Science One Term 1 Physics Exam

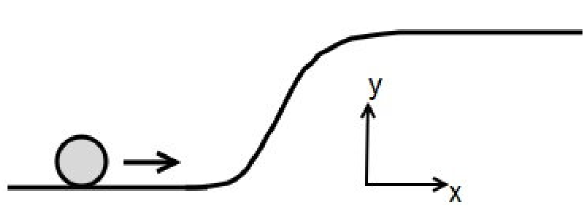
December 17, 2013

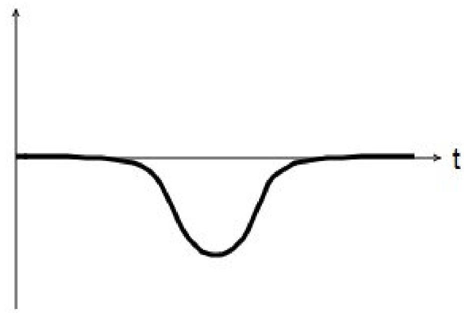
Name:
Student Number:
Bamfield Number:

Questions 1-23: Multiple Choice: 1 point each
Questions 24-31: Long answer: 27 points total
explain your work

Multiple choice answers:

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

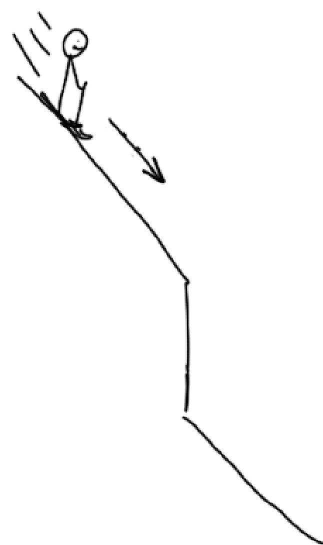


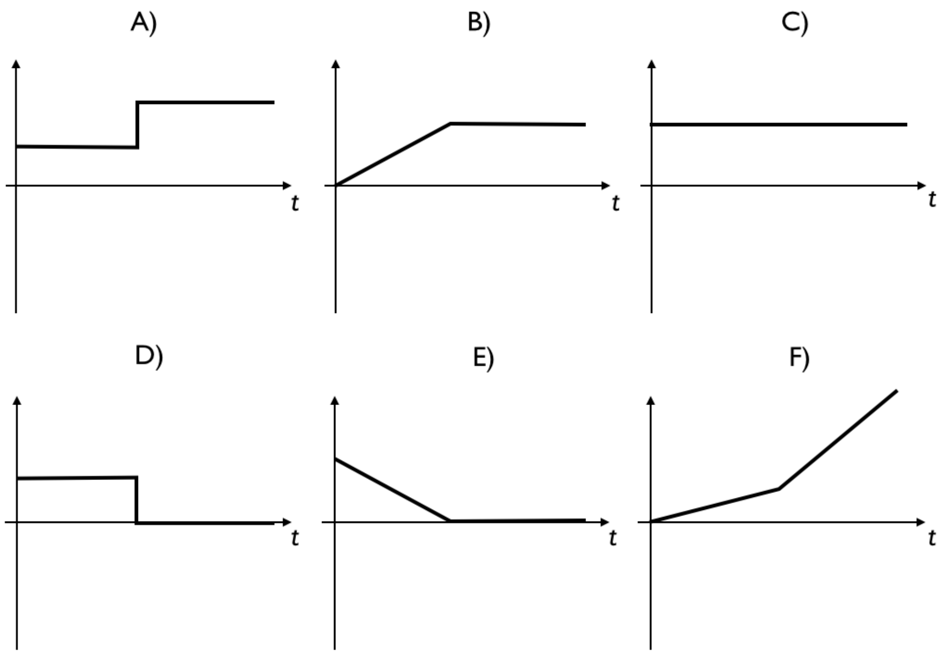


Question 1: A giant grapefruit rolls up a slope as shown, with more than enough energy to reach the top. In the graph on the right, which quantity is plotted as a function of time?

