Science One Term 1 Physics Exam

December 10, 2012

Name: Mark
Student Number:
Bamfield Number:

Questions 1-22: Multiple Choice: 1 points each
Questions 23-29: Long answer: 25 points total

Multiple choice answers:

#1	#2	#3	#4	#5
F	E	C	D	A

#6	#7	#8	#9	#10
C	C	A	A	B

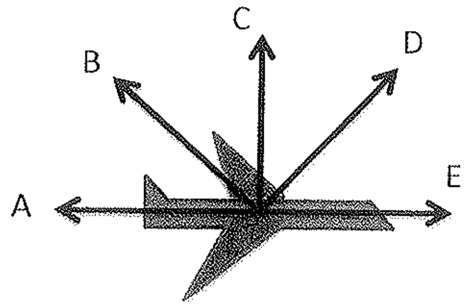
#11	#12	#13	#14	#15
B	A	C	B	D

#16	#17	#18	#19	#20
A	B	A	D	A

BONUS SQUARES!

#21	#22			
C	A			

Formula sheet at the back (you can remove it…carefully!)



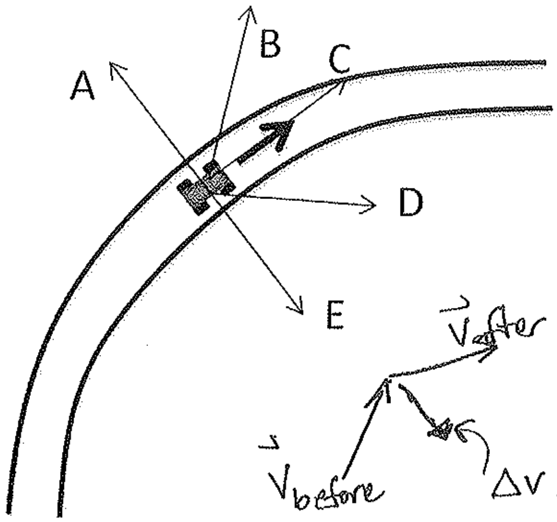
Question 1: A jet plane flies at a constant velocity of 900 km/hr. Which of the arrows best represents the net force on the plane?

const velocity

Choose A, B, C, D, E, or: F) none of the above

$\Rightarrow$ acceleration $= 0$

$F = ma = 0$



Question 2: A car travels around a curve at constant speed (velocity represented by the fat arrow). Which of the thin arrows best represents the car's acceleration?

A) A B) B C) C

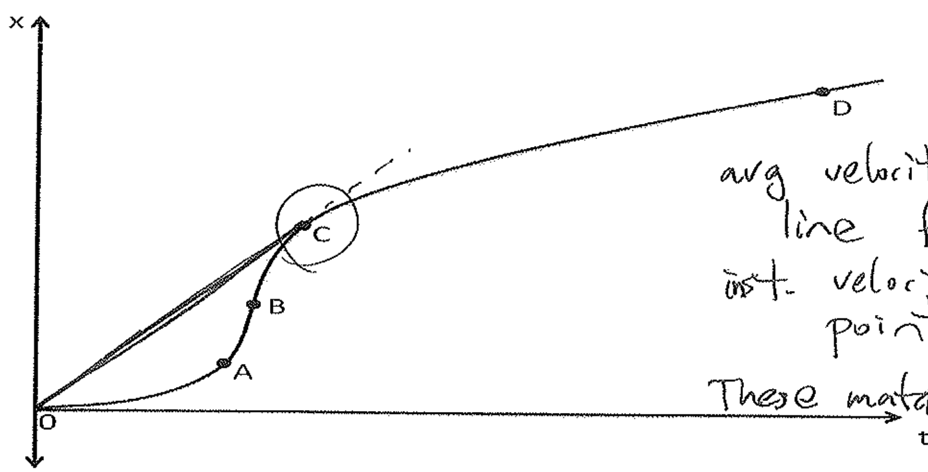
D) D E) E

F) None of the above; the acceleration is 0.

$\vec{V}_{after}$

$\vec{V}_{before}$

$\Delta v = \vec{V}_{after} - \vec{V}_{before}$ $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

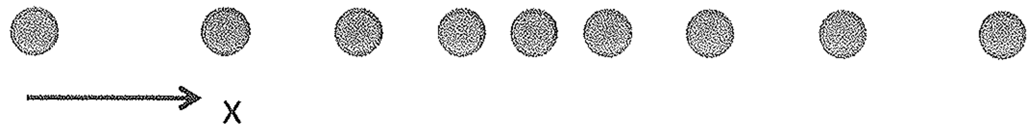


avg velocity : slope of line from 0 to point

inst. velocity = slope at point

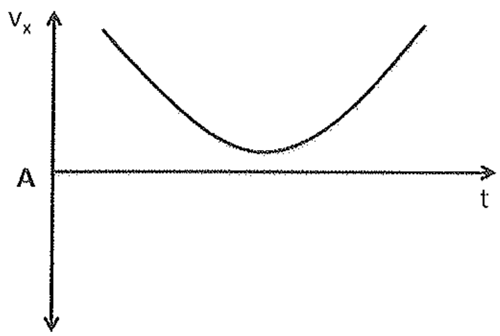
These match for point C.

