Exam 1, PHY 191B 09/27/16, **100pts**

Name ISAAC NEWTON

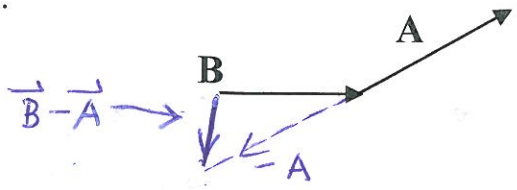
The use of a calculator and a cheat-sheet (as instructed) is allowed.
Put your cellphone, laptop, and Apple Watch in your backpack and place the backpack at the front of the hall.
Anyone found in possession of these items during the exam will be expelled from the exam.

Part A (40 points) : 10 *Conceptual questions*.
SHOW REASONING CLEARLY.
Correct answer w/o **clear** reasoning = ZERO credit!
Each question is worth 4 points.

1. Vectors **A** and **B** are represented by the arrows shown.
The arrow that likely represents **B - A** is:

a) 

b) 

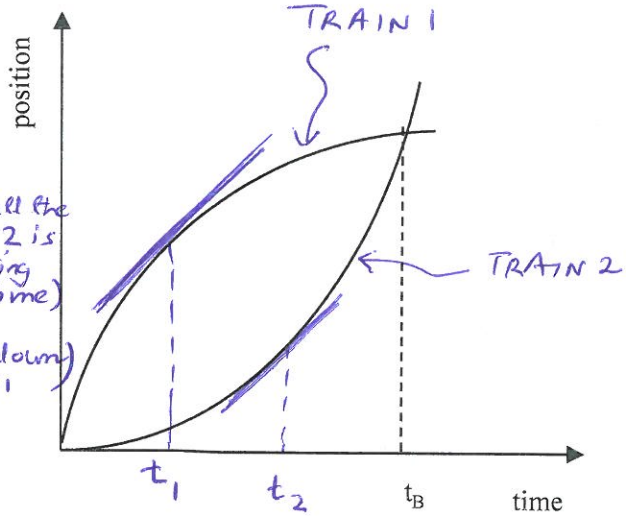


c) 

d) 

Show reasoning by making an appropriate drawing.

2. The graph shows position as a function of time for two trains running on parallel tracks.
Which statement(s) below is(are) true?
a) Somewhere on the graph, both trains have the same acceleration vector. (no, train 1 is decelerating all the time, while train 2 is accelerating all the time)
b) Both trains have the same velocity at some time before t_B (yes, see below)
c) Both trains speed up all the time. (no; train 1 slows down after t_1)
d) At time t_B, both trains have the same velocity. (no; slopes of the 2 x-t curves are different at t_B)



REASONING:

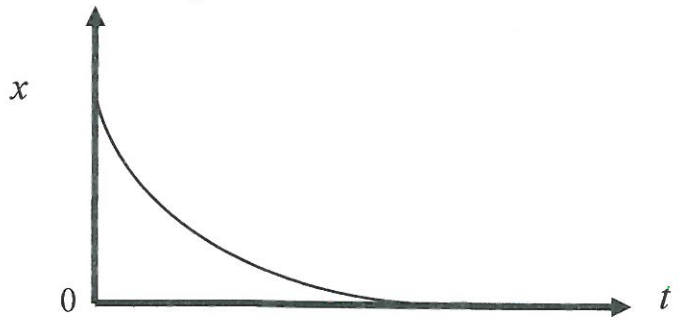
At t_1, the slope of the position-time curve for the 1st train is the same as the slope of the position-time curve for the 2nd train at t_2.