A) x B) v_x C) a_x D) y E) v_y F) a_y

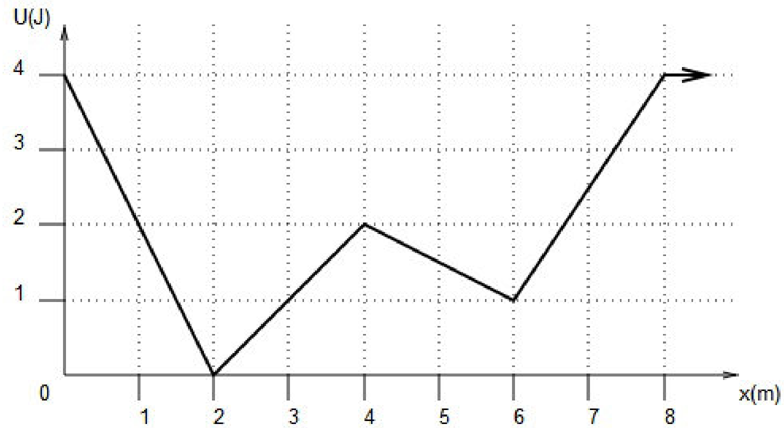
Question 2: A skier, initially stationary, slides down a slope and jumps off a small cliff, landing on the slope below. Ignoring air drag, which of the graphs below could represent the *magnitude of the vertical acceleration* of the skier from the time she starts moving to just before she lands.





Question 3: Which of the graphs above could represent the *horizontal* velocity of the same skier?

A) A B) B C) C D) D E) E F) F



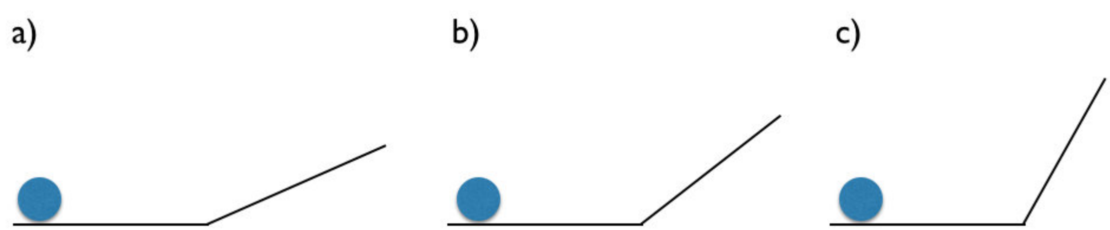
Question 4: The diagram above shows the potential energy of an object at various possible x positions. If the object is moving to the right at position x=3m with kinetic energy 1.5J, what is the maximum x position that will be reached before the object turns around?

A) Somewhere between 3m and 4m
B) Exactly 4m
C) Somewhere between 4m and 6m
D) Somewhere between 6m and 8m
E) The object will keep going past 8m

Question 5: What is the largest magnitude force that the same object will experience during its entire future motion? *Assume that the only force on the object is the one related to the potential shown.*

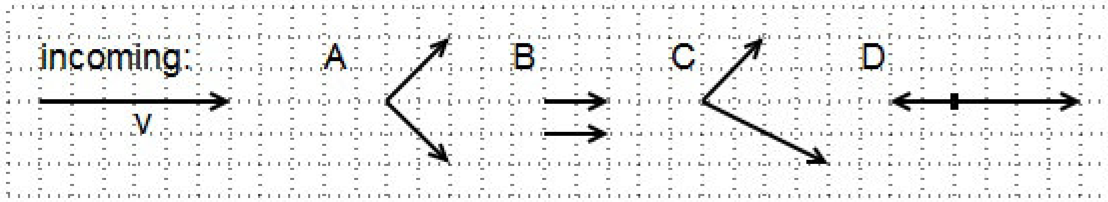
A) |F| = 0.5N B) |F| = 1N C) |F| = 1.5N D) |F| = 2N

Question 6: All the balls in the pictures below have equal mass and are moving to the right with equal speed. Each ball rolls up a ramp and then back down. Which ball will reach the highest vertical position?