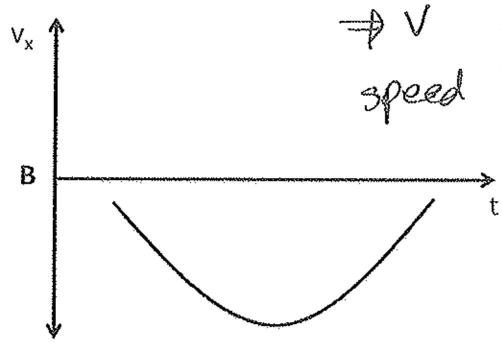
Question 3: The graph above represents the position vs time for an object. For which of the marked points on the graph does the instantaneous velocity most nearly equal the average velocity of the object from time 0 up to that time?

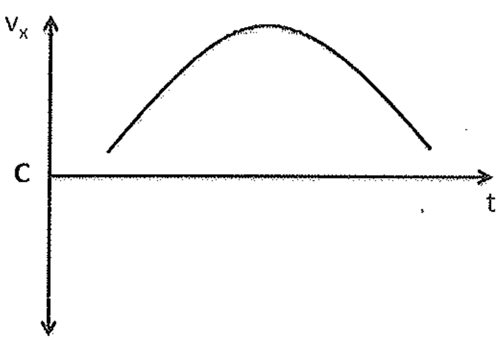


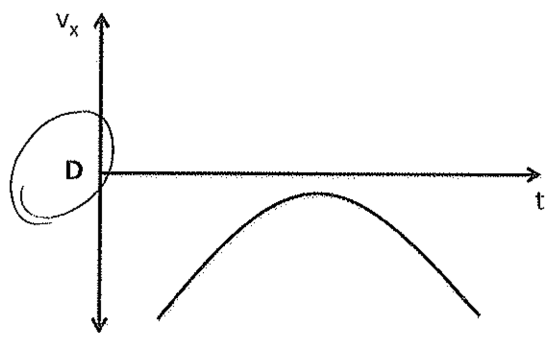
Question 4: The picture above represents the position of an object moving *from right to left* at equal time steps. The arrow indicates the positive x direction. Which of the graphs below best represents the object's x velocity vs time?

right → left
⇒ V negative
speed is larger then smaller then larger

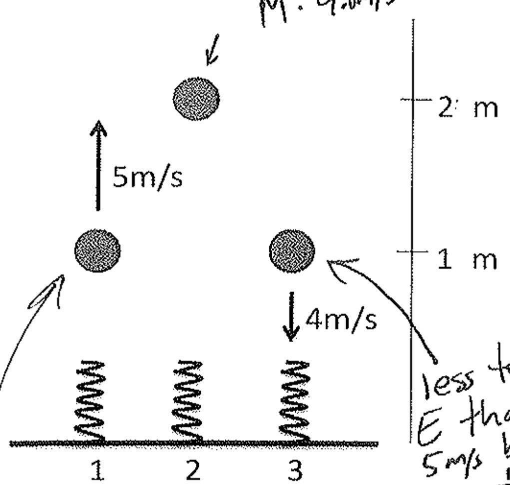








total E:
$M \cdot 9.8 m/s^2 \cdot 2m \approx 20 m^2/s^2 \cdot M$



less total E than 5m/s ball

Question 5: In the diagram at the left, rank from smallest to largest the amount by which the springs will compress if all the balls and all the springs are identical.

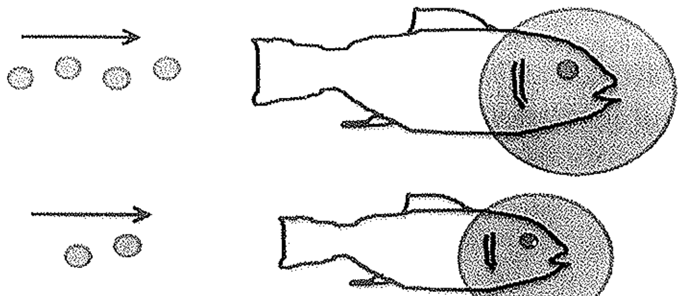
A) 1 > 2 > 3
B) 1 > 3 > 2
C) 2 > 1 > 3
D) 2 > 3 > 1
E) 3 > 1 > 2
F) 3 > 2 > 1

when spring is fully compressed, all energy is potential energy.
∴ Most compression ⇒ most potential energy ⇒ most total energy

$\frac{1}{2} M \cdot 4 m/s^2 + 9.8 m/s^2 \cdot 1m \cdot M \approx 18 \frac{m^2}{s^2} \cdot M$

total E: $\frac{1}{2} M \, 5 m/s^2 + 9.8 m/s^2 \cdot 1 m \cdot M$

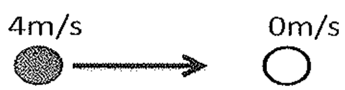
$\approx 22.5 \frac{m^2}{s^2} \cdot M$



Question 6: Two space salmon are initially at rest. A space fisherman shoots four peas at the larger salmon and two peas at the smaller salmon. All the peas are originally travelling at the same speed and all the peas bounce off with the same speed. If the smaller salmon is observed to be travelling twice as fast as the larger one after the collisions, what is the mass of the smaller salmon relative to the mass of the larger salmon?

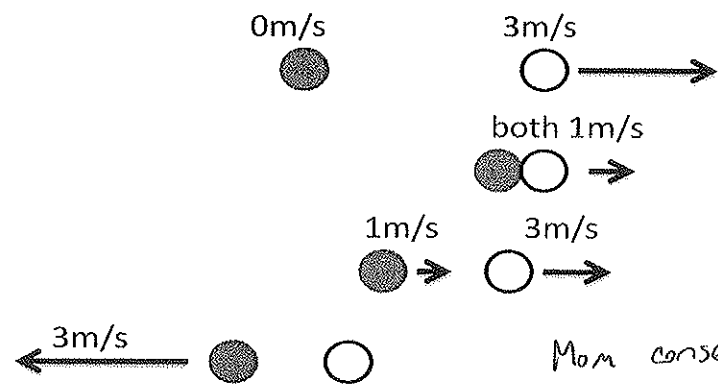
A) The same B) Half as much C) One quarter as much
D) One eighth as much E) It's actually heavier.