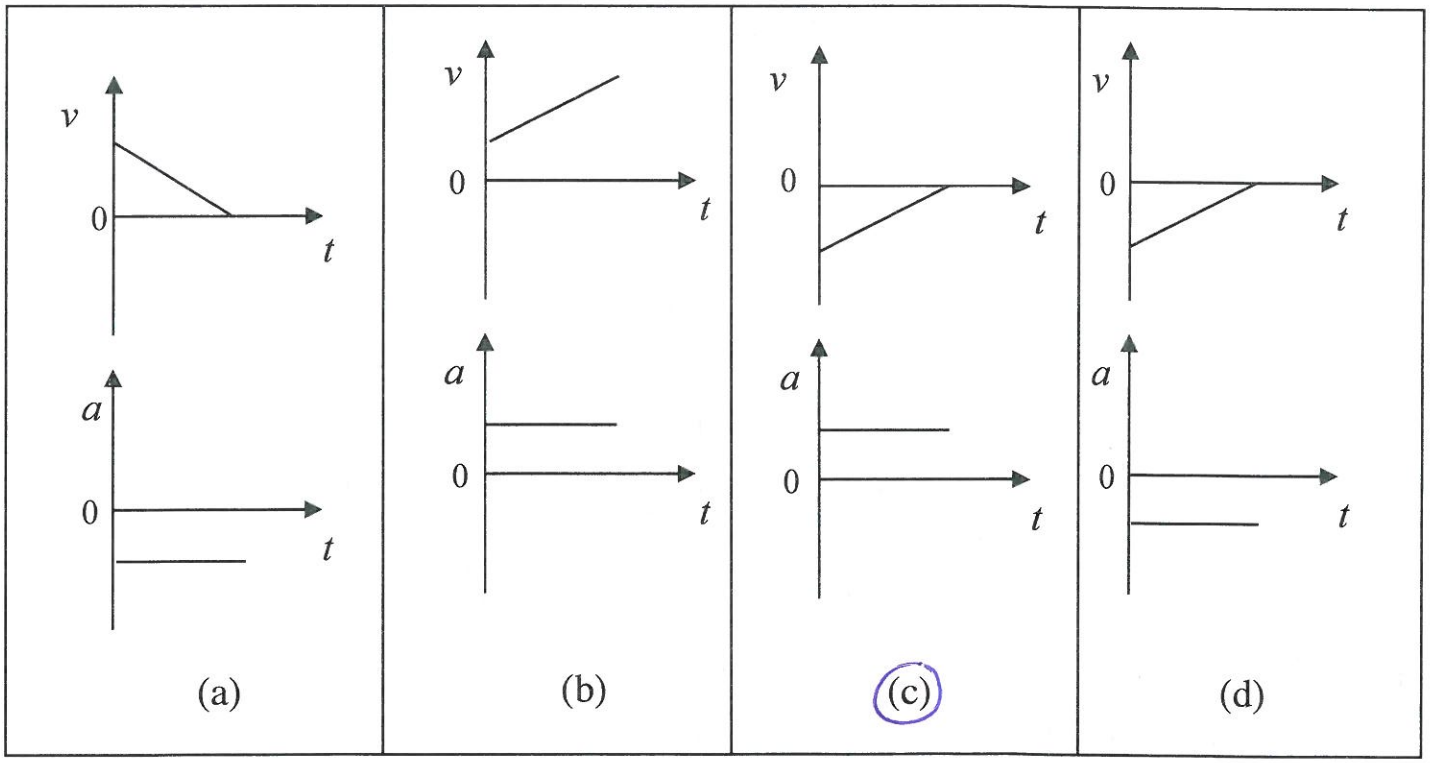
3. A person standing at the edge of a cliff throws one ball straight up and another straight down at the same initial speed. *Taking air resistance into account*, which ball hits the ground below the cliff with greater speed? (Assume the cliff is not so high that terminal velocity sets in!)

a) the ball initially thrown upward
(b) the ball initially thrown downward
c) neither – they both hit at the same speed
d) can't say; need more information

REASONING: As discussed in class, the ball thrown straight up comes back down to the edge of the cliff with a speed that is less than the initial launch speed. Therefore, it cannot acquire as great a final velocity as the ball that was initially launched downward.

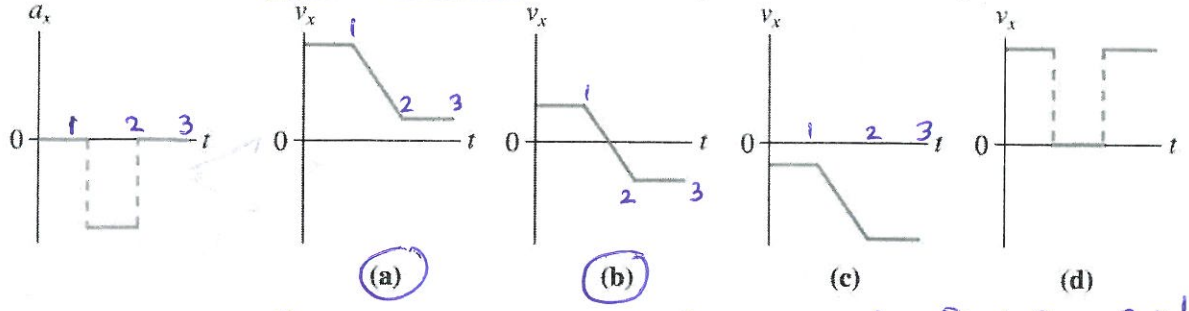
4. A moving particle has the following displacement-time graph. Which of the choices a, b, c, or d below may best represent the corresponding approximate velocity-time and acceleration-time graphs?





