Fundamental Mechanics: Class Exam 2

day month 2025

Name: _____ **Total:** /70

Instructions

- There are 7 questions on 6 pages.
- Show your reasoning and calculations and always explain your answers.

Physical constants and useful formulae

$$g = 9.80\,\text{m/s}^2$$

Question 1

A 40 kg crate is initially at rest on the ground. It is then raised vertically by a rope which exerts a constant force. At an instant 3.0 s after the moment when it leaves the ground, it moves with speed 12.0 m/s. Neglecting air resistance, determine the tension in the rope.

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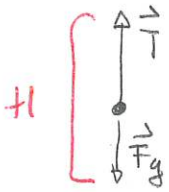


+1

$\Sigma F_{iy} = ma_y$] +1

$T - mg = ma_y$] +2

$T = mg + ma_y$ → requires acceleration

$t_f = 3s$
$y_f = 0$
$v_{yf} = 12\,cm/s$

$t_i = 0s$
$y_i = 0m$
$v_{iy} = 0m/s$

$v_{fy} = v_{iy} + a_y \Delta t$] +1

$\Rightarrow 12m/s = a_y\, 3.0s$

$\Rightarrow a_y = 4.0\,m/s^2$

+3

+2

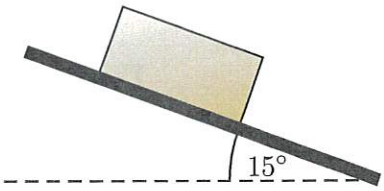
$T = m(g+a)$

$= 40kg\,(9.8m/s^2 + 4.0m/s^2)$

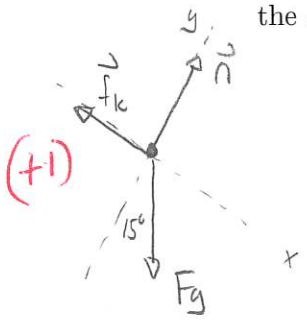
$T = 550\,N$

Question 2

A 45 kg crate slides down a ramp inclined at 15°. During a period of observation the crate moves with *constant speed of* 10m/s.



a) Determine the *coefficient of kinetic friction* between the crate and the ramp.



(+1)

$\Sigma F_{ix} = ma_x = 0$ (+1)

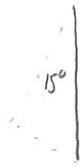
$\Sigma F_{iy} = ma_y = 0$ (+1)

$F_g = mg$ (+1)

$f_k = \mu_k n$ (+1)

	x	y
$\vec{n}$	0	n
$\vec{f}_k$	$-\mu_k n$	0
$\vec{F}_g$	$mg\sin 15^\circ$	$-mg\cos 15^\circ$

(+3)



$\Sigma F_{ix} = 0 \Rightarrow$ $mg\sin 15^\circ - \mu_k n = 0$ (+2) $\Rightarrow$ $mg\sin 15^\circ = \mu_k n$

$\Sigma F_{iy} = 0 \Rightarrow$ $-mg\cos 15^\circ + n = 0$ (+2) $\Rightarrow$ $n = mg\cos 15^\circ$

rest (+2)

$mg\sin 15^\circ = \mu_k mg\cos 15^\circ$

$\Rightarrow \mu_k = \frac{\sin 15^\circ}{\cos 15^\circ} = \tan 15^\circ \Rightarrow \mu_k = 0.26$

b) Suppose that the same crate on the same ramp was given a brief push from the top and, immediately after the push, it moved with speed 18m/s down the ramp. Which of the following is true *after the push* and as the crate slides down the ramp?

(+3)

i) The crate's speed is constant as time passes.

ii) The crate's speed increases as time passes.

iii) The crate's speed decreases as time passes.

The forces do not change from part a). Thus $\vec{F}_{net} = 0 \Rightarrow \vec{a} = 0$

$\Rightarrow$ constant speed

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Question 3

A book with mass m lies on the surface of a horizontal board. The board is lowered by hand and while this happens its speed decreases. Throughout the process, the book is in contact with the board. Which of the following (choose one) is true regarding the magnitude of the normal force, n, exerted by the board on the book?

i) $n = 0$
ii) $n = mg$
iii) $n > mg$
iv) $0 < n < mg$

The acceleration is ↑. This is because $\vec{v}$ is ↓ but speed decreases

$\vec{F}_{net} = m\vec{a}$

$\Rightarrow \vec{F}_{net}$ is ↑ $\Rightarrow n > mg$

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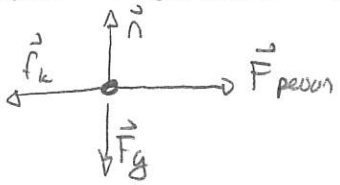
Question 4

Two people push identical crates along a rough horizontal surface. Both push horizontally. Yvette pushes her crate at a constant speed of 6.0 m/s and Zeus pushes his crate at a constant speed of 3.0 m/s. Let F_Y be the force exerted by Yvette and F_Z the force exerted by Zeus, *while the crates move at constant speed.* Which of the following (choose one) is true?

i) $F_Y = F_Z$
ii) $F_Y = 2F_Z$
iii) $F_Y = \frac{1}{2} F_Z$
iv) None of the above.

Explain your answer.

In each case acceleration $= 0 \Rightarrow \vec{F}_{net} = m\vec{a} = 0 \Rightarrow \vec{F}_{net} = 0$



→ moves

$F_{person} = f_k$

Since the friction forces are same, the person forces are the same.

Must mention friction...