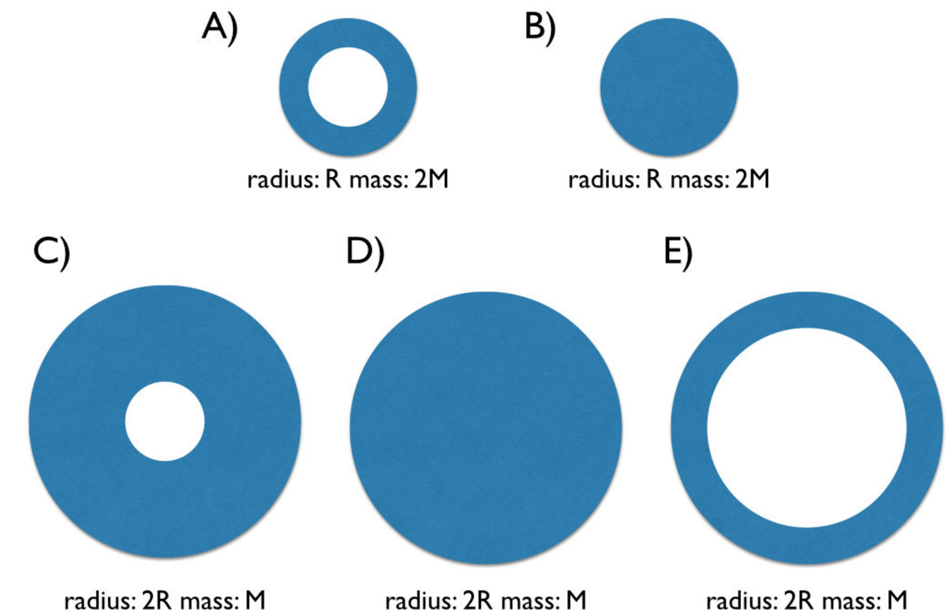
d) They will all reach the same height.

Question 7: A billiard ball moving to the right at speed v strikes a stationary billiard ball of the same mass. Which pair of arrows represents possible velocities for the two balls after the collision, if the arrow at the left represents the initial velocity of the first ball?



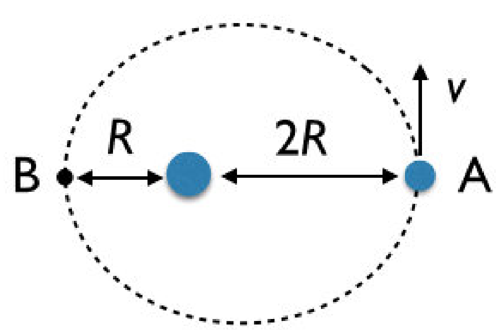
E) Any of the above

Question 8: The objects shown below are all rolled down a ramp, starting at the same time. Which will reach the bottom first?



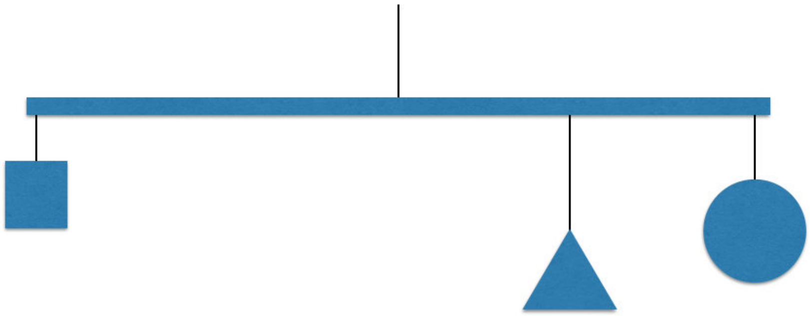
F) All will reach the bottom at the same time

Question 9: An asteroid orbiting the sun has speed v at the position A. The speed of the asteroid at position B will be:



A) 4v
B) 2v
C) v
D) ½ v
E) ¼ v

Question 10: If the triangle has mass 2M and the circle has a mass M, what mass must the square have for the mobile to balance?



