Impuse-Momentum Principle:

Let 'F' is the force acting on a body of mass m.

From, newtons second law; F = ma

But a = dv/dt

F = m dv/dt

F dt = m dv

Integrating on both sides

$\int_0^t F\,dt = \int_u^v m\,dv$

$F\,[t]_0^t = m\,[v]_u^v$

Ft = m(v-u)

Ft = mv – mu

Imulse = Final momentum – Initial momentum

Impulse = change in momentum

" **Impulse-momentum principle** states that impulse of force acting during a time interval is equal to the change in momentum of a particle during the same interval of time".

A glass marble whose weight is 0.2N, falls from a height of 10m and rebounds to a height of 8m. Find the impulse and the average force between the marble and the floor, if the time during which they are in contact is 1/10 of a second?

For a case of marble falling freely

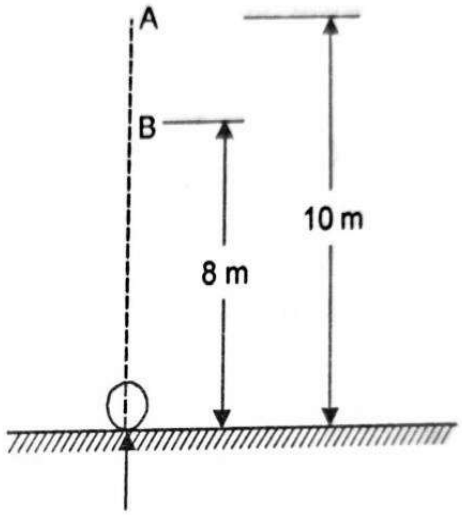
It will strikes the ground with a velocity of say v.

From, $v^2 - u^2 = 2as$

$v^2 - 0^2 = 2gh$

$v = \sqrt{(2gh)}$

$v = \sqrt{(2 \times 9.81 \times 10)} = 14.007$ m/sec



for rebound condition the velocity = $v^2 - u^2 = 2as$

$0^2 - u^2 = -2gh$

$U = \sqrt{(2gh)} = \sqrt{(2 \times 9.81 \times 8)} = 12.528$ m/sec

From, impulse-momentum principle

$I = m(v - u)$

$I = (W/g)(v - u)$

$I = (0.2/9.81)(12.52 - (-14.007))$

$I = 0.541$ N-sec

$F \times t = 0.541$

$F \times (1/10) = 0.541$

$F = 0.541 \times 10 = 5.41$N

A 1N ball is bowled to a bats man. The velocity of ball was 20 m/sec horizontally just before batsman hits it. After hitting it went away with a velocity of 48 m/sec at an inclination of 30° to horizontal as shown in figure. Find the average force exerted on the ball by the bat if the impact lasts for 0.02 sec.

Let P_x is horizontal component of force

P_y is vertical component of force

Impulse-momentum principle in horizontal direction:

$P_x t = m(v - u)$

$P_x (0.02) = (W/g) (48 \cos 30^\circ - (-20))$

$P_x (0.02) = (1/9.81) (48 \cos 30^\circ + 20)$

$P_x = 313.81N$

Impulse-momentum principle in vertical direction:

$P_y t = m(v - u)$

$P_y (0.02) = (W/g) (48 \sin 30 - 0)$

$P_y (0.02) = (1/9.81) (48 \times 0.5)$

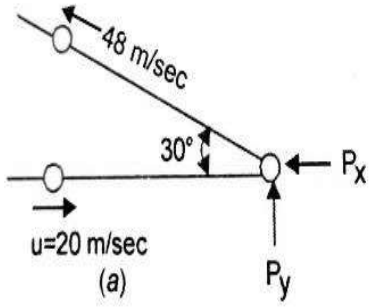
$P_y = 122.32N$

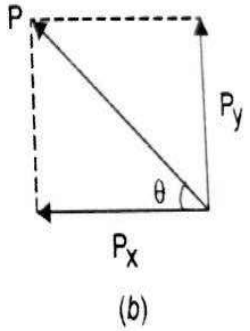
$P = \sqrt{(P_x)^2 + (P_y)^2}$

$P = \sqrt{(313.81)^2 + (122.32)^2} = 336.81N$

$\tan\theta = P_y/P_x = 122.32/313.81$

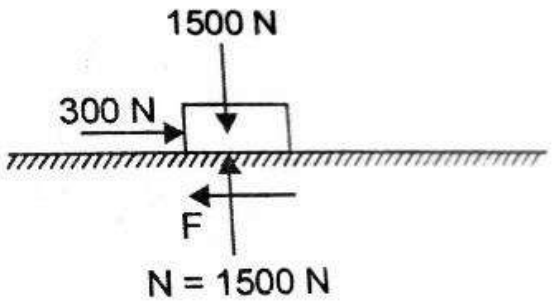
$\theta = 21.30$





A 1500N block is in contact with a level plane, μ = 0.1 if the block is acted upon by a horizontal force of 300N, what time will elapse before the block reaches a velocity of 16 m/sec starting from rest? if 300N force is removed, how much longer will the block continues to move? Use Impulse-momentum principle?

