THE UNIVERSITY OF BRITISH COLUMBIA

Science 1 Physics

Christmas Examination

17 December 1999

TIME: $2\frac{1}{2}$ HOURS

FULL NAME: ______________________ STUDENT # : ______________

SIGNATURE: ______________________

This Examination paper consists of 11 pages (including this one). Make sure you have all 11.

INSTRUCTIONS:

Write your name on every sheet.

No written or computerized memory aids allowed.

Forgotten formulae can be "bought" for 5 marks each. Hints are cheaper.

MARKING:

Q1	/24	**Q4**	/16
Q2	/15	**Q5**	/15
Q3	/15	**Q6**	/15
TOTAL			/100

NAMES OF INSTRUCTORS: Jess H. Brewer & Domingo Louis-Martinez

Q1 "QUICKIES" [24 marks — 4 each]

(*a*) A particle has a position (x) as a function of time (t) given by $x = b\cos(\omega t + \phi)$ where $b = 2$ m and $\omega = \pi$ s^{-1}. What is the *acceleration* of the particle when $x = 0$?

(*b*) Match up these common shapes with their moments of inertia about axes through their centres of mass. (There may be multiple matches.)

spherical shell   hoop   thin rod   solid cylinder   cylindrical shell   disc   solid sphere

$\frac{1}{12}ML^2$ $\frac{1}{2}MR^2$ $\frac{2}{5}MR^2$ $\frac{2}{3}MR^2$ MR^2

(*c*) Imagine that all diseases have been cured, all hazardous materials have been eliminated from the environment and all dangerous practices have been curtailed, so that your only risk of death (other than from boredom) is due to murder. However, for some reason the murder rate has increased to one per year per 100 people. What is your statistical probability of living for 100 years?

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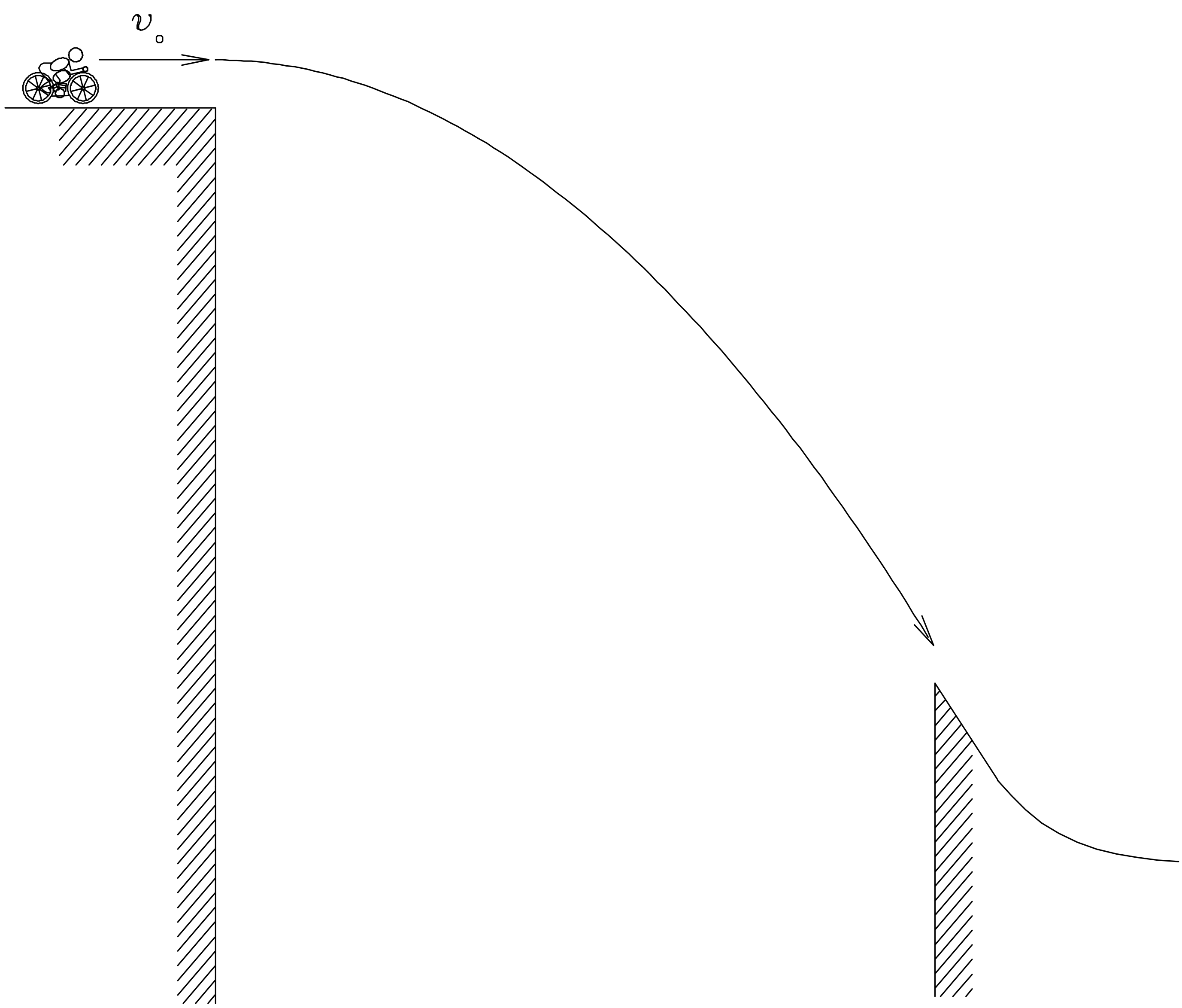
(*d*) What is meant by the *temperature* of an isolated system? (Use words only; no numbers or mathematical symbols.)

