Solutions

ph201_f24_m1

Name:______________________________ ID:______________________________

Physics 201

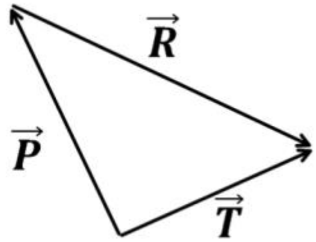
Midterm 1

10/23/2024

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

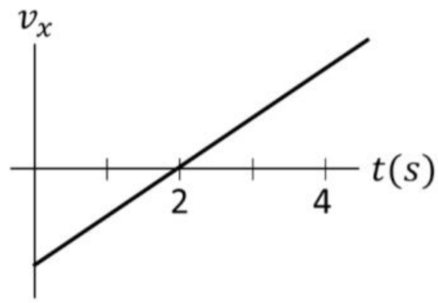
For questions 1 through 4 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **6** correct answers in this section and only the first **6** filled in answers will be graded. There is no partial credit.

1. Which of the following equations correctly represent the relationship between the vectors drawn in the diagram:



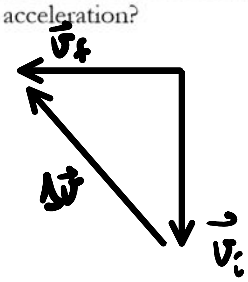
□ (a) R = P - T
✔ (b) R = T - P
□ (c) R = T + P
✔ (d) T = P + R
□ (e) P = R - T

2. Samie the snail is sliding along the x-axis. Their x-motion is plotted in the following graph. Which of the following statements must be true about Samie's motion?



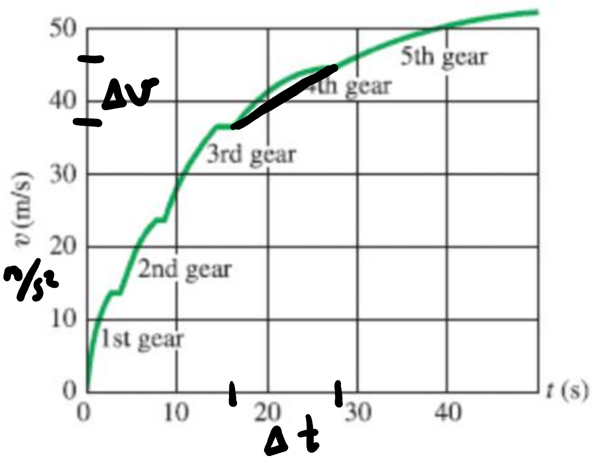
□ (a) after three seconds, Samie's x-position is positive
□ (b) Samie's acceleration is zero
✔ (c) Samie's acceleration is a constant positive value
□ (d) Samie's acceleration is negative then positive
□ (e) Samie's velocity is constant
✔ (f) The magnitude of Samie's displacement after 4 seconds is zero

3. At one point in time, Bernice is travelling in the Southern direction. Sometime later, Bernice is travelling in the Western direction. Between these times, which one of the following best describes the direction of Bernice's average acceleration?



✔ (a) Northwest
□ (b) Northeast
□ (c) Southeast
□ (d) Southwest
□ (e) East
□ (f) West
□ (g) North
□ (h) South

4. The velocity as a function of time is plotted for an electric car. Which of the following are closest to the average acceleration for the car during 4th gear?



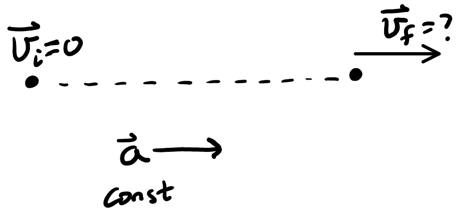
$\sim \frac{10\,m/s}{10\,s} = 1\,m/s^2$

✔ (a) 0.8 m/s
□ (b) 2.4 m/s
□ (c) 10 m/s
□ (d) 24 m/s
□ (e) 32 m/s

5. (6 points) Benny is riding on his scooter and accelerates from rest at **130 feet per minute²** for **0.12 hours**. At the end of this time, how fast is Benny travelling in m/s? (hint: there are **2.54 cm** in **one inch**, and **12 inches** in **one foot**)

$$a = 130 \ \mathrm{ft/min^2}$$

$$\Delta t = 0.12 \ \mathrm{hrs}$$



$$v_f = v_i + a\Delta t$$

$$= 0 + \left(130 \ \frac{\mathrm{ft}}{\mathrm{min^2}}\right)(0.12 \ \mathrm{hrs}) = 15.6 \ \frac{\mathrm{ft \cdot hrs}}{\mathrm{min^2}}$$

!!!

Convert units to m/s

$$v_f = \left(15.6 \ \frac{\mathrm{ft \ hrs}}{\mathrm{min^2}}\right)\left(\frac{60}{1} \ \frac{\mathrm{min}}{\mathrm{hrs}}\right) = 936 \ \frac{\mathrm{ft}}{\mathrm{min}}$$

1

$$= \left(936 \ \frac{\mathrm{ft}}{\mathrm{min}}\right)\left(\frac{12}{1} \ \frac{\mathrm{in}}{\mathrm{ft}}\right)\left(\frac{2.54}{1} \ \frac{\mathrm{cm}}{\mathrm{in}}\right)\left(\frac{1}{100} \ \frac{\mathrm{m}}{\mathrm{cm}}\right)$$

$$\times \left(\frac{1}{60} \ \frac{\mathrm{min}}{\mathrm{s}}\right)$$

$$v_f = 4.75 \ \mathrm{m/s}$$

assume standard coord. sys.

