UNIVERSITY OF TORONTO
Faculty of Arts and Science

Term Test 3

PHY140Y

Duration - 2 hours

The only allowed aids are hand-held calculators and an attached appendix of formulae. Answer BOTH sections. Show all derivations, and justify each significant step in your answer.

Section A (20%)

Each question is of equal value. Answer all questions.

1. Define "gravitational" and "inertial" mass. Identify which two laws introduce these concepts. Can we prove that these are equal?

2. Calculate the moment of inertia of two 1 kg masses, held together by a very thin bar a distance of 0.25 m, about the axis perpendicular to the bar and located midway between the two masses. What is the analogue of the moment of inertia when we consider linear motion?

3. We characterise gravity as the weakest of all forces. Yet it appears to be the most obvious in our every day life. Why? You can contrast gravity and the electrostatic force in your answer.

4. Why tides? Explain qualitatively why our tides happen on an approximately 12 hour period.

5. What do we mean by a "black body?" What is the black-body spectrum (you don't have to right down a formula – just give a qualitative description)?

Section B (80%)

Answer any 4 of the 6 questions. Each question is of equal value.

1. Choose one of the two following topics and write a short ($\sim$ 500 word) essay on it. Structure your answer! A "stream-of-consciousness" response will not receive full marks. Your answer should introduce the topic, flesh out the details and then conclude with your own perspective.

   (a) The relationship between the $1/r^2$ behaviour of the gravitational and electrostatic forces and the existence of a physical quantity that we consider responsible for these forces (mass and electric charge, respectively). You can bring in Gauss's Law if you believe that will help knit your answer.

   (b) The relationship between the quantities that we define as linear momentum and angular momentum and Newton's Second Law. Discuss the importance of their conserved nature in the absence of external forces or torques.

2. The asteroid Eros, one of the many minor planets or asteroids that orbit the sun between Mars and Jupiter, has a radius of 7.0 km and a mass of 5.0×10^{15} kg. The 1998 movie "Armageddon" also featured a "killer" asteroid that astronauts prance all over. Let's see whether that really works.

   (a) What is the acceleration due to gravity on the surface of Eros?

   (b) If you were standing on Eros, would it be difficult to pick up a 2000-kg truck? What would it compare to on the earth?

   (c) If on Earth, you could jump up to a height of 0.5 m, would you jump off Eros if you attempted a similar thing on the asteroid?

   (d) If you assume that all asteroids have the same mass density as Eros, what would be the minimum size of an asteroid to keep "jumpers" like you from literally jumping off the planet? (The volume of a sphere of radius R is $4\pi R^3/3$.)

   (e) In the 1998 movie "Armageddon," a killer asteroid is going to hit the earth. It's described as about the size of downtown Manhattan (several km across). Yet, astronauts are able to walk on its surface. Does the movie get its "physics" about right?

3. A transport truck has a total mass $M_t = 20,000$ kg. It also has 18 wheels, each weighing $M_w = 50$ kg and having a diameter of 1.2 m. The truck accelerates uniformly from rest, reaching a cruising speed of 120 km/h on the 401 (about typical for an Ontario trucker!).

   (a) What is the moment of rotational inertia of each wheel about its axis? Make reasonable approximations and state them (for example, I would start out by assuming each wheel is a solid disk). The moment of inertia of a solid disk with mass M and radius R is $MR^2/2$.

   (b) It takes the truck 60 s to reach its cruising speed. What is the angular acceleration of each wheel during this period?

   (c) What is the total kinetic energy of the truck at cruising speed? What is the fraction of this energy in the form of rotational motion?

   (d) A wheel flies off and embeds itself in a shock-absorbing barrier. What is the energy that must be absorbed by this barrier?

4. We have an apparatus to measure the "work function" associated with the photoelectric efect of a given metal plate, as shown in Fig. 1. A potential V can be placed across the metal surface (whose properties we are examining) and the grid. We can measure the current flow between the surface and grid as well as their voltage difference.

   (a) Describe qualitatively the photoelectric effect. What is the work function? How can it be measured using this apparatus?

   (b) We have to buy an adjustable monochromatic light source (a source that emits a certain small range of frequencies of light) in order to measure the work function. Suppose that we want to measure work functions that range from 1.0 to 10.0 eV. What range of frequencies should this source be capable of emitting?

   (c) If there is a voltage $V = 100$ V placed across the metal surface and the grid, what is the electric field between the two plates?

   (d) What range of voltages should we be able to apply between the metal surface and grid to be able to measure work functions as described in b) with a source with those frequency ranges?

