vance natural sciences, particularly chemistry. The sum will be about £18,000.

The four largest courses in Harvard College last year were government 1 with 479 undergraduates, economics 1 with 438, philosophy E (elementary psychology) with 373, and chemistry 1 with 333. The other two courses which had over 200 undergraduates were philosophy A, Professor Palmer's course on the Greek philosophy, with 272, and history 1 with 250.

The vice-chancellor of the University of Cambridge has appointed April 19 for the election to the Plumian professorship of astronomy and experimental philosophy, vacant by the death of Sir George Darwin. Candidates are requested to send their names to the vice-chancellor on or before April 11.

Professor Henkel, of Königsberg, has been appointed director of the institute of pathology at Breslau, as successor to Professor Ponfick.

Professor Hoffman, of Prague, has been appointed to succeed Professor L. Hermann as director of the institute of physiology at Königsberg.

DISCUSSION AND CORRESPONDENCE

A SIMPLE FORMULA FOR COMPUTING GYROSCOPIC FORCES IN AN AEROPLANE

The recent letter of Mr. James Means, in Science for December 13, 1912, has called renewed attention to the problem of the gyroscopic action of a revolving motor as affecting the safety of an aeroplane. The following simple formula for computing the magnitude of this gyroscopic action is offered as a contribution toward the symposium suggested by Mr. Means.

We shall regard the rotating motor as consisting essentially of a single wheel or disc, whose axle is supported by two bearings at known distances from the center of the wheel.

If the aeroplane is compelled by the rudder, or by a sudden gust of wind, to change its direction of flight, this compulsion may be thought of as due to the pressure of a flat board against the side of the axle, at a point, say, in front of the wheel. As is well known, the axle will resist this pressure on account of the gyroscopic action of the rotating wheel, and will *strive to move off at right angles to the impressed force,* and in so doing, will *strive to carry the whole aeroplane with it.* If the wing surface of the aeroplane is large, this motion will be practically entirely prevented by the resistance of the air, and the result of the gyroscopic action will be the setting up of *internal stresses* in the framework of the machine.

The object of the following formula is to provide a simple means of computing the maximum value of these internal stresses in any given case.

Let $a =$ the distance between the bearings, measured along the axle, in *feet,* and let $P =$ the pressure, due to gyroscopic action, on each bearing, in *pounds.* Then P is given by the following formula:

$$Pa = (0.00034 \ldots) Wr^2Nn,$$

where

$W =$ weight of the rotating wheel, in *pounds,*
$N =$ angular velocity of the rotating motor, in *revolutions per minute,*
$n =$ the angular velocity with which the aeroplane is turning out of its path, measured in *revolutions per minute,* and
$r =$ the radius of gyration of the wheel about its axle, in *feet.*

Note 1.—A fair estimate of the radius of gyration can be obtained by a mere inspection of the linear dimensions of the wheel. For example, if the wheel were a homogeneous disc of radius R, then $r = (0.7)R$, approximately; while if all the material were concentrated in the rim, then $r = R$; intermediate cases can be judged by the eye.

Note 2.—The coefficient $0.00034 \cdots$ represents the value of $\pi^2/900g$, where $g = 32$ ft. per sec. per sec. If the lengths r and a are measured in *centimeters* instead of in feet, this coefficient must be replaced by $0.0000112 \cdots$. If r and a are measured in *inches,* the coefficient is $0.000029 \cdots$.

As an illustrative numerical case, suppose $W = 167$ lbs. (which is the actual weight of a fifty-horse power Gnome motor), $N = 1{,}200$

revolutions per minute, $n = 5$ revolutions per minute (estimated), and $r = 2/3$ ft. (estimated). Then if $a = 1$ foot, we shall have $P =$ about 150 lbs.; or, if $a = 2$ ft., $P = 75$ lbs., etc.

It thus appears that under ordinary conditions of flight, the effect of these gyroscopic forces could hardly be serious.

In conclusion, we note the following simple rule for determining the *direction* in which the force P will be exerted. (This rule was first published by the writer in the *Engineering News* for June 21, 1910. See also *The Scientific American* for November 23, 1912.)

Imagine the deflecting force (that is, the force which compels the aeroplane to change its direction of flight) to be due to the pressure of a flat board against the spinning axle (say in front of the motor), and *note the direction in which the axle, if rough, would tend to roll along the board;* this will give the direction in which the (forward) end of the axle will tend to move as the result of gyroscopic action—that is, the direction in which the force P will act against the (forward) bearing.

For example, suppose the axle is spinning in the clockwise direction, as seen by an observer looking forward, and let the aeroplane make a sharp turn to the *left;* then the forward end of the axle will strive to *rise.* Similarly, if the aeroplane makes a sharp dive *downward,* the forward end of the axle will strive to turn to the *left.*

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FUR-BEARING MAMMALS: AN UNAPPRECIATED NATURAL RESOURCE

> The manor of living nature is so ample, that all may be allowed to sport on it freely; the most jealous proprietor can not entertain any apprehension that the game will be exhausted, or even perceptibly thinned.

In such wise did Dr. Richard Harlam, writing in 1825, comment on the inexhaustibility of our natural game resources. As late as 1857 the following in substance appears in the report of an Ohio state senate committee:

> The passenger pigeon needs no protection. Wonderfully prolific, having the vast forests of the north as its breeding grounds, traveling hundreds of miles in search of food, it is here to-day and elsewhere to-morrow, and no ordinary destruction can lessen its numbers, nor can those killed be missed from the myriads that are yearly produced!

The tragic story of the passenger pigeon is familiar to every one. Not so familiar, perhaps, are similar stories which may be told of other species. Fortunately, there is a growing realization that our national resources in wild life are rapidly dwindling, and attention is being directed toward checking the extermination.

This consideration comes not a moment too soon. Unless protective laws are enacted before a species is nearly extinct they can not ordinarily avail much. Nevertheless, vigorous efforts should be made continually not only to conserve species which are still plentiful, but to preserve species which, through our lack of foresight, are on the verge of extinction.

There is, however, one department of our fauna which, in the opinion of the writer, has hardly received its deserved quota of attention. I refer to the several species of fur-bearing mammals whose pelts have a commercial value. The species concerned include the bear, raccoon, skunk, badger, otter, sea otter, mink, marten, fisher, red fox and wolverine.

It is estimated on fair authority that there are within California alone trappers in the proportion of ten to the county, each of whom makes a possible average of five hundred dollars from his annual catch. There are fifty-seven counties, so that five hundred and seventy persons with a total income for the fur season of $285,000 a year would on this estimate be resident in the state. Two hundred and eighty-five thousand dollars is the interest at four per cent. on $7,125,000. This, or even a quarter of it, would seem to be enough of a commercial asset to be worth at least some legislative consideration.

On the basis of figures quoted by Ernest Thompson Seton[1] it appears that an extremely

[1] "Life Histories of Northern Animals," 1909.