A) 1M B) 2M C) 2.5M D) 3M E) 6M

Question 11: A railway track is built to circle the equator of the earth. If a massive train is built to move continuously from east to west (i.e. opposite to the direction that the Earth is spinning)

A) The Earth would spin a little slower
B) The Earth would spin a little faster
C) The Earth would continue to spin at the same rate

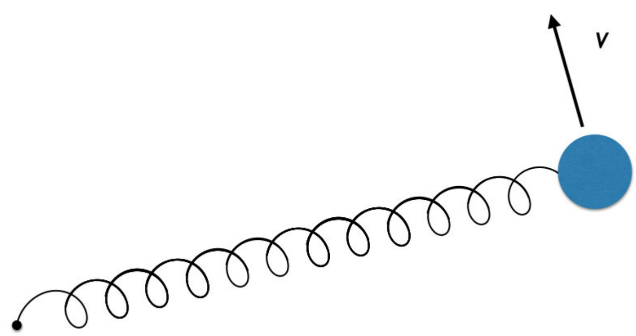
Question 12: An object of mass *m* is attached to a spring with spring constant *k* and a natural length of *L*. The object is then spun around in a circle such that the spring stretches to a length 2*L*. What is the speed of the object as it spins around?

A) $v = \sqrt{\frac{k}{m}}\,L$

B) $v = \sqrt{\frac{2k}{m}}\,L$

C) $v = 2\sqrt{\frac{k}{m}}\,L$

D) $v = 4\sqrt{\frac{k}{m}}\,L$



Question 13: An object with mass M and total energy 2 M c^2 collides with another stationary object of mass M. If the two objects merge to form a single object, we can say that the mass of the final object is

A) Less than 2M
B) Equal to 2M
C) Greater than 2M but less than 3M
D) Equal to 3M
E) Greater than 3M

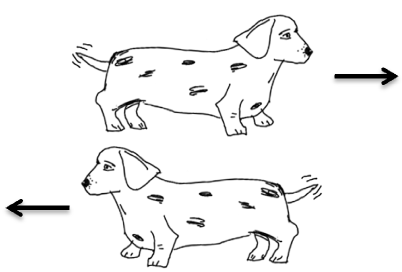
Question 14: A space probe travels at constant speed to a distant star and back to Earth. If the star's distance in Earth's frame is D, and the time elapsed on Earth is T, the speed of the probe is

A) The distance 2D divided by the time T
B) The contracted distance $2D/\gamma$ divided by the time T
C) The distance 2D divided by the dilated time $T\gamma$
D) The contracted distance $2D/\gamma$ divided by the dilated time $T\gamma$
E) None of the above

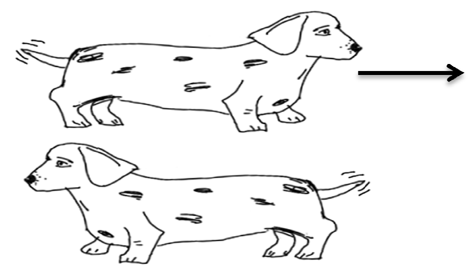
Question 15: A ship is travelling away from Earth to a distant star at speed $v = 3/5c$. The astronauts ask people on Earth to send them a live stream of the TV show "The Big Bang Theory." If the show is supposed to be watched at 24 frames per second, the signal from Earth should be send at

A) Higher than 24 frames per second
B) Lower than 24 frames per second
C) 24 frames per second

