Physics 170 Midterm 1 Review Package

UBC Engineering Undergraduate Society

Attempt questions to the best of your ability. If you’re short on time, or looking for a challenge, see the tables further down this page for specific questions that you should attempt first. There is a formula sheet attached on the last page. This review package consists of 7 pages, including 1 cover page and 0 questions. The questions are meant to be the level of a real examination or slightly above, in order to prepare you for the real exam. Material from lectures and from the relevant textbook sections is examinable, and the problems for this package were chosen with that in mind, as well as considerations based on past examination question difficulty and style. Problems are ranked in difficulty as (*) for easy, (**) for medium, and (***) for difficult. Note that sometimes difficulty can be subjective, so do not be discouraged if you are stuck on a (*) problem.

Solutions posted at: [http://ubcengineers.ca/services/academic/tutoring/](http://ubcengineers.ca/services/academic/tutoring/)

If you believe that there is an error in these solutions, or have any questions, comments, or suggestions regarding EUS Tutoring sessions, please e-mail us at: tutoring@ubcengineers.ca. If you are interested in helping with EUS tutoring sessions in the future or other academic events run by the EUS, please e-mail vpacademic@ubcengineers.ca.

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Some of the problems in this package were not created by the EUS. Those problems originated from one of the following sources:

- Exercises for the Feynman Lectures on Physics / Matthew Sands, Richard Feynman, Robert Leighton.

All solutions prepared by the EUS.

Good Luck!
1. A 2.00m tall refrigerator of mass $m$ has a static coefficient of friction $\mu_s = 0.100$. When a pulling force of 300 N is applied as shown, the refrigerator barely slips and barely tips.

(a) Find $m$ and $x$.

(b) With this information only, is it possible to find $y$? Why or why not?

\[ \Sigma F_x = 0 \]
\[ 300 \cos(30) - F_f = 0 \]
\[ F_f = 300 \cos(30) \text{N} \]

\[ \Sigma F_y = 0 \]
\[ 300 \sin(30) + F_N - F_g \]
\[ mg = F_N + 300 \sin(30) \]

Since the refrigerator is barely slipping, $F_N = F_f/\mu$

\[ mg = 300(\sin(30) + \cos(30)/\mu) \]
\[ m = \frac{300}{9.81} \left( \sin(30) + \frac{\cos(30)}{\mu} \right) = 280 \text{kg} \]
\[ F_g = 2748 \text{N} \]

The clue "barely tips" means that the normal force is acting on the corner of the refrigerator under the applied force. To simplify the question, let's do the moment balance around this point.

\[ \Sigma M = 0 \]
\[300 \cos(30) \times 1.2 = 2748 \times (0.6 - x)\]
\[x = 0.486 m\]

b) No, it is not possible to find y. Recall that a force can be moved anywhere along its line of action without consequence and \( F_y \) acts entirely in the y direction.
2. The diagram below shows a set of 3 forces and one moment acting on a rigid body.

(a) Find the equivalent force and couple moment acting at point $O$.

(b) Reduce all forces and moments to a single wrench acting on point $P$. Find the resulting force and moment vectors as well as the distances $x$ and $y$.

a) Sum all forces and move to point $O$. Make sure to label your coordinate axes properly!

$$
\mathbf{F}_R = -300\mathbf{i} - 500\mathbf{j} + 400\mathbf{k}
$$

$$
\mathbf{M}_{RO} = 200\mathbf{i} + (-300\mathbf{i} \times 2\mathbf{j}) + (-500\mathbf{j} \times -3\mathbf{i}) = 200\mathbf{i} + 0\mathbf{j} - 2100\mathbf{k}
$$

b) To reduce the system to a wrench, the force and moment vector must be parallel. We can get this line from the resultant force vector since this vector does not change. The unit vector of the resultant force is:

$$
\mathbf{u}_{F_R} = -0.424\mathbf{i} - 0.707\mathbf{j} + 0.566\mathbf{k}
$$

Using the unknowns $x$ and $y$ to write the moment equations gives:

$$
M_{Ri} = 200 - 400y = -0.424M_R
$$

$$
M_{Rj} = -400(3 - x) = -0.707M_R
$$

$$
M_{Rk} = 500x + 300(2 - y) = 0.566M_R
$$

Solving this set of equations yields:

$$
x = 1.05 \\ y = 1.67 \\ M_R = 1103\text{Nm}
$$
3. The Diagram below shows a mass supported by three cables which are anchored to fixed supports.