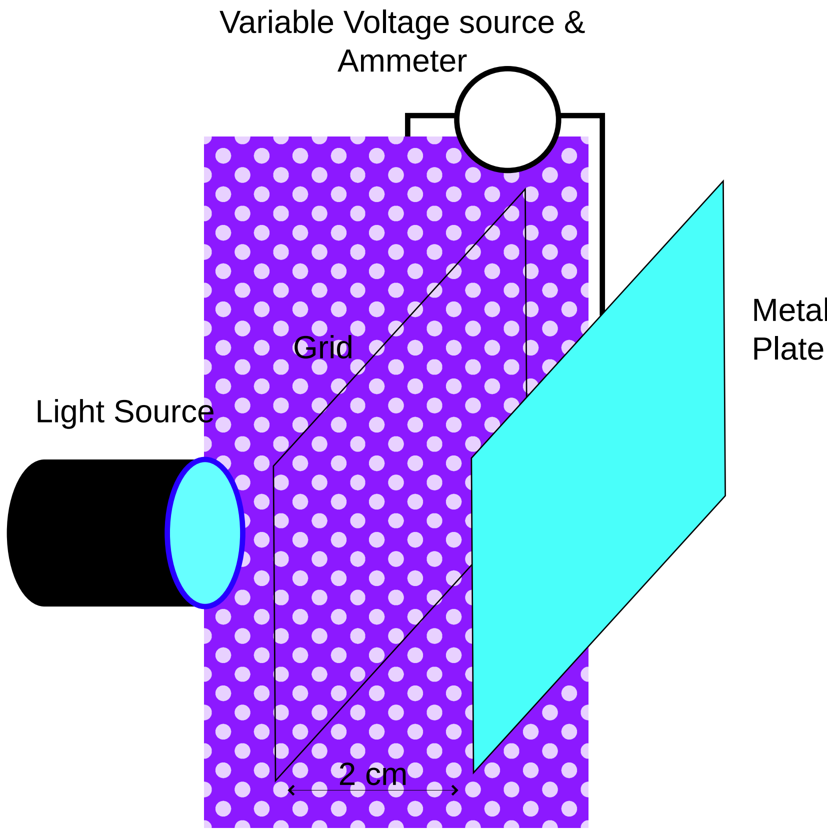

Figure 1: An apparatus to measure the photoelectric effect.

5. You're fixing the chimney on the roof of a house (it has a slope that is 30° from the horizontal) and you accidently drop a round chisel, of length l = 15 cm and mass $M_c = 0.25$ kg and diameter $D = 2$ cm, which then rolls down the roof a distance of 10 m and then drops a vertical distance of 3.0 m, as shown in Fig. 2. Since you are so cool, you immediately recall all of your PHY140 stuff and start to ponder.

   (a) What is the moment of inertia of the chisel rolling about its axis of cylindrical symmetry?

   (b) What is the speed of the chisel when it careens off the edge of the roof?

   (c) How far from the house does the chisel land?

   (d) What energy must be absorbed when the chisel makes impact? If it hit your Dad's new 1999 Accord, would you consider skipping town?

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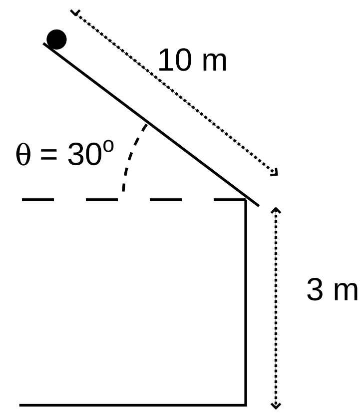

Figure 2: The chisel starting its roll off the roof.

6. The emission of a black body changes as its temperature T increases. Suppose we are in the business of detecting objects by the nature of the radiation they emit.

   (a) The human eye is most sensitive to green light (around 5500 Å). What is the temperature of an object that emits most strongly in this range? (Hint: The Wein displacement law states that $\lambda_{max}T = 2.898 \times 10^{-3}$ m K.)

   (b) How does that compare with the temperature of the surface of the sun (5800° K)? Why would you expect any similarity?

   (c) The first planet visited by mankind in the future is in orbit around a red giant star, whose surface temperature is only 3000° K. Assuming that the red giant star is the same apparent size as our sun is when observed from the earth, how much dimmer would "sunlight" be on the surface of this planet at high noon?

   (d) How much closer should the planet be to the red giant in order that high noon on each planet have the same intensity of light?