s^2
(D)　12 m/s^2

35.　What is the magnitude of the net horizontal force acting on the object below?

$F_{app} = 155$ N

$55°$

$F_f = 45$ N

(A)　44 N
(B)　82 N
(C)　1.1×10^2 N
(D)　1.3×10^2 N

36.　What is the net horizontal force acting on the object below?

(A)　3.07 N
(B)　8.88 N
(C)　10.0 N
(D)　12.0 N

$F_A = 12.0$ N

$F_f = 2.00$ N

$25.0°$
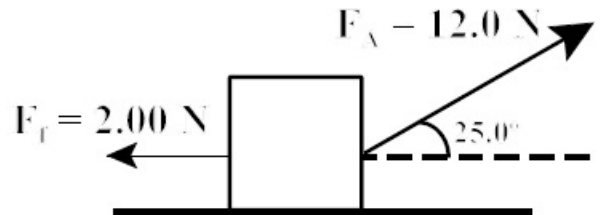
37.　What is the magnitude of the acceleration of the object below if the force of friction is 7.0 N?

(A)　0.57 m/s^2
(B)　2.0 m/s^2
(C)　2.3 m/s^2
(D)　2.7 m/s^2

$F_A = 30.0$ N

a

$25°$

10.0 kg
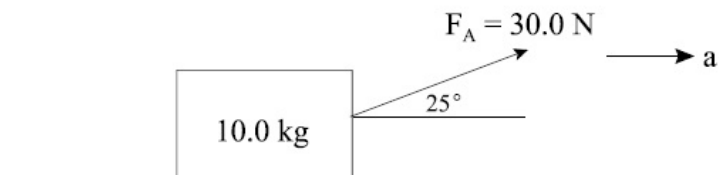
PART B: WRITTEN RESPONSE

1.   A 3.00 kg box slides along a smooth (i.e. frictionless) horizontal surface. Draw an arrow to show the direction of the reaction force of the surface on the box. What is the magnitude of the normal force?
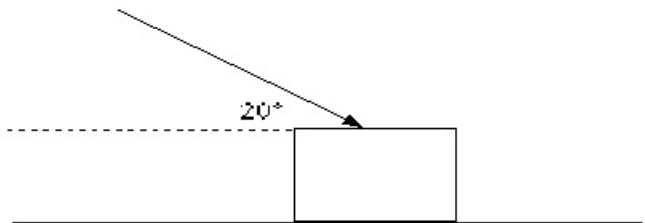
motion
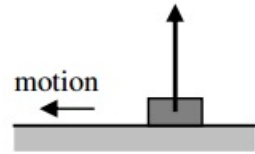
2.   A 6.00 kg box is resting on a table.

(A) What is the normal force of the box?

(B)   You push down on the box with a force of 8.00N. What is the magnitude of the normal force of the table on the box?

(C)   What would be the normal force on the box if you pulled up on the box with a force of 8.00N?

(D)   What would be the normal force on the box if you pulled up on the box with a force of 25.0N at an angle of 40º with the horizontal?

3.   A 3.00 kg box is pulled along a smooth horizontal surface with a force of 15 N at 30° to the horizontal. Draw an arrow to show the direction of the reaction force of the surface on the box. What is the magnitude of the normal force?

15 N
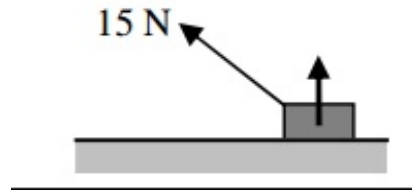
4.   An applied 25 N force pushes on a 5.0 kg block resting on a frictionless horizontal surface. The force is directed downwards at an angle of 20°. What is the normal force?

20°

5.   Do the following:

A.   A force of 13.2 N is applied to a dynamics cart with a mass of 1.50 kg. A frictional force of 4.7 N resists the motion. Calculate the acceleration of the cart.

B.   A horizontal force of 150.0 N is applied to a block with a mass of 70 .0 kg. The resulting acceleration is 1.30 m/s2. What is the frictional force which resists the motion?

6.   A block of wood with a mass of 1.0 kg sits on a table. A horizontal force of 10.0 N is applied to the block. The coefficient of friction between the block and the table is 0.300.

A.   Calculate the frictional force that resists the motion.
B.   Calculate the net force that caused the acceleration.
C.   Calculate the acceleration.

7.	A puck with a mass of 0.200 kg rests on the ice. The coefficient of friction between the ice and the puck is 0.05. What will be the acceleration if a horizontal force of 0.22 N is applied to the puck?