REASONING: At small times, the slope of the x-t curve (i.e., the velocity) is steep (i.e. large) and negative. At later times, the slope monotonically flattens to zero. Both (c) & (d) have appropriate v-t curves. But (c) is correct, b/c the acceleration (slope of v-t curve) must be positive.

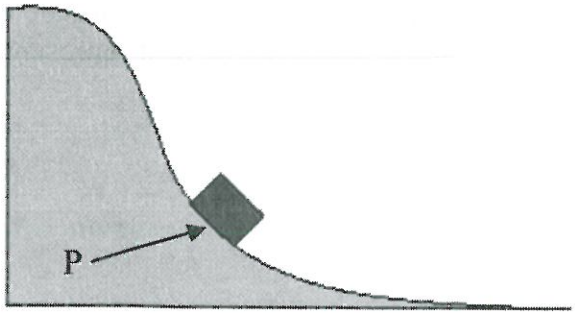
5. Which velocity-versus-time graph or graphs go with the acceleration-versus-time graph on the left? The particle is initially moving to the right (i.e., in the positive x-direction).



(a) (b) (c) (d)

REASONING: a_x from 0→1 & 2→3 is zero ⇒ $v(t)$ should be flat from 0→1 & 2→3.
a_x from 1→2 is negative & constant ⇒ $v(t)$ should be a downward sloping straight line.
ABOVE CONDITIONS are fulfilled by (a), (b), & (c). [RULES OUT (d)]
Particle initially moving to right ⇒ initial v_x is positive [RULES OUT (c)].

6. A block slides down the frictionless track as shown. The picture shows the block passing from the region of steeper slope to the region of gentler slope. What happens to its speed and acceleration in the direction of motion as it passes the point P shown in the picture?

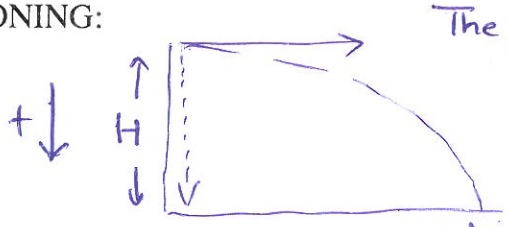


a) Both decrease.
b) Speed decreases, but acceleration increases.
c) Both remain constant.
(d) Speed increases, but acceleration decreases.
e) Both increase.

REASONING: Slope is more gradual after P, but still downward-sloping ⇒ acceleration downward along slope is less in magnitude than above P, but it's still causing the velocity to speed up (just not as much as before!)
So ... speed continues to increase (just not at as fast a rate)!
But acceleration decreases, of course.

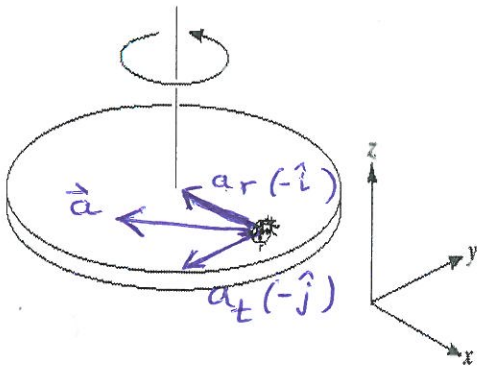
7. Two teletubbies, Tinky-Winky and Po, who are of very unequal mass, are standing at the edge of a cliff. A homicidal parent sneaks up behind them and pushes them both simultaneously off the cliff. The heavier Tinky-Winky barely drops off the cliff, while the lighter Po rockets off the cliff with a velocity (only horizontal; no vertical component) of 5 m/s.
Neglecting air resistance, which of the following statements is true?
(a) They both hit the ground at the same time, and die a miserable death.
b) Tinky-Winky hits the ground first, and dies a miserable death.
c) Po hits the ground first, and dies a miserable death.
d) Can't say - need more information. But they both die. Miserably.