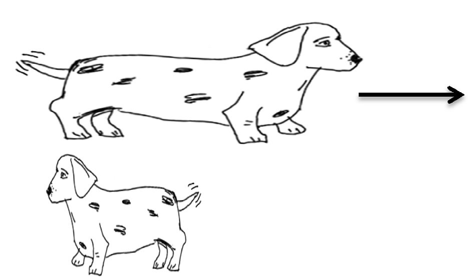
Question 16: The first picture below shows two wiener dogs passing each other at a relativistic speed in some frame of reference. Which of the other diagrams could represent the same two dogs in the frame of reference of the lower dog?



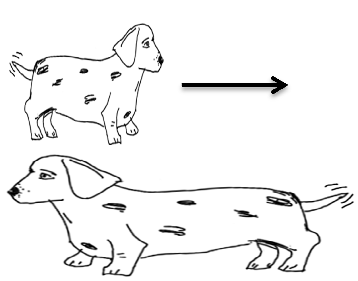
A)



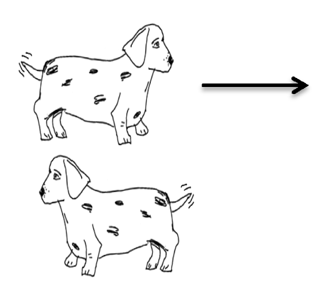
B)

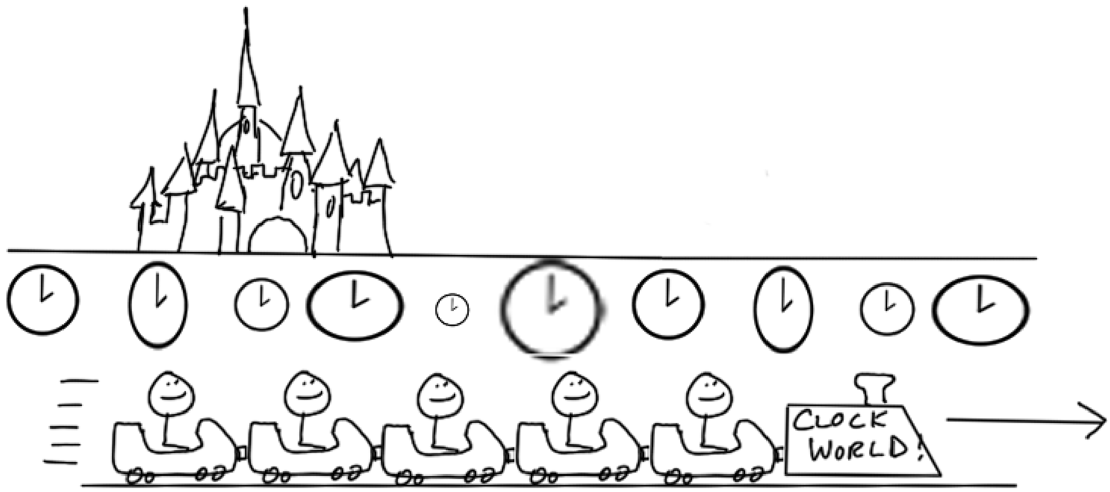


C)



D)





Question 17: In the new **ClockWorld!** ride at Disneyland, a train travelling at nearly the speed of light passes a whole bunch of clocks which are synchronized in the frame of the track. If observers at the front and back of the train each look out at a clock when the time in the train is noon, we can say that