(*e*) If the Earth had no atmosphere, it would be possible to put a satellite into an orbit just above the Earth's surface. How long would such a satellite take to go around the Earth once?

(*f*) In 2100, Evel Knievel's great grandson "Goodie" decides to jump his motorcycle over the Valles Marineris on Mars at the point where it is 7 km deep. He has found a spot where the take-off point is just the right height above the landing point on the other side so that he will touch down at the desired position if his initial velocity is 250 km/h horizontally. The planned trajectory is shown below.

Unfortunately, Goodie forgot to include air friction in his calculations. (Mars' air is thin, but not negligible.) Assuming linear drag (the drag force is proportional to and opposing the velocity), *sketch in Goodie's actual trajectory* for the *two cases* of *weak* air friction (terminal velocity much greater than 250 km/hr) and *strong* air friction (terminal velocity less than 250 km/hr). You do not need to solve any equations here, but try to make your trajectories as realistic as you can.)



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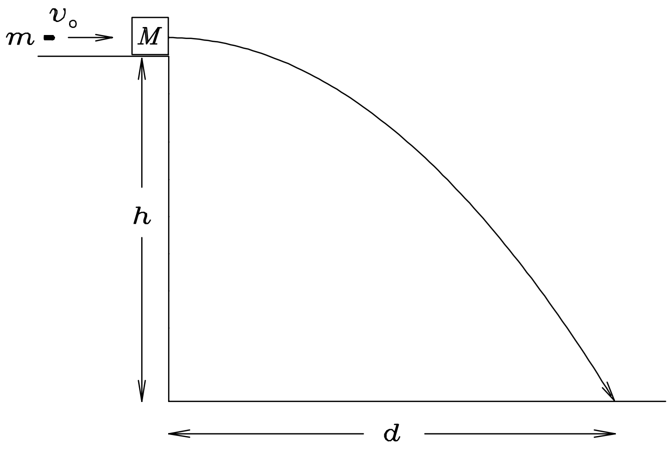
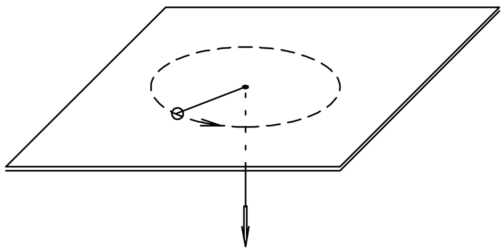
Q2 Firing Range [15 marks]



A bullet of mass m is fired horizontally into a block of mass M initially at rest on the edge of a frictionless table of height h. The bullet remains in the block. After the impact the block flies off the table and lands a distance d from the bottom of the table. Determine the initial speed of the bullet in terms of the other quantities given.
(Neglect air friction.)

Q3 Tetherball with a Tug [15 marks]

A small ball of mass m is attached to an idealized massless cord that passes through a small hole in a frictionless horizontal surface. The mass is initially moving at constant speed $v_\circ$ in a circle of radius $r_\circ$ centred on the hole. The cord is then pulled slowly down from underneath the surface, decreasing the radius of the circle to $r < r_\circ$.