REASONING:



The initial vertical velocity for both teletubbies is zero. They both descend the same height H under the same downward acceleration 'g'. Their vertical eqn. of motion $\Delta y = H = 0 + \frac{1}{2} g t^2 \Rightarrow t = \sqrt{2H/g}$ is the same for both.

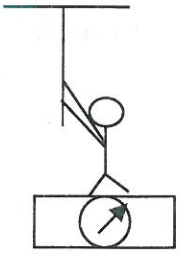
8. A ladybug sits at the outer edge of a turntable that is rotating in the manner shown but is continually slowing down. What is the direction of the *total acceleration* of the bug, at the instant shown?

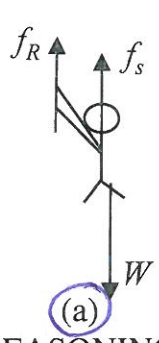


a) $+z$ b) $-z$
c) pointing in a direction between y and $-x$
(d) pointing in a direction between $-y$ and $-x$
e) pointing in a direction between $-y$ and x

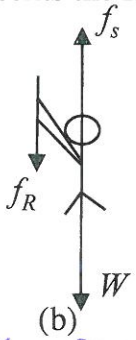
REASONING: $\vec{a}_r$ points toward center ($-x$ direction), $\vec{a}_t$ points opposite to the velocity b/c slowing down ($-y$ direction); $\vec{a} = \vec{a}_r + \vec{a}_t$

9. A boy stands on a scale and pulls on a rope tied to the ceiling as shown. The boy has weight W, and pulls down on the rope with a force of magnitude f_R. The magnitude of the force exerted by the boy on the scale is f_S. Which figure below best represents the free-body diagram *for the boy*?

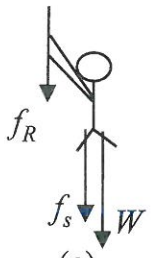




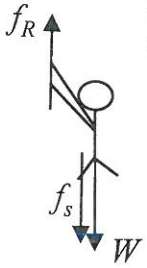
(a)



(b)



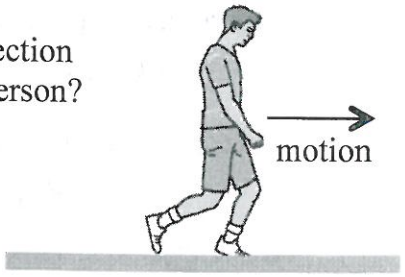
(c)

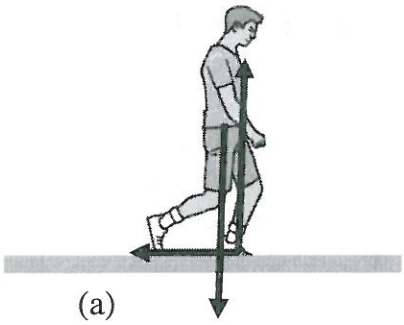


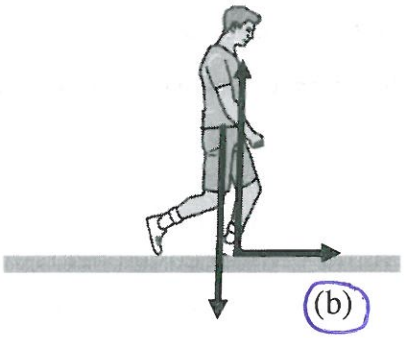
(d)

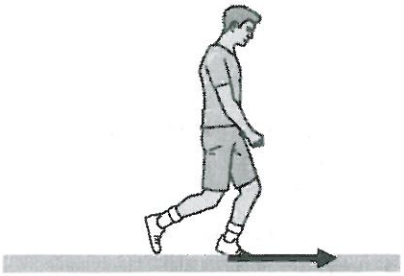
REASONING: The directions for f_R & f_S should be correctly shown as forces ON the boy by the rope & scale, respectively.

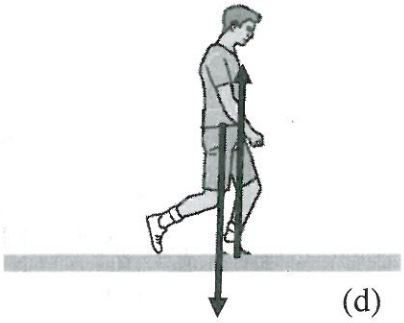
10. Consider a person walking on level ground, without slipping, in the direction shown. Which below represents the correct free body diagram for the person?