For 1 pea, the smaller salmon would be going half as fast, so the same speed as the larger salmon. Mass is prop. to # peas needed to reach a particular speed.
So: $M_{BIG} = 4 \cdot M_{SMALL}$.



Question 7: A ball moving at 4m/s collides with a stationary ball of equal mass. If the collision is not perfectly elastic, which of the following could be the result of the collision?

A)
B)
C)
D)



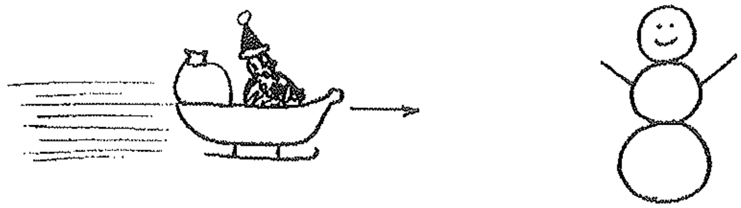
E) Any of the above are possible

Mom conserved, so
$m \cdot 4m/s = m(v_1 + v_2)$
only C is possible.

Question 8: An object confined to the x axis is acted on by a single force associated with a potential energy function U(x). If at some time the object is at a place where U(x) is minimum, we can say that

$F = -\frac{\partial U}{\partial x} = 0$ for minimum
so $a = \frac{F}{m} = 0$.
V could be anything.

A) its acceleration is zero B) its velocity is zero
C) both A and B D) neither A nor B



Question 9: Santa Claus is travelling in his hyper-sleigh at velocity $\sqrt{3/4}c$. Which of the pictures below best represents the proportions of Frosty the Snowman as measured by Santa?

No vertical length contraction.

A)

Santa sees contraction in direction of motion.

C)

B)

D)

Question 10: A large spacecraft with a self-sustaining population of humans and other species travels at v=0.6c from Earth to the recently discovered planet Kepler22b, 600 light years from Earth. How many years pass on the ship's clock during the voyage to planet Kepler 22b?

$t_{Earth} = \frac{600 \text{ lyrs}}{0.6c} = 1000 \text{ years}$

A) 1250 B) 800 C) 1000 D) 600 E) 480

Earth sees ship's clock slower $t_{ship} = \frac{1000 \text{ years}}{\gamma} = 800 \text{ years}$

Question 11: A nucleus of mass M decays into another nucleus of mass M' by emitting an α particle. We can say that the original mass M is

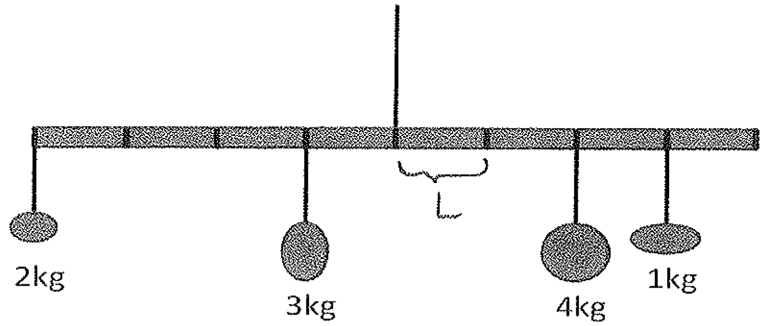
A) less than $m_\alpha + M'$
$\boxed{B}$) greater than $m_\alpha + M'$
C) equal to $m_\alpha + M'$
D) any of the above are possible

$E_{initial}$: all mass energy
E_{final}: partly kinetic energy so mass energy is less

Question 12: A ball of gold cools by emitting infrared radiation. During this process,

A) the mass of the ball decreases
B) the mass of the ball increases
C) the mass of the ball stays the same

Mass = total energy of an object in its rest frame.



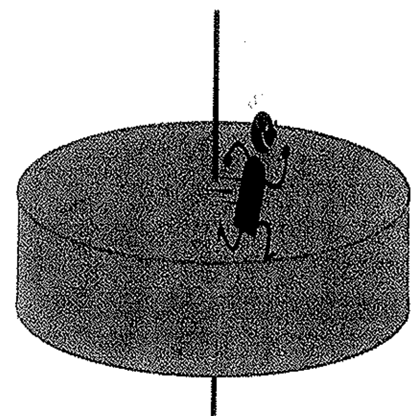
~~(sign)~~ + for clockwise, − for counterclock.

$$\tau = 4\text{kg}\cdot 2L + 1\text{kg}\cdot 3L - 3\text{kg}\cdot L - 2\text{kg}\cdot 4L = 0$$

Question 13: An artist gives you the design above for a piece of art that will hang from the ceiling. He asks you whether the art work will stay horizontal. After a quick calculation, you tell him that   Want to find net torque

A) the art will tip to the right.
B) the art will tip to the left.
C) the art will stay balanced.

Question 14: A big solid disk sits on a frictionless axle. A man stands at the edge of the disk. If the man tries to run,



A) the man will stay in the same place and the disk will rotate under him.
B) the man will move counterclockwise around the axle, while the disk will rotate clockwise around the axle (viewed from the top).
C) the man and the disk will both start moving clockwise around the axis.
D) the man and the disk will both end up moving counterclockwise around the axis.
Ignore any effects associated with air resistance.