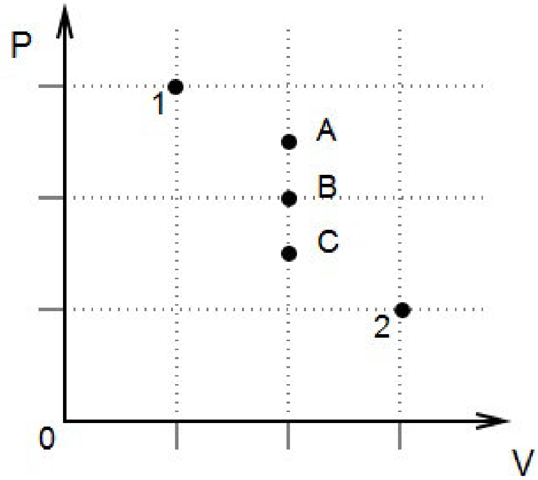
A) The person at the front of the train will see an earlier time
B) The person at the back of the train will see an earlier time
C) The two observers will see the same time

Question 18: A train with clocks at the front and back passes by at a relativistic speed. We can say that

A) Observers on the track will measure the front clock to be ticking slower than the back clock
B) Observers on the track will measure the back clock to be ticking slower than the front clock
C) Observers on the track will measure the clocks to be ticking at the same rate

Question 19: A container of oxygen (O_2) and an identical container of helium (He) are each at 300K and atmospheric pressure. We can say that

A) The average density (number per volume) of oxygen molecules is significantly greater than the average density of helium molecules
B) The average density of helium molecules is significantly greater than the average density of oxygen molecules
C) The average density of oxygen molecules is about the same as the average density of helium molecules
D) There is not enough information to decide which of A, B, or C are true.



Question 20: A gas expands slowly at constant temperature from point 1 to point 2 on the PV diagram shown. Which of the points on the diagram best represents the volume and pressure after half of the expansion has occurred?

A) A B) B C) C D) Any of A,B,C are possible

Question 21: A gas is cooled at constant pressure. For this process, we can say that

A) The work W done on the gas is positive
B) The work W done on the gas is negative
C) The work W done on the gas is zero
D) Any of the above are possible

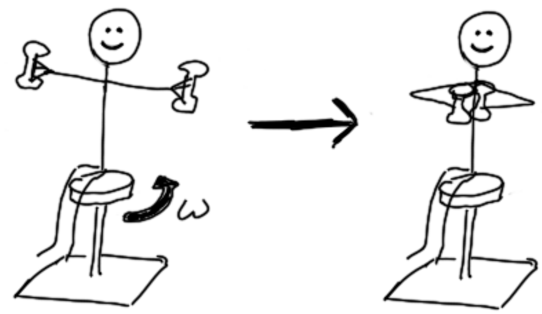
Question 22: Molecular hydrogen (H_2) gas is heated until it has four times as much thermal energy as it had initially. We can say that

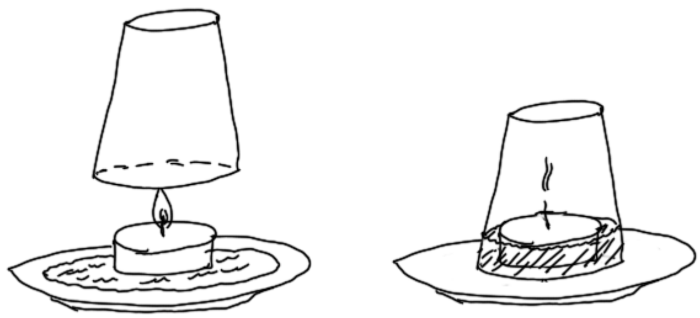
A) The average speed of the molecules is more than four times as much as before
B) The average speed of the molecules is four times as much as before
C) The average speed of the molecules is between two and four times as much as before
D) The average speed of the molecules is twice as much as before
E) The average speed of the molecules is less than twice as much as before

Question 23: Three cylinders of gas are compressed, one isobarically, one isothermally, and one adiabatically. If the work done is the same in all cases, for which case is ΔE largest?

