PHY 231 Lecture Section C
Midterm 1

Name:

SID:

Please do not talk to or communicate with anyone other than myself regarding this midterm. Doing so will constitute prima facie evidence of cheating and will be subject to disciplinary action.

Show your work. I cannot read minds. Always put a box around your final answers, and always use the proper units with the answer.

There are three questions: The first is a set of multiple-choice questions testing your conceptual understanding. The other two are multi-part numerical questions. Answer all questions.

Useful laws and formulas

$\vec{x}(t)$ = position vector

$\Delta\vec{x}$ = displacement vector

$$\vec{v}_{av} = \frac{\Delta\vec{x}}{\Delta t} = \text{average velocity}$$

$$\vec{v}(t) = \frac{d\vec{x}}{dt} \qquad \vec{a}(t) = \frac{d\vec{v}}{dt}$$

Motion under constant $\vec{a}$

$$\vec{v}(t) = \vec{v}_0 + \vec{a}t$$

$$\vec{x}(t) = x_0 + \vec{v}_0 t + \frac{1}{2}at^2$$

Newton's Laws: (I) If $\vec{F}_{tot} = 0$ $\vec{a} = 0$

(II) $\vec{F}_{tot} = m\vec{a}$

(III) $\vec{F}_{12}$ = force due to 1 on 2

$\vec{F}_{21}$ = force due to 2 on 1

$$\vec{F}_{12} = -\vec{F}_{21}$$

Question 1a:

5 points

You are in an elavator which is going down and is in the process of slowing down to a stop. Which of the following alternatives are correct (more than one may be)? Take the upward direction to be positive.

(i) Your velocity and acceleration are both positive.

(ii) Your velocity is negative but the acceleration is positive.

(iii) Both velocity and acceleration are negative.

(iv) Velocity is zero but acceleration is -g.

You are moving down so $v_y < 0$. V_y increases towards zero with time so $a_y > 0$

Question 1b:

5 points

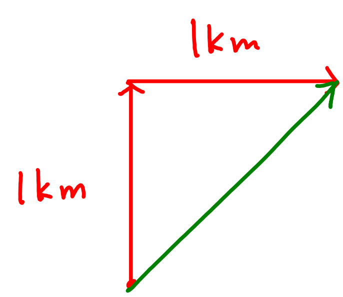
A swimmer swims due North for 1km in 10 minutes and immediately swims due East for 1km in 12 more minutes. Her average velocity is

(i) 1.51 m/s Northeast.

(ii) 1.51 m/s Southwest.

(iii) 1.66 m/s Northeast.

(iv) 1.07 m/s Northeast.



$$\Delta\vec{r} = 1000\,m\,\hat{i} + 1000\,m\,\hat{j}$$

$$\Delta t = 22 \text{ minutes} = 1320\,s$$

$$\vec{v}_{av} = \frac{1000}{1320}(\hat{i} + \hat{j}) \qquad |\vec{v}_{av}| = \frac{1000\sqrt{2}}{1320} = 1.07\,m/s$$

Question 1c:

5 points

You are in a car at rest and press the accelerator. You feel pressed back into the seat as it accelerates. This is because:

(i) The car's acceleration exerts a backward force on your body.

(ii) Inertia exerts a backwards force on your body.