Angular mom conservation
$\Rightarrow$ final L must be zero.
So man & disk go in opposite directions.

Question 15: In roughly 5 billion years, our Sun is expected to expand into a red giant star. If its radius increases by a factor of 400, its period of rotation would

A) stay the same
B) become 20 times longer
C) become 400 times longer
D) become 160000 times longer
E) become 20 times shorter

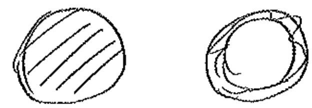
$R \to 400R$

$\Rightarrow I \to 160000\, I$

$\Rightarrow \omega \to \frac{1}{160000}\,\omega$

since $I\omega = L$ is conserved.

Question 16: Suppose that we replaced the wheels of a bicycle with solid disks with the same mass and radius as regular bicycle wheels. Ignoring any possible effects associated with air resistance, and assuming that the surface of the wheel is the same as a regular bicycle tire, we would expect that

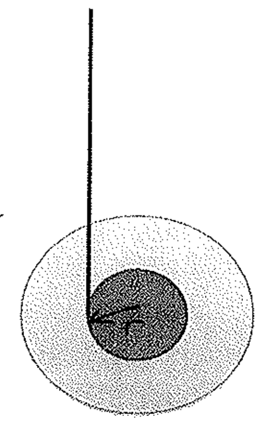


$\tau = I\alpha$.

A) the bicycle would be easier to pedal.
B) the bicycle would be harder to pedal.
C) the change would not affect how easy it would be to pedal the bike.

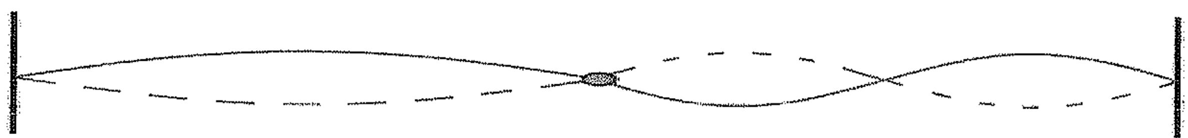
↖ lower I so more α for a given τ

Question 17: The picture at the right shows the cross-section of a yo-yo. The radius of the inner circle is r and the radius of the outer circle is R. We can say that the linear downward velocity v and the angular velocity ω of the yo-yo are related by



2π rotation $\Rightarrow$ $2\pi r$ of string lets out

A) $v = \omega R$
B) $v = \omega r$ So: $\Delta y = r \cdot \Delta\theta$
C) $v = 2\pi\omega R$
D) $v = 2\pi\omega r$ $\Rightarrow \frac{\Delta y}{\Delta t} = r\frac{\Delta\theta}{\Delta t} \Rightarrow v = r\cdot\omega$
E) none of these; v and ω are independent of each other



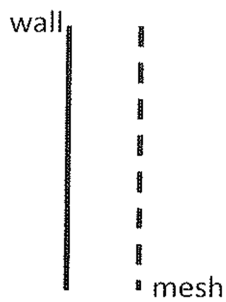
Question 18: Two strings of equal length (but different density) are joined together and set to vibrate in a standing wave. If the wave is as shown in the figure above, what is the ratio of the linear density of the string on the left to the linear density of the string on the right (μ_L/μ_R)?

A) 1/4
B) 1/2
C) 1
D) 2
E) 4

Question 19: The speed of a wave travelling in shallow water depends only on the depth of the water h (assumed to be much less than the wavelength) and the acceleration of gravity g. The speed is given by one of the formulae below; use dimensional analysis to determine which is the correct one.

A) $v = g/h$ B) $v = (g/h)^{1/2}$ C) $v = gh$ D) $v = (gh)^{1/2}$ E) $v = (h/g)^{1/2}$

Question 20: In an effort to control the noise in the Science One study room, James suggests that a wire mesh be installed on the walls to reduce the reflected noise. Some portion of the sound wave will be reflected off it, while the rest will pass through and get reflected off the wall. If James particularly wants to eliminate high-pitched giggling noises whose sound waves have wavelength 0.2m, how far should James install the mesh from the wall? (note: there is no phase shift for the reflections from the mesh or wall)



A) 0.05m
B) 0.1m
C) 0.2m
D) 0.4m
E) 0.8m

Question 21: In a double-slit experiment, laser light is shone through a pair of slits, and a pattern of light and dark spots is observed on a screen. In which of the following situations will the spacing between the spots be the same as it was originally?

A) Laser light with twice the wavelength is used, and distance between the slits is halved.
B) Light with twice the frequency is used, and the distance between the slits is doubled.
C) Laser light with twice the wavelength is used, and distance between the slits is doubled.
D) Laser light with twice the amplitude is used, and the distance between the slits is doubled.