A) In the isobaric (constant pressure) case
B) In the isothermal case
C) In the adiabatic case
D) ΔE is the same in all cases

Question 24: Brianna is spinning around on a frictionless stool, holding weights with her arms extended. If she pulls the weights in towards her body and holds them there, sketch Brianna's angular speed and angular acceleration as a function of time on the axes below. Indicate the times when she starts and finishes moving the weights. (**2 points)**





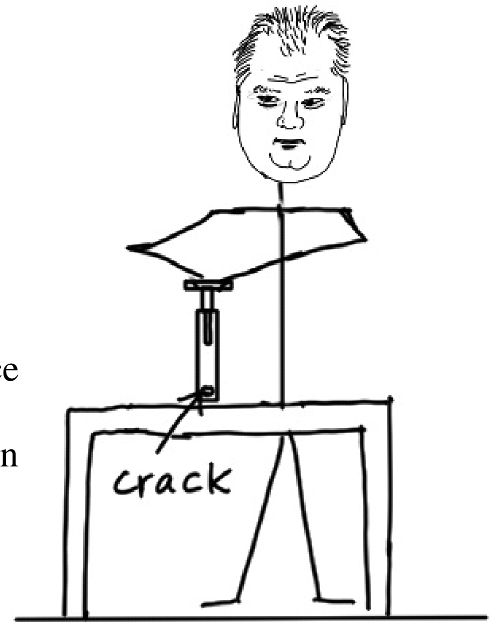
Question 25: A candle sits in a small pool of water on a dish. A glass is held above the candle, then quickly brought down over the candle so that the rim of the glass is in the water. It is observed that the candle goes out and the water is sucked up into the glass. Provide a concise explanation for this phenomenon. (**3 points)**

Question 26: A bungee jumper with mass 100kg jumps off a bridge attached to a bungee cord that can be modeled as a spring with normal length 10m and spring constant k = 100N/m. When the cord has stretched to a length of 20m (call this time t=0), the jumper's vertical velocity is -16 m/s.

If the air drag force can be modeled as $F = - C v^2$, where C = 0.3kg/m, estimate the change in the length of the cord and the change in the vertical velocity of the jumper between t=0 and t=0.1s. (**4 points)**

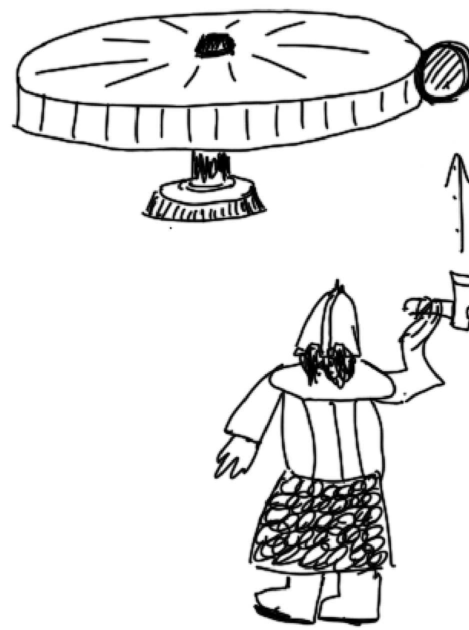
Question 27: A proton (mass m) from space with total energy $E = 5/3\ m\,c^2$ collides with a stationary proton in the upper atmosphere. As a result of the collision, the protons annihilate, leaving a stationary Q^{++} particle (mass 1.257 m) and a meson (an unstable particle with mass 0.457 m) which travels directly towards the Earth's surface. If the collision happens 100km above the Earth's surface and the half-life of the meson is $\tau = 5.71 \times 10^{-6}$ s, what are the chances that the meson will reach the surface of the Earth before decaying? *(Note: the half life τ is defined so that for a particle at rest, the chance of that the particle hasn't decayed is 1/2 after time τ, 1/4 after time 2τ, 1/8 after time 3τ, etc…)* **(4 points)**