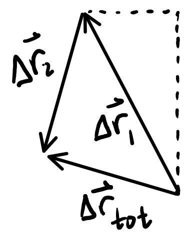
6. (10 points) Nessie the wonder-dachshund (a dog) is wearing her best Elphaba the witch costume. She sets off in search of food from the origin at a constant velocity of **9.4 m/s** in a direction **35 degrees** from the positive y-axis towards the negative x-axis. She continues in this direction for **45 seconds**. At this time, she smells a delicious smell and in **29 seconds**, travels a displacement of **< -43, -220 > m** where she finds the scrumptious dinner.

(a) What is Nessie's displacement after the first 45 seconds?

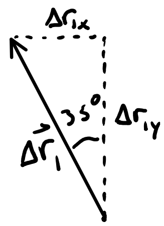
(b) Sign sensemaking - answer the following prompts.

- Before you solved for her displacement numerically, what would you have expected the signs of the x and y components of her displacement (during the first 45 seconds) to be?
- Explain your prediction using any combination of words, diagrams, algebra, etc.
- Compare your prediction with your result from part (a).

(c) Between the time she starts and the time at which she finds her dinner, what is Nessie's average velocity?



(a)



$$|\Delta\vec{r}_1| = v_i \Delta t + \tfrac{1}{2} \cancel{a}^{\,0} \Delta t^2$$

$$= (9.4\ m/s)(45\ s)$$

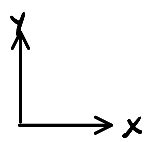
$$= 423\ m$$

$$\sin\theta = \frac{\Delta r_{1x}}{|\Delta\vec{r}_1|} \Rightarrow \Delta r_{1x} = -|\Delta\vec{r}_1| \sin(35°)$$

$$\cos\theta = \frac{\Delta r_{1y}}{|\Delta\vec{r}_1|} \Rightarrow \Delta r_{1y} = |\Delta\vec{r}_1| \cos(35°)$$

$$\Delta\vec{r}_1 = \langle -243, 347 \rangle\ m$$

(b) I expect the x-component to be negative & the y-component to be + because the displacement is in ↖ direction & our coord. sys. is standard.



My answer to (a) matches my prediction, yay!

(c) $\Delta\vec{r}_{tot} = \Delta\vec{r}_1 + \Delta\vec{r}_2 = \langle -243, 347 \rangle m + \langle -43, -220 \rangle m$

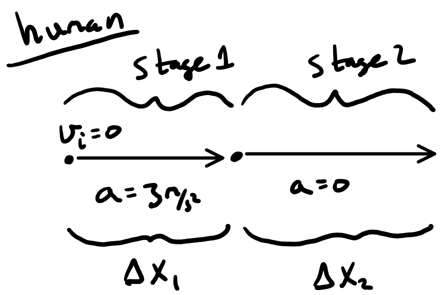
$$= \langle -286, 127 \rangle\ m$$

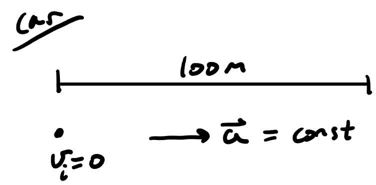
$$\vec{v}_{avg} = \frac{\Delta\vec{r}_{tot}}{\Delta t_{tot}} = \frac{\langle -286, 127 \rangle m}{(45 + 29)\ s} = \langle -3.86, 1.72 \rangle \tfrac{m}{s}$$

7. (10 points) At a worldwide bioengineering competition, teams are tasked with designing and building a biomechanical racecar that is powered completely through a biological process. In order to continue to the next stage of the competition, it must beat a human athlete in a **100 m**-long race. Assume the human can accelerate at a constant rate of **3.00 m/s²** for **4.00 s** until they reach a maximum speed. At that point their acceleration drops instantly to zero. The racecar accelerates uniformly (constant) through the entire race and both the racecar and the human start from rest.

(a) What distance does the human have left in the race when they reach their maximum speed?

(b) What minimum acceleration does the racecar need to win the race?





(a) $\Delta x_1 = \cancel{v_i}^{\,0} \Delta t + \frac{1}{2} a \Delta t^2$

$= \frac{1}{2}(3\,m/s^2)(4\,s)^2$

$= 24\,m$

$\Delta x_1 + \Delta x_2 = 100\,m$

$\Rightarrow \Delta x_2 = 100\,m - \Delta x_1$

$\boxed{\Delta x_2 = 76\,m}$

(b) first: human 2nd part of race

$v_{f1} = v_{i2}$

$v_{f1} = \cancel{v_{i1}}^{\,0} + a\Delta t = (3\,m/s^2)(4\,s)$

$= 12\,m/s$

$\Delta x_2 = v_{i2}\Delta t_2 + \frac{1}{2}\cancel{a}^{\,0}\Delta t^2$

$76\,m = (12\,m/s)\,\Delta t_2$

$\Rightarrow \Delta t_2 = 6.3\,sec$

$\Rightarrow \Delta t_{tot} = 10.3\,s$

racecar

$\Delta x = \cancel{v_i}^{\,0}\Delta t + \frac{1}{2} a \Delta t^2$ ← 10.3 sec

$100\,m = \frac{1}{2} a\,(10.3\,s)^2$

$\boxed{a_{min} = 1.89\,m/s^2}$

Rubric

1 pt - physical representation

Part (a) - 3.5 points
1 pt - kinematic equation (i)
1 pt - deltaX_1 + deltaX_2 = 100 m

1 pt - application
0.5 - answer and units

Part (b) - 5.5 points
1 pt - kinematic equation (ii)
1 pt - finding Vf
1.5 - finding deltaT_total
1 pt - connecting the human and racecar via time and distance
0.5 pt - kinematic equation (i) applied to racecar
0.5 pt - answer and units