(a) Determine the tension in each of the three cables if the cylinder has a mass of 75 kg.

(b) If each cable can withstand a maximum tension of 1000 N, determine the largest mass that this system can support.

\[ \sum \mathbf{F} = 0, \mathbf{F}_{AB} + \mathbf{F}_{AC} + \mathbf{F}_{AD} + \mathbf{W} = 0 \]

Equating the i,j,k components and solving for force magnitudes should yield:

\[ F_{AB} = 831 \text{ N}, F_{AC} = 35.6 \text{ N}, F_{AD} = 415 \text{ N} \]

b) Based on the results of part a, we know the limiting case is when cable AB supports a load of 1000 N. We could solve the entire system again but it is possible (and much simpler) to scale the results from a according to the new force in the cable.

\[ \frac{F_{AB1}}{m_1} = \frac{F_{AB2}}{m_2} \]

\[ m_2 = \frac{m_1 \cdot F_{AB2}}{F_{AB1}} = 75 \times 1000/831 = 90.3 \text{ kg} \]
4. Replace the two forces in the diagram below with a single force and couple moment acting at point O.

First find the resultant force:

\[ \mathbf{F}_R = (-20i - 10j + 25k) + (-10i + 25j + 20k) = -30i + 15j + 45k \]

To calculate the moment we need the vector distance from the origin to each force:

\[ \mathbf{r}_{O1} = 1.5i + 2j, \mathbf{r}_{O2} = 1.5i + 4j + 2k \]

\[ \mathbf{M}_{RO} = \begin{bmatrix} i & j & k \\ 1.5 & 2 & 0 \\ -20 & -10 & 25 \end{bmatrix} + \begin{bmatrix} i & j & k \\ 1.5 & 2 & 2 \\ -10 & 25 & 20 \end{bmatrix} = 80i - 87.5j + 102.5k \]
5. Consider the system below of a cantilevered beam with two forces and one couple moment acting on it.

(a) Determine the equivalent force and moment acting at point A and the I beam.

(b) Can the forces and couple moment acting on this beam be reduced to a single force? If so, determine this force and its location along the beam.

(c) What conditions need to be met in order to reduce a system of forces and moments to a single force? (Hint: consider the wrench problem where the system can at most be reduced to a force and couple moment)

\[ F_x = 26\left(\frac{5}{13}\right) - 30\sin(30) = -5kN \]
\[ F_y = -26\left(\frac{12}{13}\right) - 30\cos(30) = -50kN \]
\[ F_R = \sqrt{5^2 + 50^2} = 50.2kN \]
\[ \theta = \tan^{-1}\left(\frac{50}{5}\right) = 84.3^\circ \]

Sum moments around point A
\[ M_{RA} = 30\sin(30) \times 0.3 - 30\cos(30) \times 2 - 26\left(\frac{5}{13}\right) \times 0.3 - 26\left(\frac{12}{13}\right) \times 6 - 45 = -239 kNm = 239 kNm \text{ CW} \]

b) Find the distance d along AB where the resultant force produces a moment around A equal to the initial moment.
\[ \Sigma M_A = -50(d) = 30\sin(30) \times 0.3 - 30\cos(30) \times 2 - 26\left(\frac{5}{13}\right) \times 0.3 - 26\left(\frac{12}{13}\right) \times 6 - 45 \]
\[ d = 4.79 \text{ m} \]

c) Forces must be coincident, coplanar, or perpendicular in order to be reduced to a single force with no moment. If this criteria is not met, the wrench is the most that the system can be simplified.