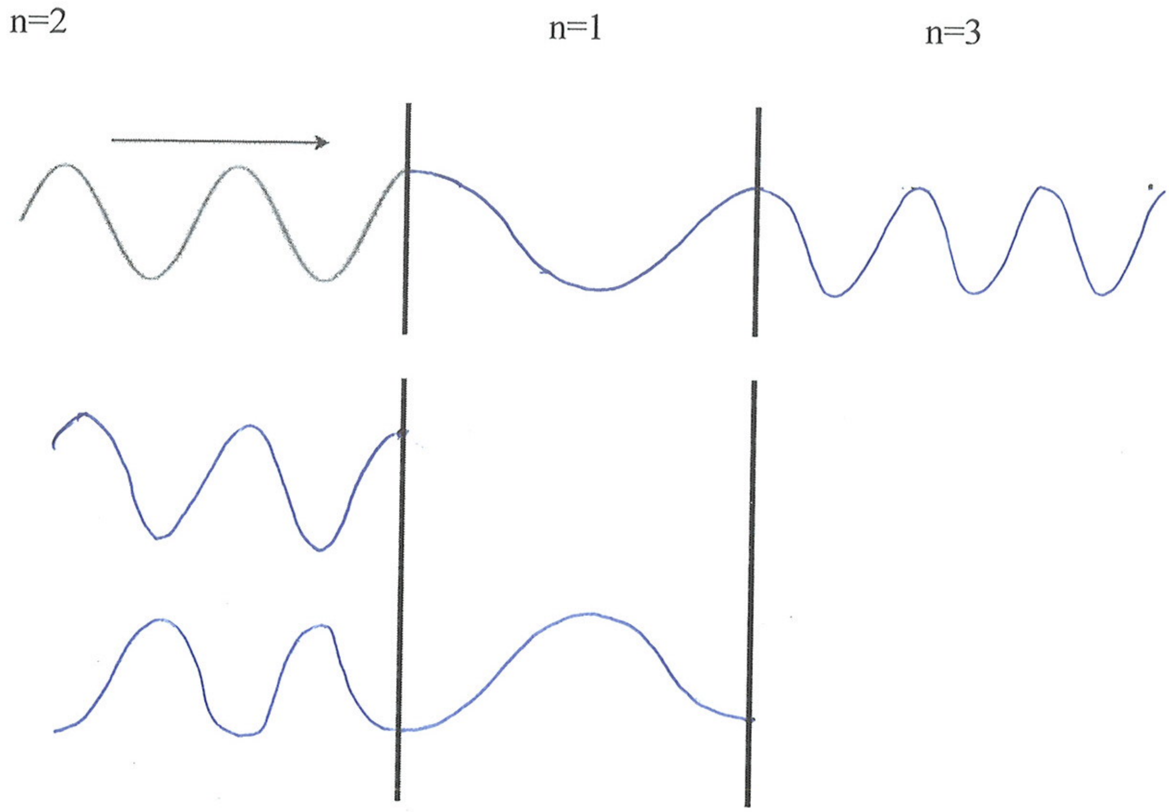
Question 22: In a double-slit experiment, laser light is shone through a pair of slits, and a pattern of light and dark spots is observed on a screen. If an identical experiment is performed in water, we expect that,

A) The spots would get closer together.
B) The spots would get further apart.
C) The pattern would remain the same.

Question 23:

Light passes through a material that has two changes in the index of refraction. Draw the transmitted waves on the upper and the reflected waves on the lower part of the figure.

(2 points)

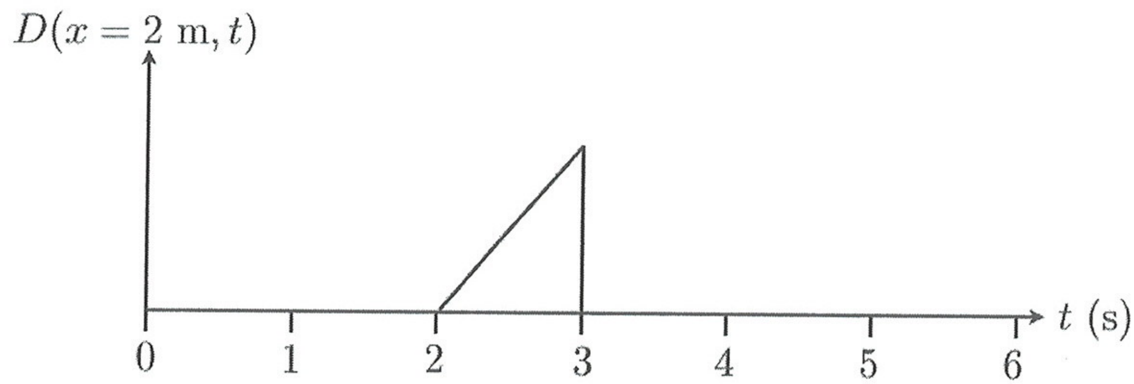


1 point: wave lengths

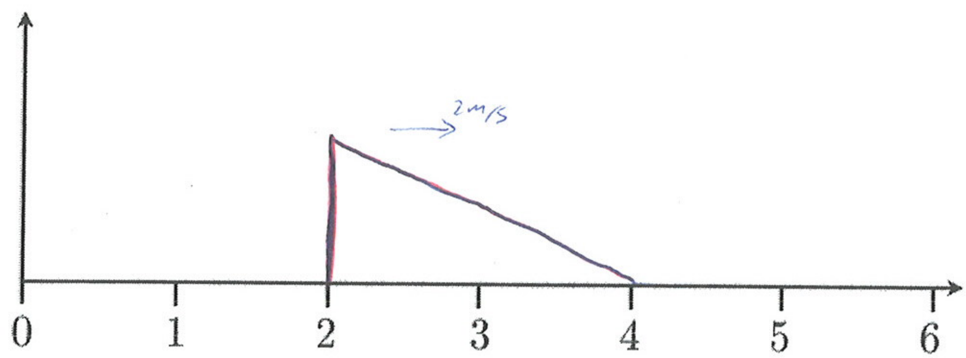
1 point: phase shifts.

Question 24: Below is a history graph of a wave pulse travelling at 2 m/s to the right.