Question 28: Rob Ford (mayor of Toronto and amateur physicist) is working on a new design for a crack pipe. The idea is put the crack in an insulated cylinder of air (initially at atmospheric pressure and temperature 300K) and ignite the crack by pressing firmly down on a piston while the cylinder (crack pipe) remains in place. If the cylinder is 15 cm long and has cross sectional area 1cm^2, what constant force would ensure that the air in the tube reaches 900K (just right to ignite the crack) after the piston has been pushed 10cm down the tube? *(You may treat the air as nitrogen gas with $c_V = 5/2\ R$.)* **(4 points)**



Question 29:

a) A group of dwarves are practicing axe-throwing. They have a target attached to a large wooden disk of mass 10 dwarvish stones (the standard unit of mass used by dwarves in Middle Earth, 1 ds = 15 kg) and radius 2 meters. If Glomdrin throws his axe (mass 1ds) with speed 10 m/s and it sticks in the target, determine the angular speed of the wooden disk just after the collision. *Assume that the target is also at radius 2m and that the axe hits the target perpendicularly.* **(2 points)**



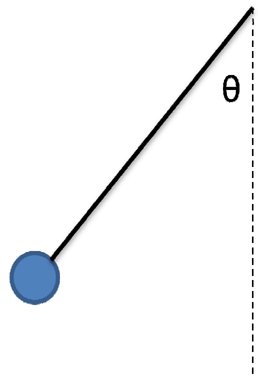
b) As the disk starts spinning, some dwarf children run in and slow it down by placing their hands on it. The frictional torque due to dwarf-child hands increases with time as more and more dwarf children put their hands on the wheel. If we model this by

$$\tau = (1\text{N m} / \text{s})\, t\,,$$

through what angle does the disk rotate before stopping? **(3 points)**

Question 30: Ethel the Invincible swings a spiky ball with mass m around on a 1m long chain. If the ball swings around once each 1.69 seconds, find the angle θ.

Hint: in what direction is the acceleration for an object in circular motion? **(3 points)**



Question 31: A sealed container, with volume 1 liter and mass 1kg, contains 1 mole of helium gas at temperature 100K. The container is floating in outer space, minding its own business, when a piece of space junk punctures a 1mm^2 hole in the wall of the container. Estimate the acceleration of the container due to the escaping helium. **(2 points)**
(*It may be useful to know that the mass of a helium atom is* 6.65×10^{-27} *kg*.)

FORMULA SHEET

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

$p \approx mv$ (if $v \ll c$) $J = \Delta p$

$F = dp/dt$

$|F| = C v^2$, $|F| = \mu N$, $|F| = mg$, $|F| = kx$ $F_x = -dU/dx$ $F = G M m/R^2$

$E = mgh$ $E = \frac{1}{2} mv^2$ $E = \frac{1}{2} k (\Delta s)^2$ $\Delta W = \vec{F} \cdot \Delta\vec{r}$

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

$\tau = dL/dt$ $\tau = F_{perp}R = F R_{perp}$ $E = \frac{1}{2} I \omega^2$

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

$I = M R^2$ (ring, point mass), $\frac{1}{2} M R^2$ (solid disk, cylinder), $\frac{2}{5} M R^2$ (solid sphere), $\frac{1}{3} M L^2$ (stick from one end), $\frac{1}{12} M L^2$ (stick through middle), $\frac{2}{3} M R^2$ (hollow sphere)

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

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

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

$PV = nRT = Nk_bT$ $R = 8.31$ J/(mol K) $k_b = 1.38 \times 10^{-23}$ J/K
$\Delta E = Q + W$ $\Delta E = n C_V \Delta T$ $C_V = 3/2\, R$ (ideal monatomic gas)
$W = -\int PdV$

$T = (2/3k_b)E_{avg}$ $P = (2/3)(N/V)E_{avg}$

1 light year $= c \times 1$ year $c \approx 3 \times 10^8$ m/s $N_A = 6.02 \times 10^{23}$
$G = 6.67 \times 10^{-11}$ N m^2/kg^2
$v_{sound} = 340$ m/s $g = 9.8$ m/s^2