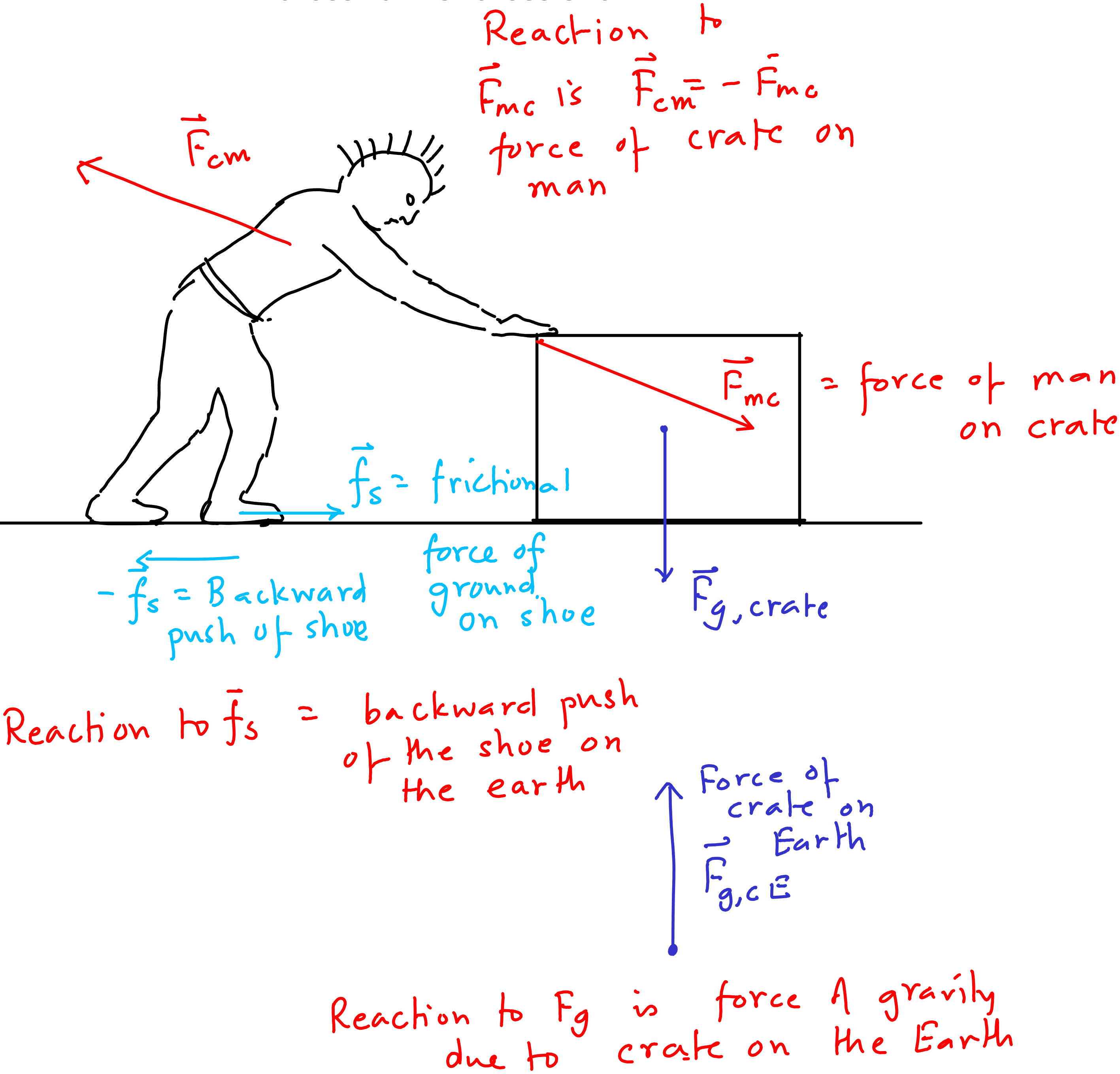
(iii) The car seat exerts a forwards force on your body to get you to accelerate with the car.

(iv) No force is exerted on your body but your body exerts a backwards force on the seat.

If no net force acted on you, you would remain in your initial state of motion, rest. To get you to accelerate with the car, a forward force needs to act on you. This is the force of the seat on your back.

Question 1d: A man is pushing a crate on the floor as shown. Draw, and describe in words, all the Newton's III Law reaction forces to the forces shown.

5 points



Question 2: A police car is going due West at 25m/s when the policeman sees a speeder going due East at 45m/s. The policeman slams on the brakes the instant he passes the speeder and decelerates to rest at 5m/s^2. He takes 1 sec to turn the car around and accelerates after the speeder at 3m/s^2 with his flashers on. As soon as the speeder sees the flashers he starts slowing down at 1m/s^2. Find out where and when they meet by following these steps.

Part a: Assume that x=0 and t=0 is when they pass each other. At what t1 does the police car come to rest? What are their positions and velocities at t1? (10 points)

Let s = speeder p = policeman

$v_{0s} = 45 m/s$ $v_{0p} = -25 m/s$

$a_p = +5 m/s^2$ + because v_p increases to 0

$v_p(t) = v_p(0) + at$ $v_p(t_1) = 0$

$\Rightarrow 0 = -25 \frac{m}{s} + 5 \frac{m}{s^2} t_1 \Rightarrow t_1 = 5 sec.$

Position of policeman at t_1 is

$x_p(t_1) = v_p(0) t_1 + \frac{1}{2} a_p t_1^2 = -25 \frac{m}{s} \times 5s + \frac{1}{2} \times 5 \frac{m}{s^2} (5s)^2$