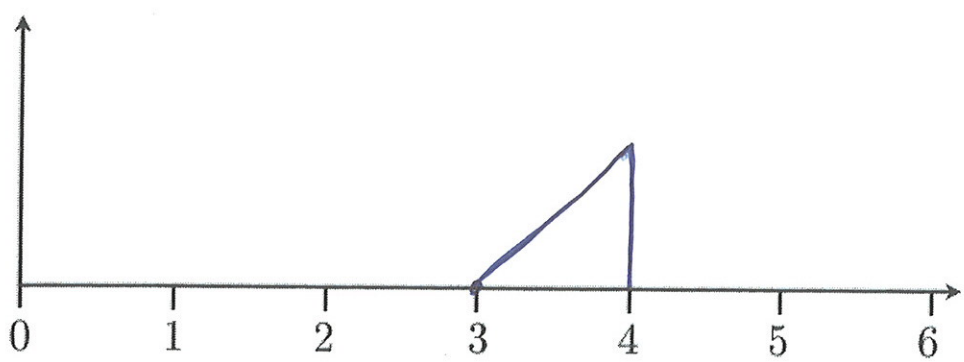
(2 points)



a) On the axes below, draw the snapshot graph for t = 3 s.



b) On the axes below, draw the history graph at x = 4 m.



Question 25: Explain concisely how Newton's Second Law can be used to predict the future.

(4 points)

~~tells you acceleration from present forces (environment)~~

$$\cancel{a = \frac{dv}{dt} = \frac{v(t+\varepsilon) - v(t)}{\varepsilon}}$$

~~so given v. now get v little later~~

~~given x now v gives x later.~~

~~repeat. to get.~~

Newton's second Law allows us to determine the acceleration of an object based on its present position and velocity (which determine the forces, given the object's environment). Since

$$a = \frac{dv}{dt} \approx \frac{v(t+\varepsilon) - v(t)}{\varepsilon}$$

we have:

$$v(t+\varepsilon) \approx v(t) + \varepsilon \cdot a$$

So, knowing the acceleration allows us to predict velocity at a slightly later time.