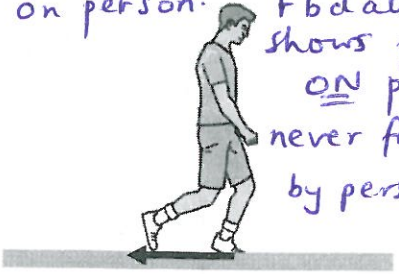

(a)


(b)


(c)


(d)

REASONING: Person pushes ground backward in order to move forward. Ground pushes forward (in reaction) on person. Fbd always shows forces ON person, never forces by person.


(e)

Part B, Questions 11 – 13 (3 points) : 3 *Extra Reading Questions*.
Pick the correct answer. No need to show reasoning!
Each question is worth 1 point.

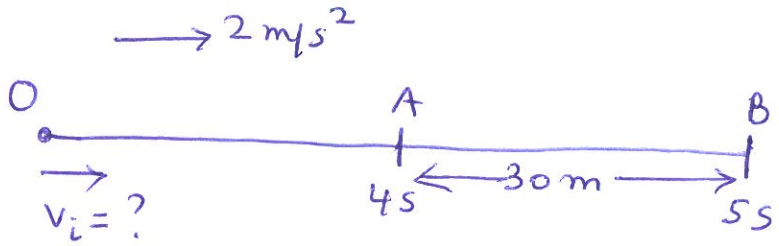
11. The *primary* reason you must never shake a small baby with even moderate force ("moderate force" meaning such a force would have no damaging effect on an adult) because
    a) you may damage the baby's rib cage even if you're holding it lightly.
    b) the baby's neck muscles are weak and unable to stabilize the relatively large head as it rapidly jerks back and forth owing to its inertia.
    c) the baby's brain does not completely fill the cranial cavity, which leads to brain damage owing to the brain freely sloshing back and forth owing to the brain's inertia.

11. The *principal* reason that humans can throw better than other, far stronger and more athletic, primates is because
    a) humans have bigger brains allowing them to figure out the physics behind throwing projectiles.
    b) humans evolved weaker bites which then caused them to throw better.
    c) humans have better socialization skills allowing them to discuss amongst themselves and arrive at a suitable solution.
    d) human shoulder sockets face out to the side, whereas they face forwards for other primates.

12. The Hyperloop refers to a proposed monorail transport system between San Francisco and Los Angeles which envisages a passenger-carrying "pod" with metal skis, that runs within a tube which has been evacuated to one-thousandth of atmospheric pressure. A linear induction motor similar to those used in modern roller coasters accelerates the pod up to speed. The *primary* purpose of a fan placed in front of the pod is
    a) to keep the passengers cool
    b) to re-direct the built-up air in front of the pod onto the rail, reducing kinetic friction with the rail.
    c) to suck away the built-up air in front of the pod and re-direct it to the surrounding air, so that the pod does not explode due to the pressure outside the pod being dangerously low.

Part C, Questions 14 – 18 (57 points) : 5 *Numerical Problems*.
SHOW WORK CLEARLY.
Correct answer w/o **clear show of** work = ZERO credit!

14. An antelope accelerates at 2.0 m/s^2 along a straight path. It passes two marks that are 30 m apart at times $t = 4.0$ s and $t = 5.0$ s. What was the antelope's velocity at $t = 0$ s? (8 pts)
SHOW WORK CLEARLY:



(1)

OA: $\Delta x_{OA} = v_i \Delta t + \frac{1}{2} a_x (\Delta t)^2$

$= 4v_i + \frac{1}{2}(2)4^2$

(2)

$\Rightarrow \Delta x_{OA} = 4v_i + 16$ ——— (i)

OB: $\Delta x_{OB} = v_i \Delta t + \frac{1}{2} a_x (\Delta t)^2$

$= 5v_i + \frac{1}{2}(2)5^2$

(2)

$\Rightarrow \Delta x_{OB} = 5v_i + 25$ ——— (ii)

Subtract eqn (i) from (ii)

$\Delta x_{OB} = 5v_i + 25$

$\Delta x_{OA} = 4v_i + 16$

(2)