$x_p(t_1) = -62.5 m$

The speeder moves at constant velocity between 0 and t_1 so

$x_s(t_1) = v_s(0) t_1 = 45 \frac{m}{s} \times 5s = 225 m$

Part b: What are the positions and velocities of the police car and the speeder the instant the policeman switches on the flashers? This is t2=t1+1. (10 points)

$x_p(t_1+1) = x_p(t_1) = -62.5\ m$

$v_p(t_1+1) = 0$

$x_s(t_1+1) = v_s(0)(t_1+1) = 270\ m$

$v_s(t_1+1) = v_s(0) = 45\ m/s$

Part c: Once the chase starts how much time does it take for the policeman to catch up to the speeder? Where are they at this time? (20 points)

Now $a'_p = 3\,m/s^2$ $\quad a'_s = -1\,m/s^2$

Let Δt be the time measured after t_1+1

$$x_p(t_1+1+\Delta t) = -62.5\,m + v_p(t_1+1)\,\Delta t + \frac{1}{2}a'_p(\Delta t)^2$$

$$= -62.5\,m + 1.5\,\frac{m}{s^2}(\Delta t)^2$$

$$x_s(t_1+1+\Delta t) = x_s(t_1+1) + v_s(t_1+1)\,\Delta t + \frac{1}{2}a'_s\,\Delta t^2$$

$$= 270\,m + 45\,\frac{m}{s}\,\Delta t - 0.5\,\frac{m}{s^2}(\Delta t)^2$$

When the policeman catches up $x_p = x_s$

$\Rightarrow$ $$-62.5 + 1.5(\Delta t)^2 = 270 + 45\,\Delta t - 0.5(\Delta t)^2$$

or $$2(\Delta t)^2 - 45\,\Delta t - 332.5 = 0$$

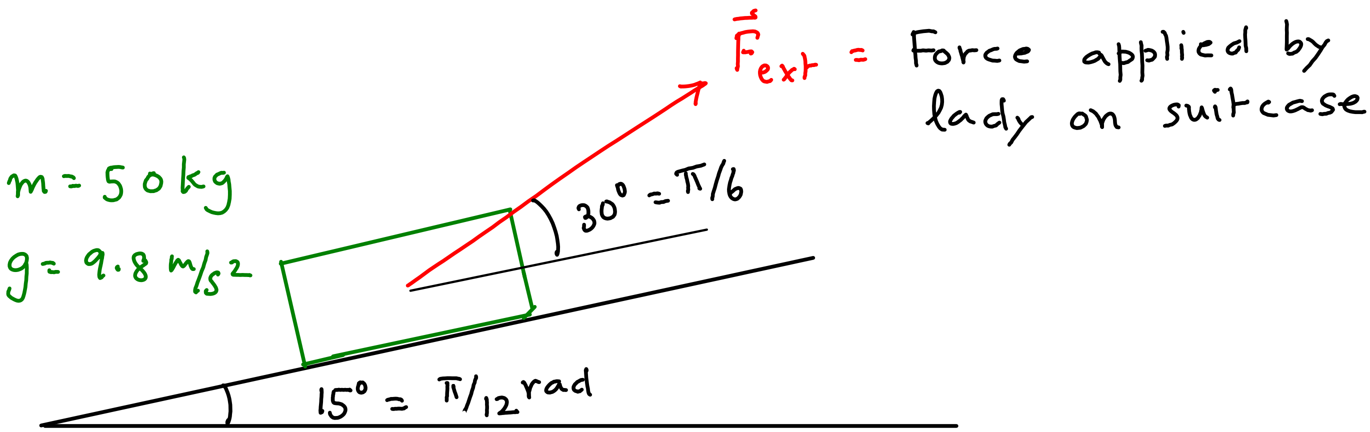
$$\Delta t = \frac{45 \pm \sqrt{(45)^2 + 2\times 4\times 332.5}}{4} = \frac{45 \pm \sqrt{4685}}{4}$$