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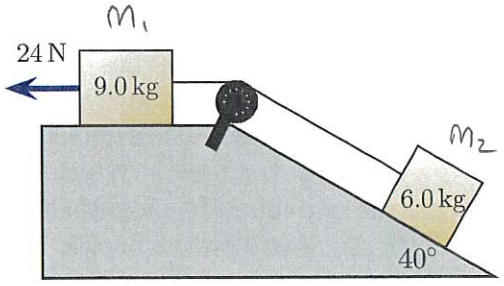
Question 5

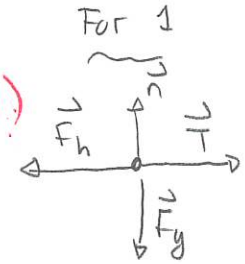
Blocks connected by a massless string are able to slide on the illustrated frictionless surfaces. The strings run parallel to the surfaces. A hand pulls with force 24 N horizontally to the left on the 9.0 kg block. In the following, ignore air resistance.

a) Determine the acceleration (including direction) of the block on the horizontal surface.



For 1

(+1)



$\sum F_{ix} = m_1 a_{1x}$ (+1)

$\sum F_{iy} = m_1 a_{1y} = 0$

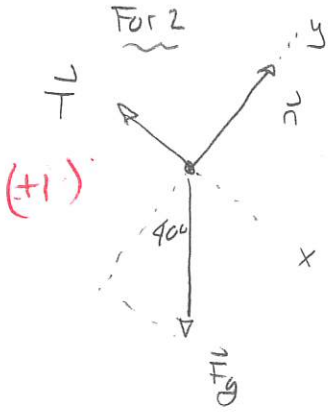
$\Rightarrow$ $T - 24N = m_1 a_{1x}$

~~+2~~ (+1) ~~(+2)~~ ~~(+1)~~

	x	y
F_N	0	0
F_g	0	$-mg$
T	T	0
24 N	-24 N	0

For 2

(+1)



$\sum F_{ix} = m_2 a_{2x}$ ~~(+1)~~

$\sum F_{iy} = m_2 a_{2y} = 0$

$\Rightarrow$ $-T + m_2 g \sin 40^\circ = m_2 a_{2x}$ F_g

~~+2~~ ~~(+1)~~ (+2)

	x	y
T	$-T$	0
F_N	0	0
$m_2 g \sin 40^\circ$	$m_2 g \sin 40^\circ$	$-m_2 g \cos 40^\circ$

~~(+3)~~ (+2)

Then $a_{1x} = a_{2x} = a$ (+1)

$\Rightarrow$ $T - 24N = m_1 a$ $\Rightarrow$ $T = 24N + m_1 a$

$-T + m_2 g \sin 40^\circ = m_2 a$

$-24N - m_1 a + m_2 g \sin 40^\circ = m_2 a$

$\Rightarrow$ $m_2 g \sin 40^\circ - 24N = (m_1 + m_2) a$

~~(+3)~~ ~~(+1)~~ ~~(+5)~~ ~~(+1)~~ (+5)

$6.0\,kg \times 9.8\,m/s^2 \sin 40^\circ - 24N = 15\,kg\, a$

$\Rightarrow$ $13.8N = 15\,kg\, a$

$\Rightarrow$ $a = \frac{13.8N}{15kg}$ $\Rightarrow$ $a = 0.92\,m/s^2$ direction $\longrightarrow$ (+1)

Question 5 continued ...

b) Determine the tension in the string connecting the blocks.

+6 for calculation plus actually considering blocks individually

$T = 24N + M_1 a$

$\Rightarrow T = 24N + 9.0kg \times 0.92 m/s^2$

$= 32N$

If blocks considered separately then +3

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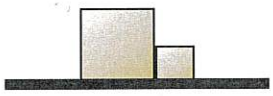
Question 6



Two springy rubber blocks lie on a horizontal frictionless surface as illustrated. The block on the left has a larger mass than that on the right. The blocks are compressed, then released and fly apart. During this they maintain contact with the surface. Consider only the period while the blocks "uncompress" (i.e. immediately after release but before they separate).

Let F_{right} be the magnitude of the force exerted by the left block **on the right block** and F_{left} that by the right block **on the left block**. Which of the following (choose one) is true while the blocks "uncompress"?

i) $F_{\text{right}} < F_{\text{left}}$.

ii) $F_{\text{right}} > F_{\text{left}}$.

iii) $F_{\text{right}} = F_{\text{left}}$. Newton's third law

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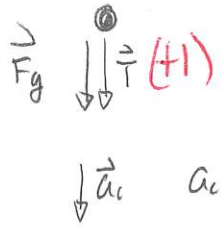
Question 7

A 0.100 kg ball swings *in a vertical circle* at the end of a string with length 0.800 m. The ball maintains a constant speed of 4.00 m/s throughout its motion.

a) Determine the tension in the string when the ball is at its highest point.



$\Sigma F_{iy} = m a_y$ (+1)

$\Rightarrow -T - mg = m\left(-\frac{v^2}{r}\right)$ (+2) $\Rightarrow T = m\frac{v^2}{r} - mg$

$\Rightarrow T = m\left[\frac{v^2}{r} - g\right]$

$\Rightarrow T = 0.100\,kg \times \left[\frac{(4.00\,m/s)^2}{0.800\,m} - 9.8\,m/s^2\right]$

(+1) $= 1.02\,N$

b) Is the tension when the ball is at its lowest point larger than, smaller than or the same as the tension when it is at the highest point? Explain your answer.

(+4)

$\Sigma F_{iy} = ma_y \Rightarrow T - mg = m\frac{v^2}{r}$

$\Rightarrow T = m\left[\frac{v^2}{r} + g\right]$

This is <u>larger</u> than $T_{upper} = m\left[\frac{v^2}{r} - g\right]$

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