W = N
N = 1500N
F = μN = 0.1 x 1500 = 150N
From, Impulse-momentum principle
F x t = m(v – u)
(300 – F) t = (W/g) (16 – 0)
(300 – μN) x t = (1500/9.81) x 16
(300 – 0.1 x 1500) t = (1500/9.81) x 16
t= 16.31 sec



If 300N force is removed:
W = N = 1500N
F = μN = 0.1 x 1500 = 150N
From, impulse-momentum principle
F x t = m(v – u)
-150 x t = (1500/9.81) (0-16)
t = 16.31 sec
i.e. the block will move for another 16.31 sec before it comes to rest.

A block weighing 130N is on an incline whose slope is 5 vertical to 12 horizontal. Its initial velocity down the incline is 2.4 m/sec. What will be its velocity 5 sec later?

$\mu = 0.3$

$\tan\theta = 5/12$

$\theta = 22.62^\circ$

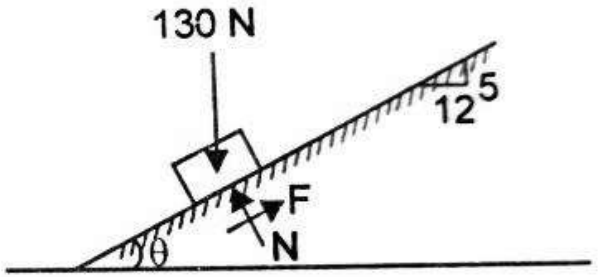
From, impulse-momentum principle

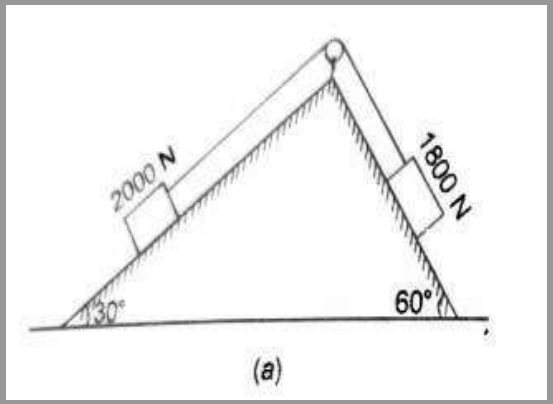
$F \times t = m(v-u)$

$(W \sin\theta - F)\, t = (W/g)(v-u)$

$(130 \sin 22.62 - 36) \times 5 = (130/9.81)(v - 2.4)$

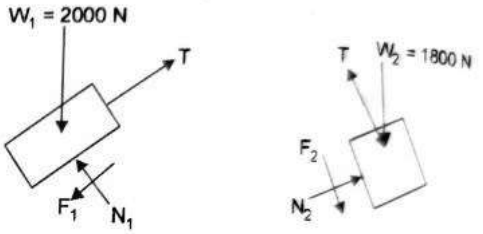
$v = 7.68$ m/sec



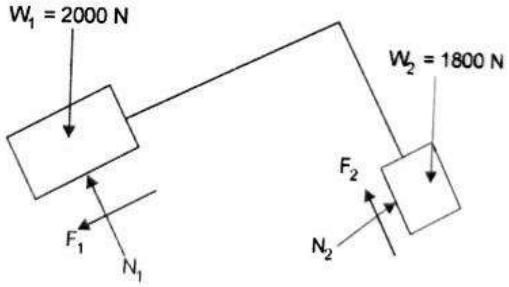


Determine the time required for weights shown in figure to attain a velocity of 9.81 m/sec. What is the tension in the chord? μ = 0.2 for both the planes, assume the pulleys as frictionless.

$N_1 = 2000 \cos 30^\circ = 1732.05N$
$F_1 = \mu N_1 = 0.2 \times 1732.05 = 346.41N$
Initial velocity u = 0
Final velocity v = 9.81 m/sec
From, Impulse-momentum principle
F x t = m(v-u)
$(T - 2000\sin 30 - 346.41)\, t = (2000/9.81) \times (9.81-0)$
$(T - 2000\sin 30 - 346.41)\, t = (2000/9.81) \times 9.81$
$(T - 1346.41)\, t = 2000$ .....(1)



$N_2 = 1800 \cos 60 = 900N$
$F_2 = \mu N_2 = 0.2 \times 900 = 180N$
From, impulse-momentum
F x t = m(v-u)
$(1800 \sin 60 - T - F2)\, t = (1800/9.81)\, (9.81-0)$
$(1800 \sin 60 - T - 180)\, t = 1800$
$(1378.85 - T)\, t = 1800$ .....(2)
(1)/(2)
$2000/1800 = (T - 1346.41)\, t / (1378.85 - T)\, t$
T = 1363.48N
t = 117.11 sec



Determine the tension in the strings and the velocity of 1500N block shown in figure? 5 seconds after starting from

(a) Rest

(b) Starting with a down ward velocity of 3m/sec

Assume pulleys are smooth and weightless.