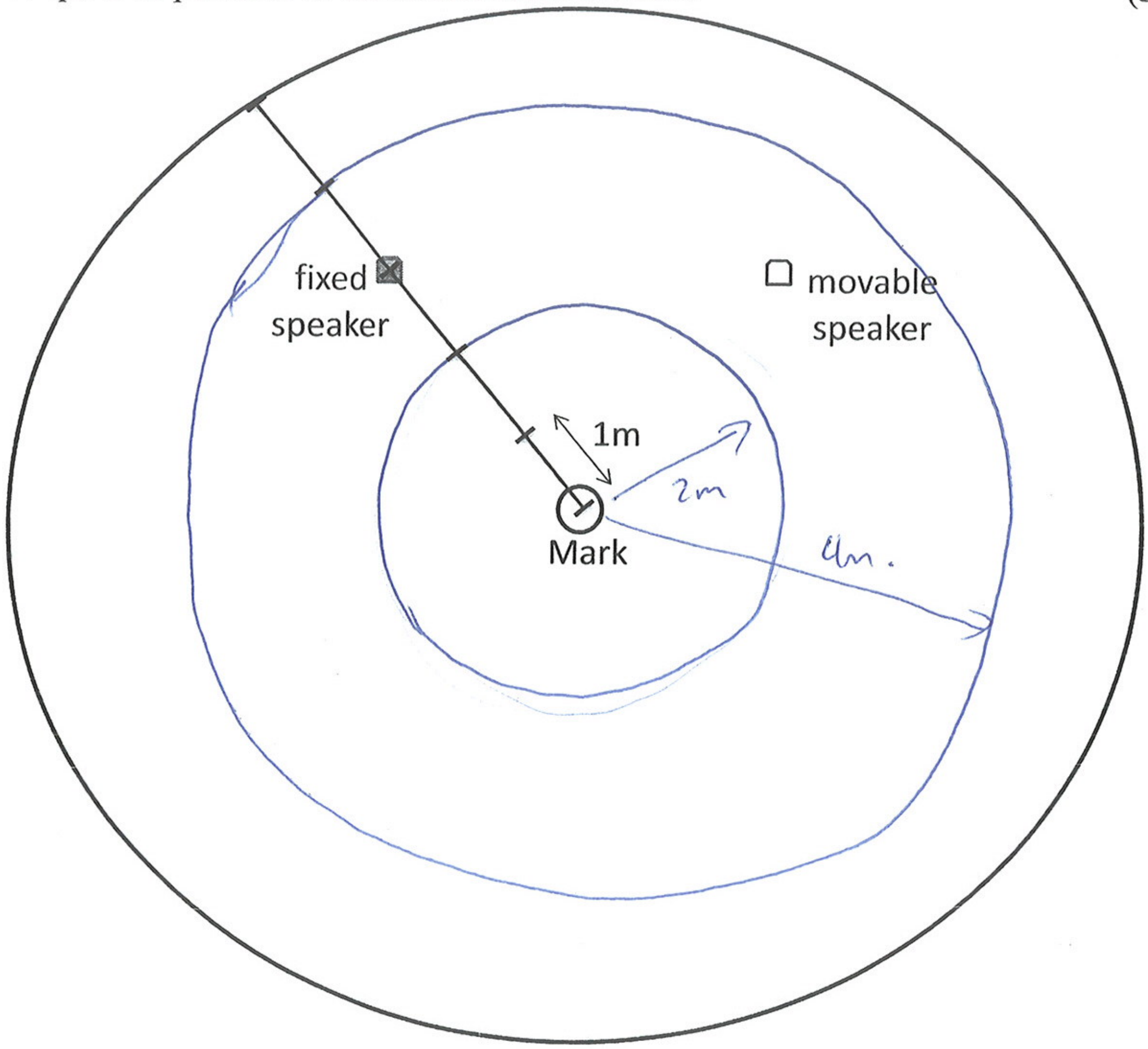
Similarly

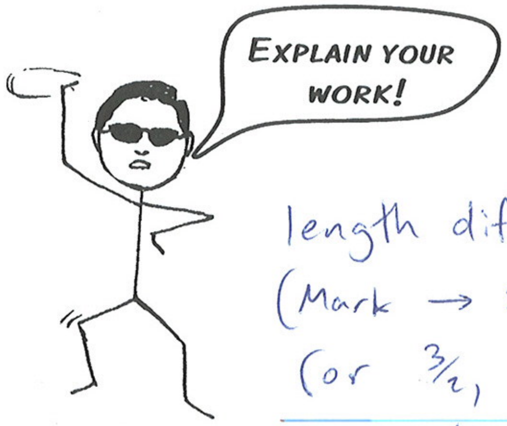
$$x(t+\varepsilon) \approx x(t) + \varepsilon \cdot v$$

so we can predict the position at a slightly later time knowing velocity.

Repeating the process, we can in principle figure out x and v at any later time.

Question 26: Mark sits in the middle of a round room listening to Gangnam Style on repeat. Several days later, he begins to get tired of listening to the song. Unfortunately, there is no way to turn off the music. Fortunately, he finds that only one of the speakers is attached to the ground, and the other one can be moved anywhere he likes. On the picture below, indicate all the places where Mark can move the second speaker so that the most annoying part of the music (which has a frequency of 170Hz) will be as quiet as possible at the location of his chair. **(3 points)**





For $f = 170\,Hz$, we have a wavelength $\lambda = \frac{V_{sound}}{f} = \frac{340\,m/s}{170\,s^{-1}} = 2\,m$. 1/2 We want destructive interference, so the path length difference between (Mark → 1st speaker) and (Mark → 2nd speaker) should be half a wavelength (or $3/2$, $5/2$, ...). So the second speaker should be at a distance $3m \pm 1m$ from Mark

Question 27: The Large Hadron Collider in Geneva accelerates protons close to the speed of light, so that their total energy is 7000 times their rest energy. If the beam has 10^{10} protons per second, and we shine the beam at a 1kg block on a frictionless table so the protons reflect directly backwards at approximately the same speed, how long will it be before the block moves one meter?

For this problem, it is reasonable to ignore the change in mass of the block.

(4 points)

Single proton:

We are given that total energy = 7000x rest energy, so:

$$\gamma mc^2 = 7000\, mc^2$$

$$\Rightarrow \quad \gamma = 7000$$

The momentum of each proton is

$$p = \gamma m v$$
$$\approx 7000 \cdot m_p \cdot c$$

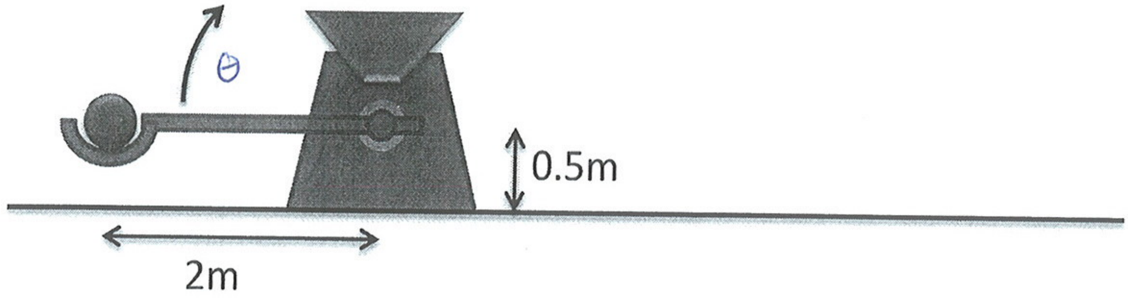
When the proton reflects off the block, its momentum changes by $-14000\, m_p \cdot c$, so the momentum change of the block must be $+14000\, m_p \cdot c$. Thus, we have, for each collision:

$$\Delta p = 14000\, m_p \cdot c$$

There are 10^{10} collisions per second, so we have:

$$\frac{\Delta p}{\Delta t} = \frac{14000\, m_p \cdot c}{10^{-10}\, s}$$

$$= 7.02 \times 10^{-5}\, kg\, m/s^2$$



Question 28: A 100kg iron ball is loaded into a catapult that starts off in the position shown. When it is fired, the catapult exerts a torque on the lever arm that increases linearly with time:

$$\tau(t) = (300{,}000\text{Nm/s})\, t$$

When the catapult arm reaches an angle of 45 degrees, it hits a barrier that prevents it from moving further, leaving the ball to fly freely. Bothvar is thinking about buying this catapult to sent iron balls over the castle walls of his enemies. What are the highest castle walls over which he will be able to send balls? **(4 points)**

Assume that the mass of the lever arm can be ignored relative to the mass of the ball. We assume τ is the net torque

We have a torque $\tau = (300\,000 \frac{\text{Nm}}{\text{s}}) \cdot t$ acting on the catapult arm, so this causes an angular acceleration

$$\alpha = \frac{\tau}{I} = \frac{300\,000\ \text{Nm/s}}{100\text{kg} \cdot (2\text{m})^2} \cdot t$$

?

$I = MR^2$

$$= (750\ \text{s}^{-3}) \cdot t$$ ← This is $\frac{d\omega}{dt}$.