8.	A force of 10.0 N, when applied to a brick with a mass of 0.500 kg, results in an acceleration of 0.40 m/s^2.

	A)	Calculate the net force that caused the acceleration.
	B)	Calculate the frictional force.
	C)	Calculate the coefficient of friction between the block and the table.

9.	Examine the following:

A)	A concrete block has a mass of 15.0 kg. The coefficient of friction between the block and the floor is 0.90. Calculate the frictional force required to keep the block moving uniformly.

B)	The coefficient of friction between a pair of sneakers and the floor is 1.2. If you have a mass of 65 kg and are standing (in your sneakers) on a horizontal floor, what force will be needed to drag you along the floor?

C)	The coefficient of friction between the tires of your bike and the road is 0.90. If you lock the wheels what frictional force will be required to drag you along? Assume that you and the bike have a combined mass of 120 kg.

10.	The coefficient of kinetic friction between the tires of a sports car and the TCH is 0.20. The car has a mass of 950.0 kg. Suppose that the driver "locks" the wheels. What frictional (braking) force will be applied to the car as a result?

11.	A skater has a mass of 72.0 kg. The coefficient of friction between the skates and the ice is 0.012. What force is needed to keep the skater moving uniformly across the ice?

12.	A heavy box of weight 555 N is being pushed across the floor with a horizontal force of 105 N. It is moving at a fixed speed of 15 cm/s. Determine

	(A) the force of friction acting on the box.
	(B) the normal force on the box.

13.	A 65 kg skater is gliding along the ice at a constant speed of 4.00 m/s when he hits a rough patch. The coefficient of kinetic friction between the rough ice and the skate blades is 0.10. Calculate how far the skater will travel on the rough ice before stopping.

14.	 A 35.0 kg anchor is dragged with a horizontal force of 125 N so that the anchor accelerates at 2.3 m/s^2 for a short period of time. What is the coefficient of kinetic friction?

15.	 Having computed μ_k in question 14, determine what the acceleration of the anchor would have been if the rope had made an angle of 60º with the wharf.

16.	After a successful hunt, a 210 kg caribou is loaded aboard a 35 kg sled and the hunter drags the load with a rope over her shoulder. The rope makes an angle of 55º with the ground. The coefficient of kinetic friction between the sled runners and the snow is 0.32. Determine the force in the rope that

	(A) maintains a constant speed of 2.2 m/s
	(B) results in the sled accelerating at 1.0 m/s^2

17.   A 23.5 kg lawn mower is pushed with a force of 225 N as shown ($\mu k = 0.510$).

225 N

30.0°

$\mu_k = 0.510$
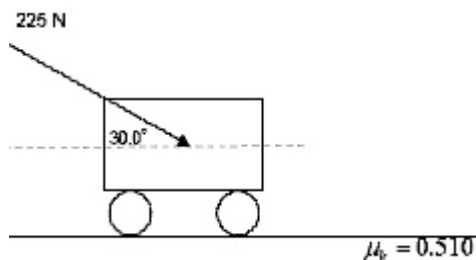
i) Draw a free body diagram for the lawn mower.

ii) Calculate the magnitude of the acceleration of the lawn mower.

18.   In the diagram below, a 24.0 kg box is pushed at a 25.0° angle with an applied force of 50.0 N. The coefficient of kinetic friction is 0.100.

$F_A = 50.0$ N

25.0°

24.0 kg
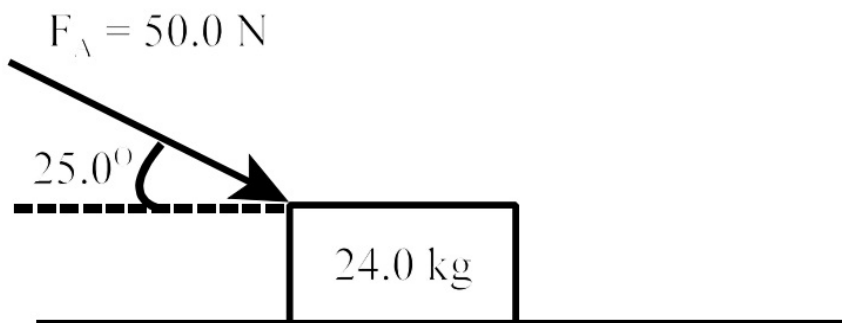
(i) Draw a free body diagram for the box. Clearly label ALL forces.
(ii) What is the acceleration of the box?

19.   A 5.0 kg block is laid flat on an horizontal table ($\mu_K = 0.10$). The block is pulled to the right with a force of 25 N, at 15° above the horizontal.

(i)   Sketch the free body diagram.

(ii)   What is the magnitude of the acceleration of the block?