From the FBD it is clear that when 1500N block moves a distance s, the 500N block will moves a distance of 2s

Similarly, if the velocity of 1500N block is v m/sec and that of 500N block will be 2v m/sec.

Let T is the tension in the chord connecting 500N block and the tension in the wire connecting 1500N block will be 2T.

Case1: starting from rest

Initial velocity u= 0

Final velocity =v

From, impulse-momentum principle

$F \times t = m(v-u)$

$(T - 500)t = (500/9.81)(2v - 0)$

$(T - 500)\ 5 = (500/9.81)(2v)$

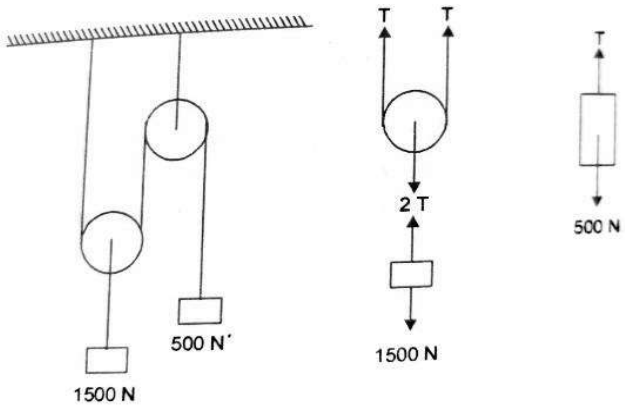
$(T - 500) = 200v / 9.81$ .....(1)

Impulse-momentum for 1500N block

$(1500 - 2T)\ t = (1500/9.81)(v-0)$

$(1500-2T)\ 5 = (1500/9.81)\ v$

$1500 - 2T = 300v / 9.81$ .....(2)



From (1) and (2)

On solving, v = 7.007 m/sec and T = 642.86N

Case2: initial velocity u = 3m/sec

From, impulse-momentum principle for 500N block

F x t = m(v-u)

(T-500) 5 = (500/9.81) (2v-3)

T – 500 = 100(2v-3) / 9.81 .....(3)

Impulse-momentum for 1500N block

F x t = m(v-u)

(1500-2T0 5 = (1500/9.81) (v-3)

1500-2T = (300/9.81) (v-3).....(4)

From, (3) and (4)

v= 9.15m/sec and T = 655.96N

The system shown in figure has a right ward velocity of 3 m/sec. Determine velocity after 5 seconds. μ=0.2 assume pulleys to be frictionless.

N1 = 500
F1 = μN1 = 0.2 x 500 = 100N
N2 = 1000 cos30° = 866.03N
F2 = μN2 = 0.2 x 866.03 = 173.2N
From, Impulse-momentum principle
(2000 – F1 – 1000sin30 – F2) t = ((2000+500+1000)/9.81) (v-u)
(2000 – 100 – 1000 sin30° - 173.2) 5 = (3500/9.81) (v-3)
v= 20.19 m/sec

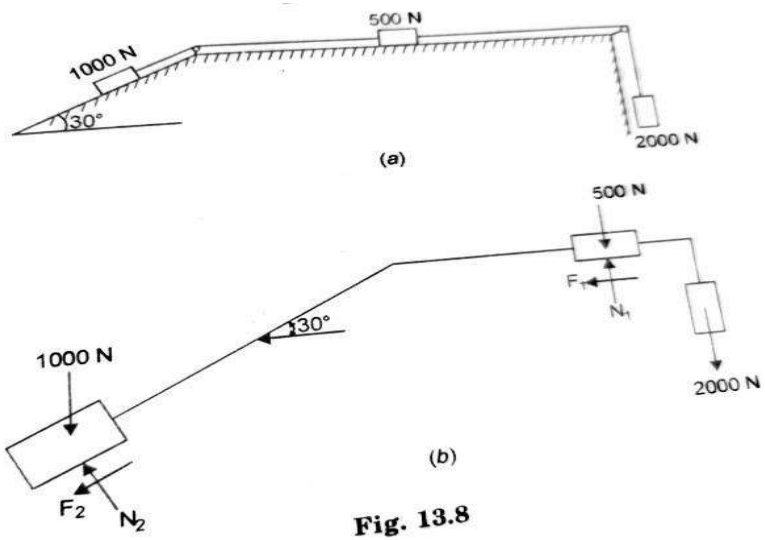


Fig. 13.8