The angular velocity is then

$$\omega(t) = \frac{1}{2}(750\ \text{s}^{-3})t^2.$$ ← This is $\frac{d\theta}{dt}$

The angular position is then:

$$\theta(t) = \frac{1}{6}(750\text{s}^{-3}) \cdot t^3$$

more space next page.

The arm reaches 45° at the time when

$$\frac{\pi}{4} = \frac{1}{6}\left(750\ s^{-3}\right)t^3$$

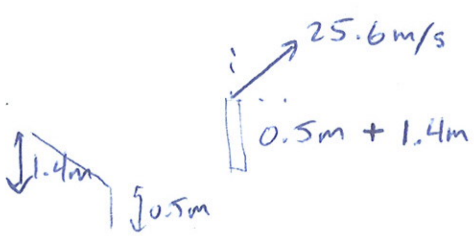
$$\Rightarrow \quad t = 0.184s$$

The angular velocity at this time is:

$$\omega = \frac{1}{2}\left(750\ s^{-3}\right)t^2$$
$$= 12.8\ s^{-1}$$

The speed of the ball is then:

$$V = R\omega = 2m \times 12.8s^{-1}$$
$$= 25.6\ m/s$$



The vertical speed is

$$V_y = 25.6\ m/s \times \frac{1}{\sqrt{2}}$$
$$= 18.1\ m/s$$

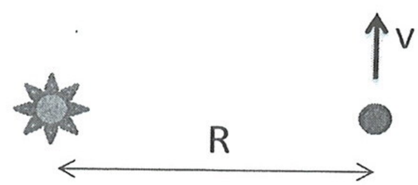
So the maximum height is found from the trajectory:

$$y = y_0 + v_0 t + \frac{1}{2} a t^2$$
$$= \underset{+1.4m}{0.5m} + (18.1 m/s) \cdot t - 4.9 m/s^2\, t^2$$

We want the time when $V_y = 0$: $18.1 m/s - 9.8 m/s^2\, t = 0$

$\Rightarrow t = 1.84s$ from ~~[illegible]~~ the 45° point.

$$\boxed{Y_{max} = 18.6\ m}$$



Question 29: In a two-dimensional alternate universe, the gravitational potential energy of an object of mass m at a distance of r from an object of mass M is

$U = G_2 M m \ln(r/R_0)$

(where ln is the natural logarithm) and R_0 is a constant. Determine the speed v so that the object in the diagram above will move in a circular orbit around the star. **(4 points)**

The gravitational potential results in a radial force

$$F = -\frac{dU}{dr}$$

$$= -\frac{G_2 M m}{r} \quad 1$$

This causes an acceleration

$$a = \frac{1}{m} \cdot F$$

$$= -\frac{G_2 M}{r} \quad 1$$

For a uniform circular orbit at radius R, we must have:

$$|\vec{a}| = \frac{v^2}{R} \quad 1 \qquad \text{or :} \qquad v = \sqrt{R|\vec{a}|}$$

$$= \sqrt{G_2 M} \quad 1$$

b) Suppose the solar system above were filled with stationary dust with density ρ (kg/m^2) that can build up on the planet's surface as it orbits. Describe qualitatively and quantitatively the effects of this dust on the orbit. You may assume that the planet's size doesn't change as it gets more massive and that any dust that sticks to the planet is replaced by other dust. **(2 points + possible bonus point)**

The planet's mass increases as it absorbs dust, so by angular momentum conservation, if $L = MV_\perp R$ stays the same, $V_\perp \cdot R$ must decrease. This means the planet will start to spiral in to the star.

~~Let the~~ Extra points for estimating how long this takes

FORMULA SHEET

$v = dx/dt \qquad a = dv/dt$

$p \approx mv \qquad (\text{if } v \ll c) \qquad J = \Delta p$

$F = dp/dt$

$|F| = C\,v^2, \quad |F| = \mu\,N, \quad |F| = mg, \quad |F| = kx \qquad F_x = -dU/dx$

$E = mgh \qquad E = ½\,mv^2 \qquad E = ½\,k\,(\Delta s)^2 \qquad \Delta W = \vec{F} \cdot \Delta\vec{r}$

$L = I\,\omega \qquad L = M\,v_{perp}\,R \qquad \omega = d\theta\,/dt \qquad \alpha = d\omega\,/dt$

$\tau = dL/dt \qquad \tau = F_{perp}\,R \qquad E = ½\,I\,\omega^2 \qquad \tau = I\alpha$

$a = v^2/R \qquad \omega = v/R$

$I = M\,R^2$ (ring, point mass), $½\,M\,R^2$ (solid disk, cylinder), $^2/_5\,M\,R^2$ (solid sphere),
$^1/_3\,M\,L^2$ (stick from one end), $^1/_{12}\,M\,L^2$ (stick through middle), $^2/_3\,M\,R^2$ (hollow sphere)

$\lambda\,f = v \qquad v = (T/\mu)^{1/2} \qquad d\,\sin\theta = n\,\lambda$

$\gamma = (1 - v^2/c^2)^{-1/2} \qquad v\gamma = c\,(\gamma^2 - 1)^{1/2}$

$x' = \gamma\,(x - v\,t) \qquad u' = (u - v)/(1 - uv/c^2)$
$t' = \gamma\,(t - (v/c^2)x)$

$\vec{p} = \gamma\,m\,\vec{v} \qquad E = \gamma mc^2 \qquad v/c^2 = p/E \qquad E^2 = p^2c^2 + m^2c^4$

1 light year $= c \times 1$ year
$c \approx 3 \times 10^8$ m/s
$G = 6.67 \times 10^{-11}$ N m^2/kg^2
$v_{sound} = 340$ m/s
$g = 9.8$ m/s^2