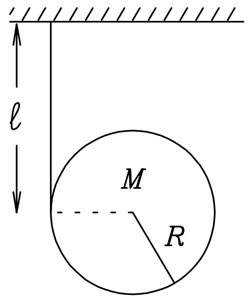
(a) In terms of the quantities given, what is the *speed* of the ball when the radius is r?

(b) What is the *change in the kinetic energy* of the ball as the radius is reduced from $r_\circ$ to r?

(c) From where did the ball gain or lose energy? Explain.

Q4 Falling Disc [16 marks]

A string is wound around a uniform disc of radius R and mass M. The disc is released from rest at $t = 0$ with the string vertical and its other end tied to the ceiling a distance $\ell_\circ$ from its point of contact with the disc, as shown. The distance ℓ from the ceiling to the point of contact then increases as the string unwinds.



(a) Find the *tension in the string* as a function of the quantities given.

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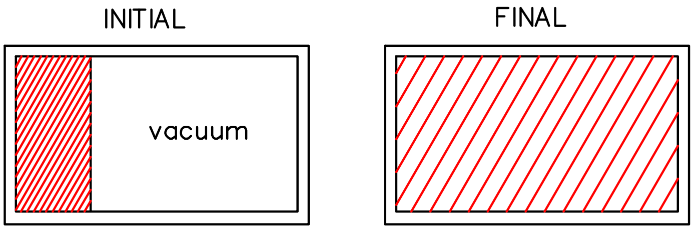
(b) Find the magnitude of the *acceleration* of the centre of mass as a function of the quantities given.

(c) Find the *speed* of the centre of mass as a function of the quantities given.

Q5 Free Expansion of an Ideal Gas [15 marks]



A diaphragm initially constrains N atoms of a monatomic ideal gas to a volume V_i at one end of an insulated container. The diaphragm is suddenly broken so that the gas can expand (irreversibly) to fill the entire volume $V_f > V_i$. Calculate the change in the *entropy* of the gas, $\Delta S = S_f - S_i$, as a function of the quantities given.

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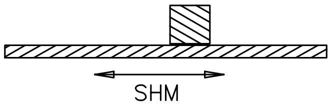
Q6 Simple Harmonic Friction [15 marks]

A small cube is placed on a horizontal platform that oscillates back and forth horizontally in simple harmonic motion with a period of 2.0 s. For sufficiently small amplitude oscillations, the cube moves with the platform, but when the amplitude reaches 0.30 m the cube starts to slide. Find μ_s, the coefficient of static friction between the cube and the platform.



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Constants and Conversion Factors. (You may not need all of these.)

Exchange Rate (17 Dec 1999)	\$1.00 CDN	=	2,8205 Zloty (Poland)
Universal Gravitational Constant	G	=	6.672×10^{-11} m^3 kg^{-1} s^{-2}
Acceleration due to gravity	g	=	9.81 m-s^{-2} (at Earth's surface)
Mean radius of Earth	R_E	=	6367 km
Mass of the Earth	M_E	=	5.974×10^{24} kg
Mass of the Moon	M_M	=	7.348×10^{22} kg
Mean Earth-Moon distance	R_{EM}	=	3.844×10^{8} m
Mass of the Sun	$M_\odot$	=	1.989×10^{30} kg
Mean Sun-Earth distance	R_{SE}	=	1.496×10^{11} m
Speed of light in vacuum	c	=	2.997×10^{8} m/s
Avogadro's number	N_0	=	6.022×10^{23} molecules per mole
Freezing point of water	0°C	=	273.15 K
Boltzmann constant	$k_{\rm B}$	=	1.3807×10^{-23} J/K
Planck's constant / 2π	$\hbar \equiv \dfrac{h}{2\pi}$	=	1.0546×10^{-34} *J-s* $= 0.6582 \times 10^{-15}$ *eV-s*

Atmospheric pressure: 1 atm = 760 torr = 1.013×10^5 Pascal (N/m^2)

Energy of an monatomic ideal gas of N atoms at temperature T: $U = \frac{3}{2} N k_{\rm B} T$.

Equation of State for an ideal gas of N particles: $pV = N k_{\rm B} T$. (p = pressure, V = volume)

Sackur-Tetrode Equation for the entropy of a monatomic ideal gas of N atoms of mass m at temperature T in a volume V:

$$S = N k_{\rm B} \left[\ln \left(\frac{n_Q}{n} \right) + \frac{5}{2} \right]$$

where $n_Q \equiv \left[\dfrac{m k_{\rm B} T}{2\pi\hbar^2} \right]^{3/2}$ and $n \equiv N/V$.

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