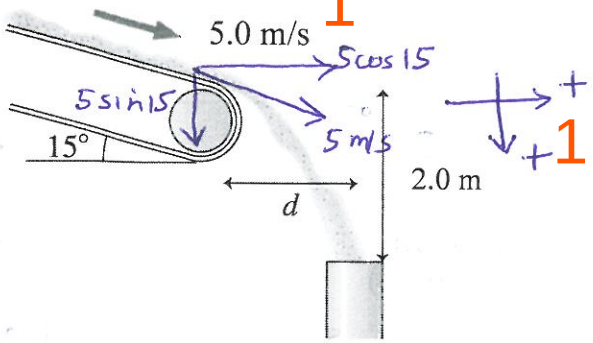
$\Delta x_{OB} - \Delta x_{OA} = 30 = v_i + 9$

$\Rightarrow \boxed{v_i = 21 \text{ m/s}}$

(1)

Part C, Questions 14 – 18 (57 points) : 5 *Numerical Problems*.
SHOW WORK CLEARLY.
Correct answer w/o **clear show of** work = ZERO credit!

15. Gravel is carried at 5 m/s by a conveyor belt that is tilted at 15^0. The gravel enters a pipe 2.0 m below the end of the conveyor belt, as shown. What is the horizontal distance d between the conveyor belt and the pipe? (10 pts)
SHOW WORK CLEARLY:



1

HORIZONTAL: $\Delta x = v_{0x}\Delta t$

$d = (5\cos 15)\Delta t$ — (i) 2

VERTICAL: $\Delta y = v_{0y}\Delta t + \frac{1}{2}a_y(\Delta t)^2$

$2 = (5\sin 15)\Delta t + \frac{1}{2}(9.8)(\Delta t)^2$ — (ii) 4

or $4.9(\Delta t)^2 + (5\sin 15)\Delta t - 2 = 0$,

Eqn (ii) is a quadratic equation in Δt. Solve:

$$\Delta t = \frac{-5\sin 15 \pm \sqrt{(5\sin 15)^2 - 4(4.9)(-2)}}{2(4.9)}$$ 1

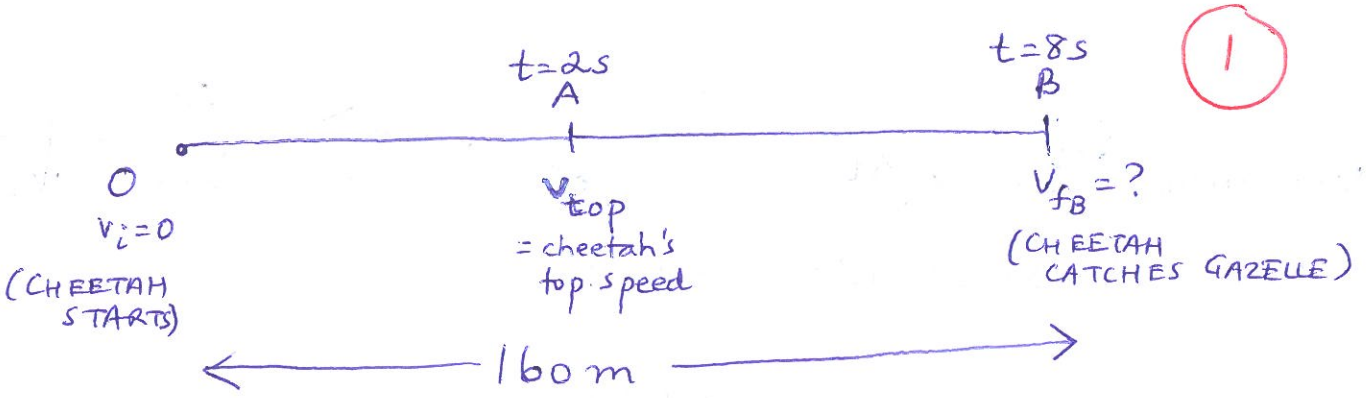
KEEP POSITIVE ROOT, $\Delta t = 0.52$ s

$\therefore$ from eqn. (i), $d = (5\cos 15)(0.52)$

$\boxed{d = 2.5 \text{ m}}$ 1

Part C, Questions 14 – 18 (57 points) : 5 *Numerical Problems*.
SHOW WORK CLEARLY.
Correct answer w/o **clear show of** work = ZERO credit!