$$= \frac{45 \pm 68.45}{4} \quad \text{have to choose } +$$

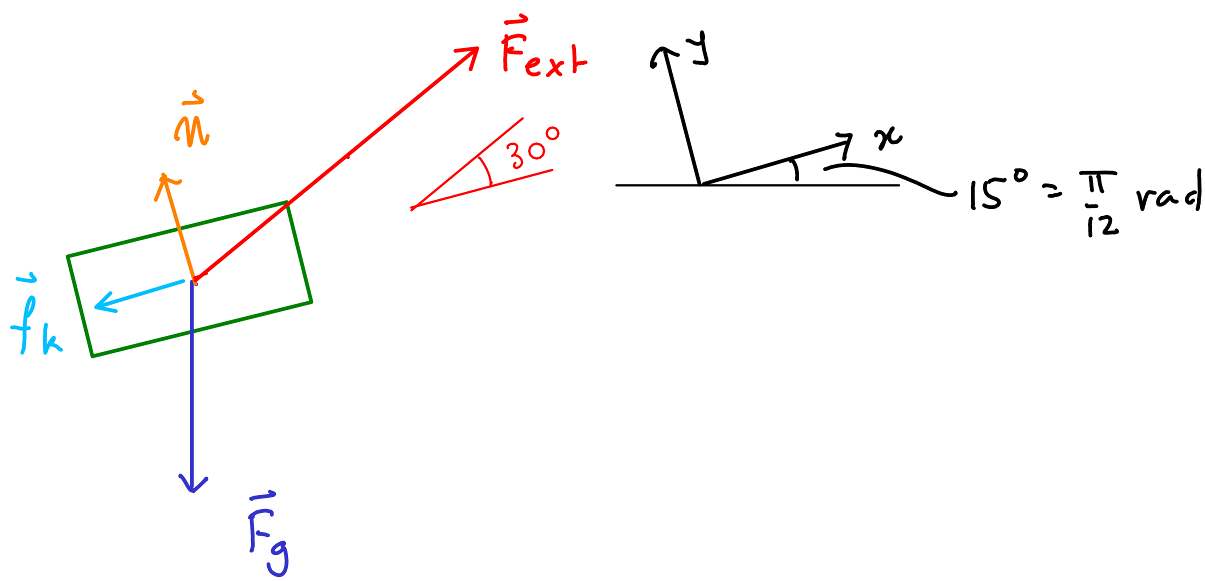
$\boxed{\Delta t = 28.36 \text{ sec}}$ $\quad$ $\boxed{t = t_1+1+\Delta t = 34.36\,s}$

Position is $\boxed{x_p = -62.5 + 1.5(\Delta t)^2 = 1144.1\,m}$

Question 3: A lady is dragging a suitcase on a ramp at an airport. The coefficient of kinetic friction between the suitcase and the ground is μ_k=0.15. The lady wants to give the suitcase an acceleration of 1m/s^2 up the slope. What should the force she applies on the suitcase be? Follow these steps



Part 3a: Draw a Free Body Diagram of the suitcase. (10 points)



Part 3b: Choose a convenient coordinate system and write down the vector components of all the forces. Find the total force. (10 points)

Choose +x up along the slope

$\vec{n} = n\hat{j}$ $\vec{f}_k = -f_k\hat{i}$

$\vec{F}_g = -mg\sin 15^\circ\,\hat{i} - mg\cos 15^\circ\,\hat{j}$

$\vec{F}_{ext} = F_{ext}\cos 30^\circ\,\hat{i} + F_{ext}\sin 30^\circ\,\hat{j}$

$mg = 490\ N$ $\cos 15^\circ = 0.966$
$\sin 15^\circ = 0.259$

$$\vec{F}_{tot} = \hat{i}\left(F_{ext}\,0.866 - 126.9 - f_k\right) + \hat{j}\left(n + \tfrac{1}{2}F_{ext} - 473.3\right)$$

All numbers are in Newtons

Part 3c: From the fact that you know a_y for the suitcase, find the force of normal reaction, and thus the force of friction in terms of F_ext. (10 points)

$a_y = 0 \Rightarrow \quad F_{tot,y} = 0 \Rightarrow$

$$n = 473.3\ N - 0.5 F_{ext}$$

$$f_k = \mu_k n = 0.15\,(473.3\ N - 0.5 F_{ext})$$

$$= 71\ N - 0.075\ F_{ext}$$

Part 3d: From the fact that you know the a_x of the suitcase find the magnitude of F_ext. (10 points)

$$F_{tot,x} = 0.866\,F_{ext} - 126.9 - f_k$$

$$= 0.866\,F_{ext} - 126.9 - 71 + 0.075\,F_{ext}$$

$$\boxed{F_{tot,x} = 0.941\,F_{ext} - 196.9\,N}$$

By Newton II

$$\boxed{F_{tot,x} = ma_x = 50\,kg \times 1\,\frac{m}{s^2} = 50\,N}$$

$$0.941\,F_{ext} - 196.9\,N = 50\,N$$

$$\boxed{F_{ext} = 262.4\,N}$$