16. Starting from rest, a cheetah rapidly accelerated and closes in on a fleeing gazelle. The cheetah can accelerate with constant acceleration for 2 s before reaching top speed. It then continues at this top speed until it eventually catches the gazelle after running a total distance of 160 m in 8 s. What is the cheetah's speed as it catches up with the gazelle? (12pts)
SHOW WORK CLEARLY:



(1)

OA : Use $v_f = v_i + a\Delta t$ to find $v_{top} = 0 + a(2)$ (3)

i.e. $v_{top} = 2a$ —— (i)

AB : Constant speed ! So $AB = (v_{top})(\Delta t)$ → $8s - 2s = 6s$

i.e. $AB = 6v_{top}$ —— (ii) (2)

Also, for OA, determine $OA = v_i \Delta t + \frac{1}{2} a(\Delta t)^2$

$= 0 + \frac{1}{2} a(2^2) = 2a$ (3)

i.e. $OA = 2a$ —— (iii)

Use equations (i), (ii), (iii) & $OA + AB = 160$

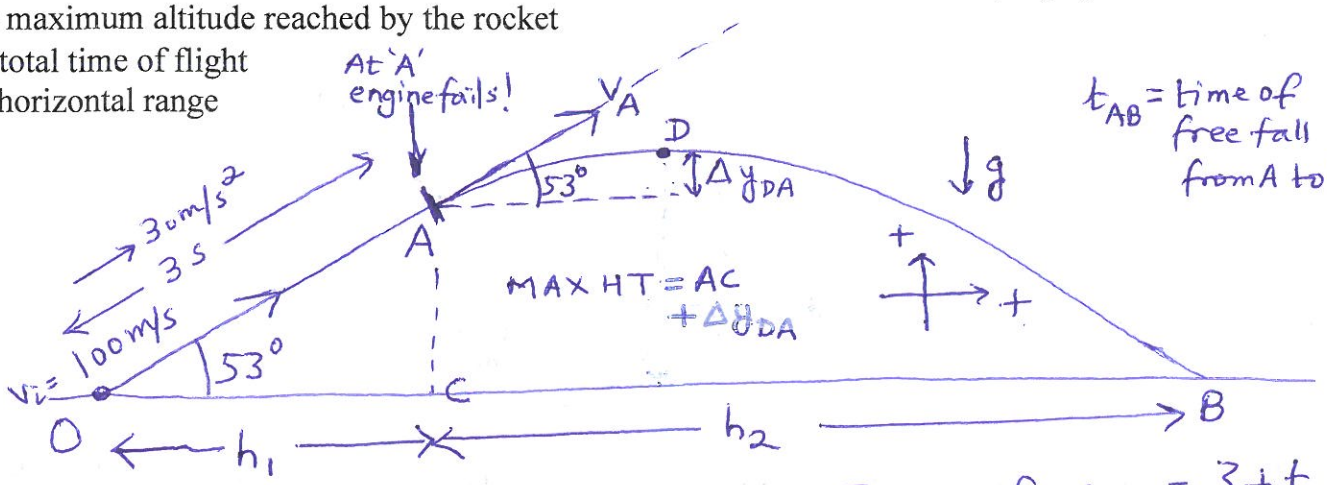
to find $2a + 6(2a) = 160$ (2)

$\Rightarrow a = \frac{160}{14} = 11.4 \text{ m/s}^2$

$\therefore v_{top} = 2(11.4) = \boxed{22.8 \text{ m/s}}$ (1)

Part C, Questions 14 – 18 (57 points) : 5 *Numerical Problems*.
SHOW WORK CLEARLY.
Correct answer w/o **clear show of** work = ZERO credit!

17. A catapult launches a rocket at an angle of 53.0^0 above the horizontal with an initial speed of 100 m/s. The rocket engine immediately starts to burn and for 3.00 sec the rocket *moves along its initial line of motion* with an acceleration of 30.0 m/s^2. Then its engine fails, and the rocket proceeds to move in free fall. Find (15 pts)
a) the maximum altitude reached by the rocket
b) its total time of flight
c) its horizontal range



t_{AB} = time of free fall from A to B.

HORIZONTAL RANGE = $h_1 + h_2$; TOTAL TIME OF FLIGHT = $3 + t_{AB}$

OA : 1D motion along direction OA

Use $v_f = v_i + a\,\Delta t$ to write $V_A = 100 + 30(3) = 190$ m/s —— (i)

(5) Also, use $\Delta X = v_i \Delta t + \frac{1}{2} a (\Delta t)^2$ to write $OA = 100(3) + \frac{1}{2}(30)(3^2)$

i.e. $OA = 435$ m

$\Rightarrow$ using $\cos 53^\circ = \frac{h_1}{435}$, we find $h_1 = 261.8$ m —— (ii)

AB : HORIZONTAL MOTION, use $\Delta X = V_{0x} \Delta t$ to write

$h_2 = (190 \cos 53)\, t_{AB}$ —— (iii)

VERTICAL MOTION, use $\Delta y = v_{iy}\, t_{AB} + \frac{1}{2} a_y (t_{AB})^2$ to write

(5) $-AC = -435 \sin 53^\circ = (190 \sin 53^\circ)\, t_{AB} + \frac{1}{2}(-9.8)(t_{AB})^2$

i.e. $4.9(t_{AB})^2 - 151.7\, t_{AB} - 347.4 = 0$ QUADRATIC EQN in Δt, solve.

$t_{AB} = \dfrac{151.7 \pm \sqrt{151.7^2 - 4(4.9)(-347.4)}}{2(4.9)} = 33.1$ s (KEEP POSITIVE ROOT!)

$\therefore$ TOTAL TIME OF FLIGHT = $3 + 33.1 = \boxed{36.1\text{ s}}$ (b)

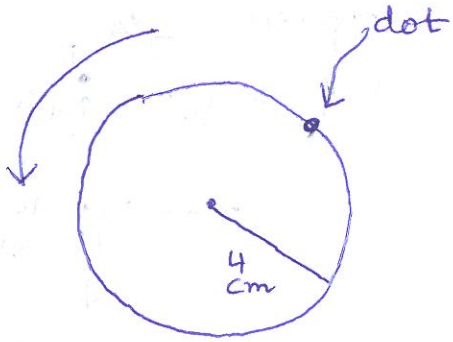
& HORIZONTAL RANGE = $h_1 + h_2 = 261.8\text{m} + (190\cos 53)(33.1) = \boxed{4047\text{m}}$ (c) (from eqn. (iii))

(5) AH! I FORGOT ABOUT PART (a)! FOR MOTION FROM A TO D, use $v_f^2 = v_i^2 + 2a\Delta y$ to find FOR THE VERTICAL MOTION, $0 = (190\sin 53)^2 + 2(-9.8)\Delta y_{DA} \Rightarrow \Delta y_{DA} = 1175$ m

$\therefore$ MAX. HT. = $AC + \Delta y_{DA} = 435 \sin 53 + 1175 = \boxed{1522\text{m}}$ — (a)

Part C, Questions 14 – 18 (57 points) : 5 *Numerical Problems*.
SHOW WORK CLEARLY.
Correct answer w/o **clear show of** work = ZERO credit!

18. A disk which is 8.0 cm in diameter has a small dot painted on its edge. The disk is initially at rest, then accelerates at 600 rad/s^2 for ½ s, after which it coasts at a steady angular velocity for another ½ s. (12 pts)
    a) What is the speed in m/s of the dot at t = 1.0 s?
    b) Through how many revolutions has the disk turned?



a) DURING 1st ½-sec, $\alpha = 600\ rad/s^2$, $\Delta t = ½\ s$, $\omega_i = 0$

use $\omega_f = \omega_i + \alpha \Delta t$ to find $\omega_f = 0 + 600(\frac{1}{2}) = 300\ rad/s$ — (i)

$\therefore$ Speed $v = r\omega = (4\times10^{-2})(300) = \boxed{12\ m/s}$

stays at this value for the 2nd ½-sec. (3)

b) DURING 1st ½-sec: $\Delta\theta_1 = \omega_i \Delta t + \frac{1}{2}\alpha(\Delta t)^2$

$= 0 + \frac{1}{2}(600)(\frac{1}{2})^2$ (3)

$= 75\ rads$

$\Delta\theta$ DURING 2nd ½-sec: $\Delta\theta_2 = \omega \Delta t$ → this is ω_f in eqn. (i) above

$= 300(\frac{1}{2}) = 150\ rads$ (2)

$\therefore$ TOTAL $\Delta\theta = 75 + 150 = 225\ rads$ (1)

$\Rightarrow$ TOTAL REVS $= \frac{225}{2\pi} = \boxed{35.8\ revs \\ \simeq 36}$ (1)

(2)